Appendix C
Design Criteria

APPENDIX C

Design Criteria

In conformance with requirements from the 1996 Corrective Action Consent Agreement (CACA) (California Department of Toxic Substances Control 1996) and the 2013 Remedial Action/Remedial Design (RD/RA) Consent Decree (U.S. Department of the Interior [DOI] 2013), this appendix describes the design criteria for the groundwater remedy at the Topock Compressor Station (TCS). The design criteria are the technical parameters upon which the design is based, and are based on the translation of the identified applicable or relevant and appropriate requirements (ARARs) and the Environmental Impact Report (EIR; California Department of Toxic Substances Control [DTSC] 2011) mitigation measures (where applicable) into site-specific engineering parameters.

The design criteria are grouped into engineering disciplines (Civil [Section C.2], Structural [Section C.3], Geotechnical [Section C.4], Mechanical [including lighting] [Section C.5], Electrical [Section C.6], Instrumentation and Control [Section C.7], and Architectural [Section C.8]). In addition, this appendix describes PG&E Personnel Requirements (Section C.9) and design criteria for Health and Safety (Section C.10) and Noise (Section C.11). Content of the former Construction Requirements section (Section C.11 in the previous version of this appendix from the 30% design submittal) has been removed and will be merged with the forthcoming Construction/ Remedial Action Work Plan, where construction provisions will be discussed in detail.

This appendix includes five Attachments that contain a large amount of data; these Attachments are presented in PDF format on the CD-ROM version of the 60% Basis of Design Report (enclosed within the report binders).

- Attachment A contains a detailed description of the in situ remediation design basis including carbon substrate selection and discussion of chemical reactions.
- Attachment B provides calculations in the following order:
  - Remedy-produced water pump calculations – recirculation; filter feed; conditioned water transfer
  - Remedy-produced water influent tank eductor sizing
  - Remedy-produced water caustic usage
  - Remedy project structural calculations – Remedy-produced Water Conditioning Building; Conditioned Water Tank; Injection Well and Valve and Meter Vaults; Pipe bridge deflection
  - Freshwater injection/remedy-produced water collection/conditioned remedy water distribution and disposal hydraulic network modeling calculations from EPANET software[1]
  - Hydraulic calculations for National Trails Highway In-situ Remediation Zone (NTH IRZ), Inner Recirculation Loop, and TCS Recirculation Loop wells
  - Structural design calculations for the MW-20 Bench Carbon Amendment Building
- The new Attachment C summarizes information on existing site geology and geotechnical data in support of the groundwater remedy design and to propose areas where supplemental geotechnical investigation is needed to verify design parameters.
- The new Attachment D includes a bulletin on remediation well design and field approach.
- The new Attachment E includes a summary of the hydraulic analysis of the firewater system.

C.1 Codes and Standards

The Groundwater Remedy Project is being designed in accordance with the applicable standards, codes, ordinances and regulations, including but not limited to:

[1] Developed by the U.S. Environmental Protection Agency for hydraulic network modeling and drinking water quality analysis. For details, see http://www.epa.gov/nrmrl/wswrd/dw/epanet.html.

- American Concrete Institute (ACI)
- American National Standards Institute (ANSI)
- American Society for Testing and Materials (ASTM)
- American Water Works Association Standard (AWWA)
- Arizona Department of Transportation Policy for Accommodating Utilities on Highway Rights of Way
- Burlington Northern Santa Fe Railway (BNSF) Utility Accommodation Policy
- California Building Code (2010) as amended by San Bernardino County
- California Fire Code (2010)
- California Mechanical Code (2010)
- California Plumbing Code (2010)
- California Division of Occupational Safety and Health (Cal/OSHA)
- County of San Bernardino 2007 Development Code
- Illuminating Engineering Society of North America (IES) procedures
- International Energy Conservation Code (IECC)
- International Green Building Code
- Institute of Electrical and Electronic Engineers (IEEE)
- Instrument Society of America (ISA)
- Insulated Cable Engineers Association (ICEA)
- Minimum Design Loads for Building and Other Structures (American Society of Civil Engineers [ASCE] 7-10)
- Mohave County Regulations (including Drainage Design Manual for Mohave County)
- Mohave County Floodplain Administrator requirements
- National Electrical Manufacturers Association (NEMA)
- National Electrical Code (NEC)
- National Electrical Safety Code (NESC)
- National Fire Protection Association (NFPA)
- Occupational Safety and Health Administration (OSHA)
- PG&E standards
- San Bernardino Fire Department/Certified Unified Program Agencies (CUPA) requirements
- San Bernardino County Floodplain regulations
- Uniform Fire Code (UFC) (Local Fire Code)
- Underwriters Laboratory (UL)

C.2 Civil

C.2.1 Site Datum

Following completion of recent aerial photogrammetry, the topographic map has been updated to 1-foot topographic contours. The new topographic map, which has been incorporated into the design drawings, is included as Figure 2.4-2 in the Basis of Design Report. The following data were used to establish control for the project and conduct site survey work:

- All coordinates listed are 1983 State Plane Ground Coordinates, Zone 5 (NAD1983, State Plane, California, V, FIPS, 0405). Standard transverse Mercator projection, with projection, with a scale origin point of x=0.0000 y=0.0000, using a grid adjustment factor of 1.000123. These coordinates can be used as ground datum. To convert back to grid coordinates, each coordinate value would be divided by 1.000123.
- The elevations are based on North American Vertical Datum of 1988 (NAVD88) based on NGS data sheets EU1248 and EU0763 in U.S. Survey feet.
- Units = International feet: 1 foot = 0.3048 meter exactly.
- All bearing are grid bearings, distances are ground distances, and coordinates are ground coordinates.

C.2.2 Earthwork

This section describes the design criteria for the movement of soil and rock into forms and structures needed for the project.

- Grading, Paving and Access Roads

  Cut and grading will take place at the site to install new remedy facilities. Access roads may be required to access certain project locations for construction and O&M. Access roads will be designed to the following standards (barring terrain or cultural, biological or natural resource constraints):

  - Maximum grade ≤ 10%
  - One way traffic width = 14 feet
  - Two way traffic width = 20 feet
  - Cut slopes ≤ 1.5:1
  - Fill slopes ≤ 2:1 (H:V)
  - Out slope road (1/4 inch per foot) so that drainage flows perpendicular to road centerline
  - Roadside ditches (V shaped or trapezoidal) with a minimum top width of 2 feet
  - Per San Bernardino County requirements (Chapter 82.13 Section 82.13.080) compaction to 90% minimum

  Pavement replacement will be in accordance with the California Department of Transportation's (Caltrans') *Flexible Pavement Structural Section Design Guide for California Cities and Counties* (latest edition).

- Utility trenches will be excavated to a minimum 3 feet deep and 3 feet wide. Utility trenches may include pipes (freshwater, extracted groundwater, carbon-amended water, remedy-produced water, clean in place (CIP), acid, coagulant, caustic, slurry, waste sump, utility, or spare pipes), as well as electrical and instrumentation conduits. Trench cutoff walls with drain systems may be installed at locations where pipe slopes exceed 8%-10% for long runs (300 to 500 feet) to help divert any potential water flow that may undermine the trench section. These will be added in the design submittal if needed. In areas where utility crossings exist there will be a minimum of 2 feet separation between utilities unless directed otherwise by the utility owner. GPS-based locations of utilities will be recorded as part of the as-built submittals as well as size, material, and horizontal and vertical separation distance from utilities. Construction GPS mapping and surveys of other pipelines will be required as appropriate.
- Pipe and conduit bedding material will be free of rock(s), rubbish, debris, and other objectionable material, and minimum compaction will be 90% to 95% relative density, per American Society for Testing and Materials (ASTM) D-1557 in areas sensitive to settlement. The minimum pipe bedding thickness will be 6 inches and the minimum pipe/conduit backfill zone thickness will be 3 inches. Bedding will be without voids, placed and consolidated to the proper depth in 8-inch maximum lifts. The backfill will be placed to final grade to conform to the elevation of the adjoining surface elevation.
- A survey of aboveground and underground utilities will be conducted within all work areas prior to beginning intrusive site work and construction activities. This survey will include, but will not be limited to, the following activities:

  - Notify Underground Service Alert (USA) or "Dig Alert"
  - Geophysical survey to identify underground features
  - It is Topock Compressor Station policy to minimize operational and safety risks by limiting subsurface intrusion as much as possible, and thus abandoned utilities are typically left in place. Because positive identification of all active and abandoned underground utilities prior to any intrusive activity within the station fence line is impossible, Compressor Station protocol requires all intrusive work be performed by hydrovac or hand excavation methods.

    As described during the October 24, 2011 site visit with the DTSC and the DOI, PG&E policy requires all excavations in the vicinity of existing infrastructure to be hand dug to *a minimum* of 3 feet; in more open

areas, hydrovac excavation may also be used. Depending on the location, density of utilities encountered, and available information regarding a specific location, hand excavation or clearing using the hydrovac may be required as deep as 10 feet below ground surface. No power equipment is used until the excavation has been physically cleared for utilities. A station employee observes each excavation effort and determines when it is safe to proceed with more intrusive methods. PG&E does not have a written procedure for this requirement; however, it is policy and is understood and strictly followed by all station personnel.

- Piping installed in utility corridors will be placed above ground or below ground. The preferred installation is below ground for many reasons, including but not limited to the following:

  a) The National Electrical Safety Code (NESC) considers an above-ground, non-overhead, high voltage electrical supply line to be an example of non-Code compliant, therefore, medium and high voltage electrical lines will be place underground. In addition, aboveground low voltage electrical 480 volt power lines carry the risk of causing electrical injuries from contact, and long runs of exposed electrical conduit also present numerous design and O&M challenges.

     i. It is worth noting that along the Route 66 segment in the Upland Area, considerations were also given to the piping alignment (underground) to maintain usable road width in narrow stretches of the road. The California/San Bernardino County Fire Code (Chapter 5) requires 26 feet minimum width for vehicle access. Although variances are allowed if turnarounds are available every 600 feet (County Standard 503.1), additional grading and cut backs would be required to create these turnarounds in several narrow road sections or sections with steep ravine. Note that aboveground structures would also require drainage features which adds to the footprint.

  b) Placement of water lines underground (versus aboveground) will not only avoid increased visual impacts, but will also protect the health, safety, and free movement of humans and animals. Underground piping will also enhance the integrity of the remedy infrastructure (e.g., avoid being hit by vehicular traffic), and minimize remedy footprint and future O&M challenges.

  c) Aboveground piping is inherently vulnerable as members of the public have been known to shoot pipes and large rocks or other debris may strike the pipe during a storm event. In addition, aboveground pipe will need periodic re-coating therefore, would require more maintenance compared to underground piping and as such, create more disturbance to nearby habitats as a result of maintenance activities.

  d) However, in certain cases, aboveground installations will be necessary to protect sensitive resources (e.g., aerial crossings of Bat Cave Wash, crossing of the Colorado River on the Arch Bridge) or to avoid potentially difficult construction conditions in bedrock (e.g., the aboveground piping along Route 66 between the East Ravine and the Arch Bridge).

  Belowground utility corridors will be constructed with pre-cast utility trench boxes with lids or buried directly in the soil. The installation option was selected based on the following criteria subject to constraints for the particular route (e.g., width of usable terrain):

  – No directly buried water piping will be installed below any other water pipe or conduit.

  – Directly buried electrical conduits may be installed beneath other electrical conduits.

  – There must be at least 6 inches of clearance between directly buried water piping. The clearance between directly buried water piping may be increased up to 12 inches.

  – The minimum spacing between directly buried electrical conduit shall be 3 inches or half the diameter of the conduit, whichever is greater.

  – Tracer wire for locating non-metallic pipes or conduit will be installed in the trenches.

- Trenchless construction will be used underneath existing infrastructure such as the I-40 highway and BNSF railway bridges. In such locations, these will be installed using trenchless methods such as auger boring or horizontal directional drilling. The methods will be designed such that they comply with relevant guidelines prepared by the Arizona Department of Transportation (ADOT), Mohave County (for County Road 10 bore), and BNSF listed below (see also Section 5.3.2 of the Basis of Design Report for encroachment permits). Also, the methods will comply with San Bernardino County requirements for trenchless crossings in California.
  - Caltrans Manual for Encroachment Permits on California State Highways, Seventh Edition, January 2002, Section 518, and Table 5.24 - Permit Code TN
  - ADOT Policy for Accommodating Utilities on Highway Rights-of-Way, December 2009
  - BNSF Utility Accommodation Policy, May 2007

  Pipes and conduit will be installed in steel casings when required by BNSF, ADOT, or Mohave County. Casings will extend beyond the length of the crossing a minimum of 10 feet. The need for cathodic protection will be evaluated on a case-by-case basis using site conditions and utility requirements. The casing will have centralizers and end caps 10 feet from the end of the casing. Identified spare pipes and conduits will be installed during construction. Exhibit C.1-1 lists minimum depth of cover for trenchless crossings. In some cases, concerns for pavement or railroad settlement or potential for drill fluid "frac-out" may require a thicker cover. Geotechnical borings may be required by ADOT, BNSF, or Mohave County (see Section C.4). If drilling fluids are used, continuous monitoring for frac-out conditions will be performed to prevent harm to human health and the environment caused by the release of such fluids.
- Any earthwork in areas of sensitive habitat (including floodplain and riparian areas, wetlands, and waters of the US, as well as desert washes and desert riparian) will be subject to the substantive equivalents of Section 404/Section 1600 requirements under mitigation measure BIO-1 (see the Mitigation Monitoring and Reporting Program in the EIR [DTSC 2011]).

EXHIBIT C.1-1
Depth of Cover Design Criteria for Trenchless Crossings
Groundwater Remedy Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Transportation Agencies	Minimum Depth Of Cover
ADOT	• 3 feet minimum • 6 feet minimum for un-sleeved crossings up to 48" diameter • 10 feet minimum for pipelines larger than 48"
BNSF	• 3 feet minimum below flow line of ditch or ground surface • 5-1/2 feet minimum below base of rail, for casing diameters greater than 26" • 10 feet minimum without geotechnical study • 5-1/2 feet if it can be verified by geotechnical study

C.2.3 Storm Drainage

Stormwater will be managed to protect new structures and facilities built as part of the remedy. This section describes the design criteria associated with stormwater drainage.

Impervious surfaces will be sloped to drain. Culverts will be used to drain roadside ditches and protect stream crossings. Roof drainage from buildings will be collected in gutters and drain towards drainage systems. Stormwater captured within secondary containment will be managed at the remedy-produced water conditioning system. All drainage features and structures will be sized to meet San Bernardino County requirements for storm frequency and intensity.

- Rainfall intensity based on period equal to time of concentration for the basin being considered and 25-year recurrence interval.
- Minimum velocity for culverts is 2.0 feet per second. Maximum velocity for culverts is 10.0 feet per second.

During construction, erosion control measures will be implemented in accordance with San Bernardino County requirements and the construction Stormwater Pollution Prevention Plan (SWPPP). The erosion control measures will be tailored to the site to prevent sediment-laden water from leaving the site. The following erosion control measures will be used onsite:

- Site development considerations with construction scheduling
- Maintenance of buffer zones
- Disturbed-soil areas with decomposed granite
- Dust control on disturbed areas and access roads
- Diversion of runoff with earthen dikes, brow ditches, and berms to protect excavations
- Energy dissipaters, riprap channel protection, or outlet protection for discharge pipes, channels, and ditches
- Silt fence at limits of clearing
- Temporary sediment basins to protect existing drainage basins and culverts
- Check dams to control velocity along ditches and long longitudinal grades
- Stabilized construction entrance to all paved surfaces
- Materials management with material delivery, storage, and waste management
- Vehicle and equipment management with construction practices, cleaning, fueling, and maintenance

C.2.4 Site Security

In general, the security for remedial facilities located inside the Compressor Station will be provided for by the Compressor Station security system. Remedial facilities located outside of the Compressor Station will be equipped with security features/systems that are consistent with PG&E's current security standards. Such features, as determined necessary and in compliance with project and landowners' requirements, could include, but are not limited to, fencing to protect the equipment and provide safety for personnel and the public; locks to prevent unauthorized access; security devices and instrumentation; security communication systems; alarms to notify PG&E's security operations; and security cameras. Where appropriate, security features like cameras and card readers are noted on the 60% engineering plans/drawings (see Appendix D of this 60% BOD Report). Examples of security features to be installed at remedy facilities located at the TW Bench, MW-20 Bench, HNWR-1 well site, the North and South Aerial Crossings (crosses Bat Cave Wash) are described below. Additional details on security design criteria will be presented at the 90% design stage, after the remedy infrastructure locations have been confirmed. In compliance with the EIR mitigation measure CUL-1a-6, any additional phone calls and alarms associated with remedial activities will not be routed through PG&E's existing alarm system at the Compressor Station.

Transwestern Bench

- A perimeter fence will be installed with a motorized main gate and a personnel gate. The main gate will have a security card reader and camera to monitor and prevent unauthorized access.
- Perimeter cameras will be installed. Security cameras will also be installed inside select buildings/structures.
- The Central Maintenance Facility will have card readers at entrances.

MW-20 Bench

- Each new gate(s) will have a security card reader and camera.
- Perimeter cameras may be needed, but will be confirmed during the 90% design stage.
- Operational cameras will be installed inside select structures.

HNWR-1 Well Site

- A motorized gate with security card reader and camera will be installed.

North and South Aerial Crossings (Bat cave wash)

- Personnel gates with locks will be installed at each end of the 2 new aerial crossings.

C.2.5 Concrete Vaults

Concrete vaults will be installed to house mechanical and electrical equipment. Vaults will be precast concrete sections. The vaults will vary in depth depending upon use and location, but to the extent possible they will be designed to be shallow enough that entry would not require a confined space entry procedure. Each vault will be equipped with a steel ladder with extension, conforming to California Division of Occupational Safety and Health (Cal/OSHA) standards. Well vaults will be designed for an H-20 loading in traffic areas and the lids will be supplied with spring assists for safe opening. Fall protection removable grating (live load 300 pounds per square foot [psf]) will be provided. For non-traffic areas, standard lids (300 psf) will be supplied. All vault lids will be equipped with security locks or other security devices (e.g., embedded locks or 5-point bolts).

C.2.6 Construction in 100-year Floodplain

The 100-year floodplain is defined in the Flood Insurance Rate Map (FIRM), Panel 5705 of 9400 for San Bernardino County, California and Unincorporated Areas, Revised August 28, 2008, and Panel 5675 of 6700 for Mohave County, Arizona and Unincorporated Areas, Revised November 18, 2009 (Map Number 04015C5675G). The base flood elevation shown on the current FIRM is 464 feet NAVD at River Mile (RM) 234 of the Colorado River. A review of the Mohave County Flood Insurance Study (FIS) shows that this elevation is specific to the California side of the river only, and is different from information found in the newer FIS for Mohave County, AZ.

The effective FIS for San Bernardino County lists a regulatory base flood elevation of 463.90 feet NAVD. This design uses the more conservative elevation of 464 feet NAVD as the base flood elevation for the project on the California side of the Colorado River. The vertical datum for all flood elevations shown on the San Bernardino County FIRM is NAVD88.

The effective FIS for Mohave County lists a regulatory base flood elevation of 465.3 feet NAVD. This is used as the base flood elevation for the project on the Arizona side of the Colorado River. The vertical datum for all flood elevations shown on the Mohave County FIRM is NAVD88.

In this 60% design, certain infrastructure (piping) cannot be located outside of the 100-year floodplain as defined by the above baseline flood elevation. PG&E will work with San Bernardino County and Mohave County Flood Administrator to ensure compliance with the county requirements for construction in the floodplain.

C.3 Structural

This section describes design criteria for physical structures made of concrete and steel.

C.3.1 Concrete

Minimum requirements are listed below for structural concrete:

- Strength of poured-in-place concrete will be a minimum of 5,000 pounds per square inch (psi) at 28 days for all structures. Lower strengths of 3,000 psi will be used for non-critical structural elements as indicated in the specifications. 2,000 psi will be used for concrete fill, pipe and conduit encasement.
- Cement will be clean, fresh, Type II/, low alkali, Portland cement conforming to ASTM C150.
- Aggregate will be non-reactive.
- Cement content for all structures will be a minimum of 7.5 sacks per cubic yard of concrete.
- Slump of concrete will be as low as practicable to produce a dense, well consolidated concrete and not exceed 4” unless otherwise authorized by PG&E Project Engineer.
- Finish of formed surfaces will be smooth and free of fins, honeycomb, and segregation.

- When the surfaces have become sufficiently hardened, they will be kept continually moist for a period of not less than seven days. Curing compound conforming to ASTM C309 may be used in-lieu of wetting surfaces only where approved by the Engineer.
- In conformance with the EIR mitigation measures AES-1d and AES-2e, integral color concrete will be used in place of standard gray concrete.

C.3.2 Reinforcing Steel (Minimum Requirements)

Minimum requirements for reinforcing steel are as follows:

- Reinforcing steel will be deformed, grade 60, conforming to ASTM A615, and be free from coating which will reduce the bond.
- Reinforcing steel will be sized in accordance with the Strength Design Method or Alternate method.
- Reinforcing steel splices will be in accordance with the requirements of ACI 318-11.

C.3.3 Dead Loads

Dead loads will consist of gravity loads induced by all structural elements, equipment, piping, and contained liquids.

C.3.4 Live Loads

Live loads for different structural elements are listed below:

- Roof live loads will be designed for a minimum live load of 20 psf.
- Stairs, walkways, and platforms will be designed for a minimum live load of 100 psf.
- Concrete floor on Grade and Grating will conform to the latest edition (2010) of the California Building Code (CBC), but will be a minimum live load of 500 psf, or Wheel Load of 16 kips.
- Elevated Concrete floor – 200 psf or Fork Lift load – 4 kips.
- Live load on aerial crossings (pipe bridges) will be minimum 500 pounds at alternate panel point of trusses.

C.3.5 Seismic Loads

The design will meet CBC (2010) and as amended by San Bernardino County and/or ASCE 7-10 “Minimum Design Loads for Buildings and Other Structures”. Specifically:

- CBC 2010, Site Class D
- Ss = 0.434 (Needles, CA)
- S1 = 0.135 (Needles, CA)

C.3.6 Wind Loads

The design will meet CBC (2010) and as amended by San Bernardino County and/or ASCE 7-10 “Minimum Design Loads for Buildings and Other Structures”. Minimum Wind Load = 20 psf. Detailed structural design criteria are shown in Exhibit C.3-1.

EXHIBIT C.3-1

Structural Design Criteria

Groundwater Remedy Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Category	Criteria
General	
Governing Code	CBC (2010) as amended by San Bernardino County, IBC 2009, ASCE 7-10
Concrete: CODE and SPECIFICATION	ACI 318-11, Building Code Requirements for Reinforced Concrete ACI 350-06, Environmental Engineering Concrete Structures
Concrete Masonry Units: SPECIFICATIONS	CBC (2010)
Structural Steel: SPECIFICATIONS	AISC Allowable Stress Design Specification for Structural Steel Buildings, 13th Edition
Aluminum: SPECIFICATIONS	CBC (2010)
Concrete	
Strength	F'c = 5,000 psi for all structures (pipe bridge foundation and precast concrete containment trench), 3,000 psi for general structural concrete(pump pads, thrust blocks, valve vaults) and 2,000 psi for concrete fill, pipe/conduit encasement.
Reinforcing	ASTM A615, Grade 60, Type S
Prestressing Strand	ASTM A416
Welded Steel Wire Fabric	ASTM A185 or ASTM A497
Design	Strength Design or Alternate Method
Detailing	ACI SP-66(00) Manual of Standard Practice for Detailing Concrete Structures
Color	Integral color concrete in place of standard gray color concrete (EIR mitigation measures AES-1d and AES-2e)
Reinforced Masonry	
Concrete Masonry Units	ASTM C90, Grade N, Type I (Unit Compressive Strength f'm = 1,900 psi at 28 days
Mortar for Unit Masonry	ASTM C270, Type M, Minimum Compressive Strength at 28 days = 2,500 psi.
Reinforcing	ASTM A615, Grade 60, Type S
Cold-Drawn Steel Wire	ASTM A 482
Grout	ASTM C476, Minimum Compressive Strength at 28 days = 3,000 psi.
Structural Steel	
Structural "W" Shapes	ASTM A992 (Fy = 50 ksi)
Structural channels. plates, angles, etc.	ASTM A36 (Fy = 36 ksi)
Structural Tubing	ASTM A500, Grade B (Fy = 46 ksi)
Steel Pipes	ASTM A53, Grade B
Stainless Steel	Alloy Types conforming to ASTM A-167 and ASTM A-276.
Plates and Shapes	Type 316 unless otherwise noted
Bolts, Nuts and Washers	Type 316
Welding	AWS E70 Electrodes
High Strength Bolts	ASTM A325F, Min 3/4" Diameter
Other Bolts	ASTM A307, Grade A

EXHIBIT C.3-1
Structural Design Criteria
Groundwater Remedy Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Category	Criteria
Anchor Bolts	ASTM A36
Chemical Anchor Bolts	SS Type 316, Hilti HVA Adhesive Type or Equal
Expansion Anchors	Hilti SS Quick Bolts, Type 316 or Equal Bolts, Nuts and Washers
Timber	
TBD	CBC (2010)
TBD	National Design Specification for Wood Construction

C.4 Geotechnical

A geotechnical data summary is included in Attachment C of this Appendix. The purpose of this geotechnical summary is to provide information on existing site geology and geotechnical data in support of the groundwater remedy design and to propose areas where supplemental geotechnical investigation is needed to verify design parameters. Coordination with the Soil RFI/RI investigation program was conducted in planning of the supplemental geotechnical investigation to minimize the number of boreholes, thereby minimizing ground disturbance. It is important to note that as PG&E continues to engage in discussions with transportation agencies, counties, and other property owners/land managers to obtain institutional controls, access agreements, and permits, additional geotechnical data may be required to meet specific requirements of agencies and/or property owners/land managers.

The geotechnical design criteria presented in Exhibit C.4-1 are based on existing site-specific geologic information and geotechnical data, to support foundation and trenching designs, as well as trenchless crossings (I-40 and BNSF crossings).

EXHIBIT C.4-1
Geotechnical Design Criteria
Groundwater Remedy Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Parameter	Criteria
Moist soil unit weight	120 pounds per cubic foot (pcf)
Shear strength parameters	<u>Cohesionless Soils</u> Friction angle: from 32 to 35 degrees for compacted fill Friction angle: from 28 to 30 degrees for native soils <u>Cohesive Soils</u> Undrained shear strength: from 800 to 1,000 pounds per square foot (psf)
Controlling earthquake magnitudes	Mean earthquake magnitude is 6.6 Modal earthquake magnitude is 7.9
Peak ground acceleration	For structure design is 0.10 g (design value for Site Class D) For liquefaction assessment is 0.15 g (for Site Class D)
Allowable bearing capacity	4,000 psf
Allowable long-term settlement	1 inch

EXHIBIT C.4-1
Geotechnical Design Criteria
Groundwater Remedy Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Parameter	Criteria
Sliding coefficient of friction	0.45
Lateral soil pressure equivalent fluid unit weight	Active pressure: 45 pcf Pressure at rest : 60 pcf. Passive resistance = 175 pcf
Temporary cut and fill slopes	2 Horizontal:1Vertical
Frost depth	8-10 inches
Additional Geotechnical Criteria	

- Soil is corrosive to concrete structures and steel (resistivity > 1,000 ohm-centimeters, sulfate > 2,000 parts per million (ppm) and chloride > 500 ppm).
- Soil profile is classified as Site Class D (stiff soil site), as defined in the CBC (2010).
- Shallow foundations for buildings with support extending a minimum of 2 feet below lowest adjacent grade. Slabs and footings set on a minimum of 6" layer of granular base leveling course.
- Pipe design based on depth of fill, weight of fill, compaction of fill and modulus of soil reaction (E' = 1,000 psi).
- Native onsite materials may be considered for backfill if they have an expansion index (EI) less than 50 and contain less than 8 percent fines, as determined by ASTM D4829 and D422.

C.5 Mechanical

This section describes the design criteria associated with key mechanical elements of the project. Mechanical design will follow the California Mechanical Code (2010) unless noted, and fire requirements per the California Fire Code (2010).

C.5.1 Piping

Based on experience with operation and maintenance of the IM facilities, the groundwater in the floodplain has high levels of total dissolved solids, chlorides, sulfate, and other minerals that have caused significant corrosion to iron-based piping material from mild carbon steel to Type 316 stainless steel. Therefore, piping will be designed and installed in accordance with best practices and past site experience for operation and maintenance, including use of flanged or union joints for serviceability and isolation valves for systems requiring routine maintenance.

In general, piping materials will be compatible with the characteristic of the conveying fluids and will be single-walled unless the pipe is used to convey: (1) groundwater or remedy-produced water that exhibits the hazardous waste characteristic; or (2) concentrated carbon substrate. In these cases, double-walled piping will be used. Double-walled pipe segments conveying either of the fluids described above will include appropriately designed leak detection systems. Low point sumps/traps with level switches and alarms will be the primary method of detecting leaks. Continuous leak detection systems may be used as an alternative to low point switches if switches are deemed impractical or incompatible with the installation. Pipeline segments installed in belowground concrete trenches (e.g., Pipeline A) will be designed with leak detection at low points (level switch with alarm).

In the case of Pipeline H which connects to well IRL-4 located at the bottom of a wash, double walled pipe segments will be used to convey remedy produced water from the wellhead to a valve vault located on the plateau. As access to this well is difficult and via a steep slope, this containment design is to provide for safe operations during well rehabilitation where acids and chemicals are used. In the event of a leak, the secondary

containment will drain to a concrete sump located at the wellhead. The concrete sump will be equipment with a level switch and alarm, as well as a sump pump.

Corrosion Control

For corrosion control, above ground and belowground steel pipe will be coated. Any steel pipe near the point where it emerges from the ground will be coated. Air-to-soil transition piping is any steel piping located 18" below ground or 6" above ground. Cathodic protection equipment will be applied as follows: 1) steel piping and structures will be cathodically protected underground; 2) plastic pipe (e.g., HDPE or CPVC or PVC) will be preferentially used when appropriate for corrosion resistance; and 3) steel pipe will be cement mortar-lined to prevent internal corrosion. Piping cathodic protection will conform to National Association of Corrosion Engineers SP0177-2007 Standard Recommended Practice - Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems. Exceptions to coating and cathodic protection requirements are steel casing pipes used for trenchless crossings.

In compliance with the EIR mitigation measures AES-1d and AES-2e, the external coatings used for wells, pipelines, storage tanks, structures, and utilities will consist of muted, earth tone colors that are consistent with the surrounding natural color palette, and matte finishes. Coating materials will be corrosion-resistant to protect the underlying surfaces.

Pressure Loss

For the freshwater and the remedy-produced water piping network, a hydraulic model built using the EPANET water supply program was used to simulate and optimize the piping design. Attachment B of this Appendix contains more details about the hydraulic modeling.

For the design of the in-situ remediation piping system, to ensure adequate distribution, the pressure loss in the branch distribution piping to each of the injection wells (including frictional losses and wellhead pressures from drop pipe frictional losses and pressure drop across the foot valve) will be designed to be 10 times higher than the pressure drop in the distribution header. The CIP loop conveyance piping will be designed to operate at a velocity of 3 to 5 feet per second (fps) and will have cleanouts at least every 400 feet.

C.5.2 Process Equipment

Primary process equipment (substrate dosing pumps, compliance related sensors, safety switches, etc.) will be designed for parallel operation or provide stand-by equipment to provide sufficient redundant capacity.

To the extent practical, all valving, instrumentation, manways, and access ladders for tanks will be located on the northern face (including northeastern face) of the remedial facilities to allow O&M personnel to work on the shady side during O&M activities.

C.5.3 Valves

Valves installed for throttling and flow control will include globe, needle, and diaphragm valves. Isolation valves will include; gate, ball, and butterfly valves. Other valves expected to be included in the remedy system include spring and swing check valves, pressure relief, air relief, variable orifice, foot, and vacuum relief valves. Carbon substrate storage tanks may include additional safety valves, including emergency ventilation and combination pressure/vacuum relief valves in accordance with applicable standards. Valves will meet PG&E and industry standards appropriate to the application and process conditions.

Exhibit C.5-1 lists potential valve types associated with the major equipment. Valves will meet industry standards appropriate to the application and process conditions. More details will be provided in the Intermediate design submittal.

EXHIBIT C.5-1
Potential Valve Type with Associated Device
Groundwater Remedy Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Equipment	Potential Valve Type
Fresh Water Injection Pumps	Pressure reducing, ball, ~~gate~~, swing check
Riverbank Extraction Pumps	Swing check, globe, butterfly, ball
Transwestern Bench Extraction Pumps	Swing check, globe, ball
IRZ Pumps	Swing check, globe, ball, pressure reducing, pressure relief
East Ravine Pumps	Swing check, globe, ball
IRZ Backflush Pumps	Swing check, gate, ball
Freshwater Backflush Pumps	Swing check, butterfly, flow control, ~~multiport gate~~
Carbon Substrate Pumps	Pressure and vacuum relief, solenoid, swing check, motor operate valve, ball
Pipelines	Butterfly, motor-operated valve, combination air release, ball,
Well Maintenance Reagent Pumps	Ball, Swing check, solenoid, multi-port, motor-operated valve
Ethanol Storage and Transfer	Pressure and vacuum relief, swing check, solenoid, ball, emergency vent
Process Pumps (Submersible Sump Pumps, Air-operated Diaphragm Pumps, Metering Pumps, Centrifugal Pumps)	Butterfly, swing check, motor-operated valve, ball, solenoid

C.5.4 Water Storage Tanks

Fixed steel tanks used for storing conditioned remedy-produced water will be designed in accordance with American Water Works Association Standard D-100 (2011). Foundations will be designed in accordance with the structural criteria described in Section C.3 above. Frac tanks used for storing remedy-produced water will be fabricated of welded steel and equipped with axles and wheels to enable them to be moved. Corrosion prevention measures will be applied to all tanks, including internal coatings. Permanent metal tank(s) will also have internal and external cathodic protection except for ethanol tanks mounted on saddle-type supports.

C.5.5 Secondary Containment

Secondary containment systems will be sized and designed in conformance with NFPA standards and California Fire Code (2010). In general, key design criteria are:

- Containment Volume
  - Secondary containment for a single container (tank) will be 110 percent of the primary container. Secondary containment for multiple containers will be 100 percent of the largest container's volume or 10 percent of the aggregate volumes of all containers, whichever is greater. In addition to the aforementioned, secondary containment systems open to rainfall will also be sized to accommodate spillage from the largest single tank at a minimum plus a 24-hr rainfall, as determined by a 25-yr storm. All secondary containment systems open to fire sprinkler discharge will also be sized to accommodate the discharge from all sprinkler heads over the secondary containment system for 20 minutes. Sprinkler system requirements to be determined.

- Containment Construction and Drainage
  - Secondary containment will be constructed using materials capable of containing a spill or leak for at least as long as the period between monitoring inspections. Drainage can be accomplished through the use of one of the following methods:
    - Liquid-tight sloped or recessed floors in indoor locations or similar areas in outdoor locations
    - Liquid-tight floors in indoor locations or similar areas in outdoor locations provided with liquid- tight raised or recessed sills or dikes
    - Sumps and collection systems (e.g., collection sump)
    - Drainage systems leading to an approved location
    - Other approved engineered systems
  - Collection systems will be equipped with a monitoring system to monitor level in containment sumps. Upon detection of fluids in the sump an alarm will be initiated to alert the operators of a potential release.
- Overfill Protection
  - A means of providing overfill protection for primary container will be required. This may be an overfill prevention device and/or an attention getting high level alarm.
- Separation of Materials
  - Materials that in combination may cause a fire or explosion, or the production of a flammable, toxic, or poisonous gas, or the deterioration of a primary or secondary container will be separated in both the primary and secondary containment so as to avoid intermixing.

C.5.5.1 Remedy-produced Water Conditioning Plant and Associated Tank Farm Areas

The Remedy-produced Water Conditioning Plant will contain hazardous materials (caustic, acids, etc.) and the B-side Remedy portion of the plant will process water streams with known or suspected contamination. The conditioned water tank farm area will be equipped with the capability for local neutralization using caustic or acids. Therefore, these areas will be designed with the following secondary containment and monitoring systems:

- Area 1 – The influent storage tank farm area will have secondary containment constructed with concrete, coated with epoxy, and equipped with a collection sump and a sump pump that pumps to either the Influent Storage Tanks or the Compressor Station Clean Water Tank.[2] The destination will be selected manually. A level switch mounted in the sump will issue an alarm when liquids are detected.
- Area 2 – The remedy-produced water conditioning system will have secondary containment constructed with concrete, coated with epoxy, and equipped with a sump and a sump pump that pumps to the Influent Storage Tanks or the TCS Cooling Tower Blowdown line. Sump monitoring will be accomplished via a level switch and alarm.
- Area 3 – The conditioned water tank farm area will have secondary containment constructed with concrete, coated with epoxy, and equipped with a sump and a sump pump that pumps to the Clean Water Tank or the Influent Storage Tanks. Sump monitoring will be accomplished via a level switch and alarm.

C.5.5.2 Truck Loading/Unloading Areas

There will be three truck loading/unloading stations with one at the MW-20 Bench, one at the Transwestern Bench, and one at the Compressor Station. Each truck loading/unloading area will be equipped with a secondary

[2] The Clean Water Tank receives clean water from the Oil/Water Separator and other sources of non-oily wastewater streams such as the cooling tower blowdown. Water from the Clean Water Tank is pumped directly to the TCS evaporation ponds.

containment system constructed of epoxy-coated concrete, transfer pumps, pipes or hoses for connecting to the trucks, and sumps and sump pumps. The sumps will have level switches that will alarm in the event of a spill.

C.5.5.3 Decontamination Pad

Consistent with the EIR mitigation measure CUL-1a-9, the existing decontamination pad at the Transwestern Bench will be reused during remedy implementation. This pad will be repaired and equipped with a collection sump and a sump pump that pumps to the remedy-produced water conditioning plant at the Compressor Station. It will be used to store soil cuttings, water from groundwater sampling, and to clean/store equipment used in well installation, maintenance, and sampling.

C.5.6 Septic and Plumbing System

The bathrooms and showers in the Central Maintenance Facility at the Transwestern Bench will be connected to a new leach field. The work will follow PG&E standards and County codes (adopted California Plumbing Code 2010). Fresh water will be supplied for use in the onsite laboratories and sample preparation areas in the Maintenance Facility, Remedy-produced Water Conditioning Plant building, and the MW-20 bench. Washbasins or sinks in laboratories will be drained to tanks or containers specifically for storing the fluids. The contained fluids will be managed in accordance with applicable permits, and state and federal regulations.

Remedial buildings will include rain water downspouts with spill out fittings to outside splash blocks for surface runoff, potable water emergency eyewash and shower stations, and plant water piping with wash-down hose bibs and connections for flushing of the chemical feed systems. The emergency eyewash and shower stations will be located near the chemical storage/feed areas, unless existing stations are nearby, and will be provided with drains.

C.5.7 Fire Protection Equipment

The Remedy-produced Water Conditioning Plant at the Compressor Station and the Central Maintenance Facility at the Transwestern Bench are unclassified, as described by NFPA 820; hence, only fire hydrants for fire protection are required. No fire and explosion hazard, materials of construction and ventilation requirements are listed in NFPA 820 for these facilities. However, PG&E is evaluating the installation of a sprinkler system for the Maintenance Facility.

Portable fire extinguishers will be mounted in buildings in accordance with PG&E requirements and County Fire codes. Portable fire extinguishers will be ABC multipurpose dry chemical type UL-rated 20A:120B:C.

All electrical equipment will have Underwriters Laboratory approval where applicable. Areas of the electrical installation will be classified in accordance by Class, Division, and Group. Specifically, for the IRZ facilities at the MW-20 Bench and the Transwestern Bench, the following will apply:

- Class I, Division I within a 5-ft radius of the carbon storage tank vents.
- Class I, Division II within a 10-ft radius of the carbon storage tank vents (from vent elevation to ground).
- Class I, Division II from ground surface to 18-inches above grade within a 10-ft radius of the tank footprint.
- Class I, Division II within the carbon amendment building where there are pipes with >10% ethanol.

C.5.8 Heating, Ventilation, and Air Conditioning

The new heating, ventilation, and air conditioning (HVAC) systems in planned remedy facilities are independent of the existing Compressor Station HVAC system. The design criteria for makeup air and temperature control for the laboratory/office and motor control center (MCC) rooms are as follows:

- Office/laboratory: Summer temperature <86 degrees F with no control for humidity. Makeup ventilation rate at 0.15 cubic feet per minute (cfm) per square foot or 15 cfm/person by code requirements.
- MCC Room: Summer temperature <90 degrees F with no control for humidity.

Wall-mounted ductless mini-split heat pumps will serve the rooms. A second, 100 percent capacity redundant unit will be installed for the Office/laboratory space. Wall mounted ductless mini-split heat pumps have two main components: an outdoor compressor/condenser and an indoor air-handling unit. Each unit will be capable of both cooling and heating the space. A conduit that houses the power cable, refrigerant tubing, suction tubing, and a condensate drain links the outdoor and indoor units. The indoor units will be mounted on the upper part of the room wall. Each unit will be sized per the heating and cooling requirements of each room.

For ventilation air in the Office/laboratory space, a 60 cfm exhaust fan will be installed with either inlet door louvers or by undercutting the door to transfer outside air from the filter room.

Outside of the office/lab and MCC room, the first and second floors of the remedy-produced water conditioning system will be naturally ventilated by constructing the building with no walls on three sides of the first floor (north, east and west), a wall on the north side with louvers, and a steel grating on the second floor adjacent to the filters and outside the MCC room and laboratory/office.

C.5.9 Air Pollution Control

Temporary and permanent mobile and fixed equipment emissions will comply with Clean Air Act - USC §§ 7401, et seq. (National Emission Standards for Hazardous Air Pollutants [NESHAP]); 40 Code of Federal Register (CFR) 61; 40 CFR 63 and local air district requirements (e.g., Mojave Desert Air Quality Control District).

C.5.10 Hazardous Materials Storage

The Hazardous Materials Division of the San Bernardino County Fire Department is the Administering Agency and the CUPA for San Bernardino County with responsibility for regulating hazardous materials handlers, hazardous waste generators, underground storage tank facilities, aboveground storage tanks, and stationary sources handling regulated substances. The handling and management of hazardous materials within the remedy facilities (e.g., the remedy-produced water conditioning facility) located within the Compressor Station will be incorporated into the existing Compressor Station Hazardous Materials Business Plan (HMBP). A separate HMBP will cover the handling and management of hazardous materials at remedy facilities located outside of the Compressor Station (e.g., MW-20 Bench, Transwestern Bench). A table of contents for the HMBP is provided in Volume 1 of the O&M Manual; complete plans will be provided at the 90% design stage. PG&E is in discussion with San Bernardino County regarding the HMBP; additional details will be provided at 90% stage.

Chemicals that are anticipated to be used in remedy processes and stored on site are listed below with location (estimated quantities of chemicals will be provided in the 90% design after process parameters have been confirmed):

- Potential chemicals to be used and stored for the Remedy-produced Water Conditioning System at the Compressor Station include the following:
  - 25% sodium hydroxide (caustic)
  - 19% hydrochloric acid
  - A coagulant is under evaluation for aiding in settling solids in the Conditioning System (if determined to be needed in the process, it will be identified during the 90% design)
  - A flocculent addition is under evaluation to aid in the dewatering of the influent tank bottoms prior to pumping to the liquid phase separators (the need for this dewatering aid and flocculent type would have to be tested during operations)
- Potential chemicals to be used and stored for the freshwater pre-injection treatment at the Compressor Station include the following:
  - An oxidizer such as calcium hypochlorite
  - An acid like sulfuric acid for pH adjustment and media regeneration
  - A caustic for pH adjustment and media regeneration

- Potential chemicals to be used and stored at the carbon amendment facilities include the following:
  - Carbon substrate (95% ethanol and 5% isopropyl alcohol) – one 15,000-gallon tank located at the MW-20 Bench and one 3,000-gallon tank located at the Transwestern Bench
  - Acids, caustics, and/or dispersants for use in the Clean-In-Place (CIP) systems at the MW-20 Bench and Transwestern Bench

Potential chemicals to be used in well maintenance include hydrochloric acid, sulfamic acid, sulfuric acid, phosphoric acid, hydroxyacetic acid, acetic acid, citric acid, oxalic acid, ascorbic acid, hydrogen peroxide, sodium hypochlorite, sodium hydroxide, chlorine dioxide, potassium hydroxide, polyphosphate, Aqua Clear™ PFD, Rodine-103/Rodine 213, QC-21, CB4, NuWell 120, NuWell 130, nitrogen, and/or carbon dioxide. These materials will be brought on site during the well maintenance/rehabilitation activities, but will not be permanently stored on site.[3]

C.6 Electrical

In this section, the electrical design criteria and goals are described. Electrical systems and equipment will be designed to meet PG&E standards and the California Electrical Code (2010) unless specifically noted. The new Remedy electrical power distribution system will receive power from a single source; potential sources of power are under evaluation by PG&E. Regardless of its source, electrical power will be distributed to the project loads at the Transwestern Bench, the Remedy-produced Water Conditioning Plant at the Compressor Station, the MW-20 Bench, and three distribution locations for wells.

C.6.1 Safety, Availability, Reliability, and Efficiency

Of paramount importance is the need to minimize electrical hazards to operating personnel, including shock, arc flash, electrical fire, and combustion of explosive atmospheres. This is accomplished by applying electrical equipment within its ratings and in accordance with the electrical, fire, and life safety codes listed herein. Every 480 volt and above disconnect will have provisions for lock-out tag-out. This will provide safe working for equipment that may not be in view of the breaker handle. Where possible, the breaker handles will be in view of the connected load for additional safety.

A backup generator will be available for use by this project. The location of the generator will be determined by the 90% stage.

The power distribution system will include energy management features, such as real-time power and energy monitoring, which can be used in conjunction with process data to optimize process efficiency.

C.6.2 Distribution Voltage Selection

The project's standard distribution systems include the following:

- 12.47 kV, ungrounded delta, 3-phase, 3-wire
- 480Y/277 volts solidly grounded wye, 3-phase, 4-wire
- 240/120 volts solidly grounded wye, 1-phase, 3-wire
- 208/120 volts solidly grounded wye, 3-phase, 4-wire

The distribution voltages used throughout the project will be selected to reduce maximum load flows to levels below standard electrical equipment capacity ratings, to increase the distance that it may be transmitted, to reduce fault duty to levels standard electrical equipment withstand and interrupting ratings, and to minimize the cost of the electrical installation. Exhibit C.6-1 lists the equipment utilization voltages.

[3] For additional details, see the Operations and Maintenance Manual, Volume 1, Section 4, Exhibit 4.2-5.

EXHIBIT C.6-1
Equipment Utilization Voltages
Groundwater Remedy Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Equipment	Volts	Phase
Fluorescent Lighting	120	Single, in office areas
Incandescent Lighting	120	Single
High-Intensity Discharge Lighting	120 or 240	Single
Other lighting	120	Single
Convenience Outlets	120	Single
Motor Control	120	Single
Motors, less than 1/2 horsepower (hp)	120	Single
Motors, 1/2 hp and above	480	Three

C.6.2.1 Voltage Drop

Total voltage drop from the transformer secondary to the point of utilization, including feeder, branch circuit, and transformation, will not exceed:

- Lighting - 3 percent
- Motors - 5 percent
- Receptacles - 5 percent
- Electric Heaters - 5 percent

Voltage dip calculations will be performed for motor starting whenever an individual motor exceeds 20 horsepower or if the motor is the longest or shortest distance from the transformer.

C.6.2.2 Demand Factors

The demand factors listed in Exhibit C.6-2 will be used for sizing power switchboards, MCCs, panelboards, and transformers. Connected load will be used for circuit and equipment sizing in accordance with NEC requirements. A 10 to 20 percent spare capacity will be provided at MCCs and panelboards. In accordance with the NEC, where it is unlikely that two or more coincident loads will be in use simultaneously, only the largest load(s) that will be in operation at one time will be used for calculating the total load of a feeder.

C.6.2.3 Metering

Multifunction digital meters will be provided for the MCC in the Remedy-produced Water Conditioning Plant.

C.6.2.4 Branch Circuits

- Connected load and NEC requirements will be used for sizing branch circuit breakers and conductors.
- A minimum wire size of No. 12 American wire gauge (AWG) copper will be used for lighting and receptacle branch circuits. No. 10 AWG will be used when voltage drop requires a larger conductor on lighting circuits, and when receptacle circuits are longer than 75 feet. Where electronic ballasts are specified for fluorescent or high-intensity discharge lighting, a dedicated neutral will be provided for each lighting circuit. There will be NO common neutral for multiple lighting circuits.
- In general, lighting branch circuit loads will be limited to 1,500 watts. Lighting and receptacle branch circuits will not be combined, and the number of convenience receptacles on any one branch circuit will be limited to five duplex in process areas, and six duplex in office areas.

- The electrical design will include a circuit and raceway schedule providing unique names and termination location information for each power, control, and signal circuit.

EXHIBIT C.6-2
Demand Factors
Groundwater Remedy Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Service	Demand Factor
Lighting	1.0 x Connected Load
Emergency Lighting	1.0 x Connected Load
Air Conditioning Equipment	1.0 x Connected Load
Ventilation Equipment	1.0 x Connected Load
Drainage Pumps and Ejectors	1.0 x Connected Load
Convenience Receptacles	180 VA each [a]
Process Loads	1 x Full Load Amps of loads plus 25% of largest motor

Notes:
a. Apply NEC demand factor of 50% for totals over 10 kW
VA = volt-amperes

C.6.2.5 Panelboards

- Branch circuits or feeders on the drawings will identify the panelboard and device protecting the individual circuit or feeder.
- Each panelboard will be equipped with a minimum of 20 percent spare breakers with spaces, bus work, and terminations to complete the standard size panelboard.
- Panelboard schedules will be prepared indicating circuit identification, protective device trip rating, number of poles, load in volt-amps by phase, rating of main lugs or main circuit breaker, neutral bus size, ground bus size, and the integrated short circuit rating of the panelboard.

C.6.2.6 Uninterruptible Power Supply

Uninterruptible power supply (UPS) will be provided for each control panel. The UPS output will be automatically selected through an automatic bypass relay.

C.6.2.7 Motor Control and Protection

Safety interlocks, such as emergency stop pushbuttons, will be hardwired directly to motor control circuits. Process controls and interlocks will be hardwired from Supervisory Control and Data Acquisition (SCADA) system programmable logic controllers (PLCs) to motor starters. Electrical metering data will be transmitted from intelligent motor overloads and relays to the SCADA system over an Ethernet network. Elementary (ladder-type) control diagrams will be prepared for each motor showing control wiring, pilot devices, auxiliary contacts, and external connections. A single diagram will be used for more than one motor having the same control.

In addition, the following guidelines will be used:

- Adjustable overload relays will be provided for all MCC-mounted and remote mounted constant-speed motor controllers. MCC-type construction will be used.
- MCCs located in the same room with the switchboard that powers them will not have a main circuit breaker. MCCs located in areas remote from the common MCC or switchboard that powers them will have a main circuit breaker.

- MCC enclosures will be NEMA 1 gasketed. Circuit breakers 225 amps and smaller and motor starters NEMA 4 and smaller will be the cubicle type with auto disconnect of control and motor power conductors.
- MCCs will include feeder circuit breakers and motor starters. Motor starters for motors up to 25 hp will be the full-voltage, non-reversing, combination type with a magnetic-only circuit breaker. Motor starters for motors larger than 25 hp will be the solid-state, soft-start, reduced-voltage, combination type with a magnetic-only circuit breaker.
- Motor starters will include an ON/OFF/AUTO or HAND/OFF/REMOTE selector switch, GREEN motor ON light, RED motor OFF light, and AMBER abnormal condition, fault, or alarm lights, as required. Lights will be the LED push-to-test type. These devices will be mounted on the front of the motor starter control center cubical.

C.6.2.8 Equipment Identification

Process and instrumentation diagram (P&ID) tag numbers will be used for motors, instrumentation and control devices, and other process equipment shown on electrical drawings. This same numbering method will be used to create unique tags for major electrical distribution equipment.

C.6.3 Electrical Equipment

This section discusses general guidelines for the selection and configuration of electrical equipment.

C.6.3.1 Distribution System Equipment

Equipment will be selected with adequate momentary and interrupting capacity for the point in the system where it is used. Series-rated criteria will not be used, except for self-contained equipment. Where practical, phase and ground fault protective devices and device settings will be selected that will function selectively to disconnect that portion of the system that is malfunctioning, and with as little disturbance to the rest of the system as possible.

Distribution equipment criteria include the following:

- 15 kV-class metal-clad switchgear will be specified to provide power distribution selection at the front end of the Remedy system.
- The switches will be interlocked, so only one power feed will be allowed to connect to the system at any given time. There will not be any provisions or need for paralleling systems.
- 15 kV-class cable will connect the transformers together through underground conduit.
- Sectionalizing equipment will allow for individual transformers to be isolated and replaced or repaired.
- The transformers will be distribution style, similar to those used for commercial buildings. The secondary voltage will be 480/277 volt.
- 480-volt MCCs with combination motor starters of the motor circuit protector (MCP) type rated for the available fault current.
  - Starters that are NEMA size 2 (25 hp) and larger will be the solid-state, soft-start type or adjustable-speed drives.
  - MCCs will be hardwired to the PLC for motor control.
  - Field-mounted, maintained, emergency stop push buttons will be hardwired directly to the motor starter.
  - MCCs will be sized to accept future loads and either allow for space in the structures, or floor space for future sections.
- 480-volt and 240/120-volt power distribution and lighting panelboards with molded case, bolt-in, circuit breakers with integrated short-circuit rating suitable for the available fault current.

C.6.3.2 Raceway Systems

Separate ductbanks will be used for the following systems:

- 12.47-kV power distribution
- 480-volt power wiring and 120-volt control wiring
- Communications systems, including Ethernet, low-voltage signal for fire alarm, telephone and data systems, and fiber optic cabling

Special consideration will be given to separation of raceways involving low-level process control signal wiring and power system wiring to minimize the possibility of interference. General guidelines for raceway sizing, selection, and installation are as follows:

- Conduit sizing will be based on Type THW insulation.
- The following minimum sizes will be used:
  - 3/4-inch minimum diameter for conduit not in ductbanks used within buildings or connected directly to the equipment or device.
  - 1-inch minimum diameter for conduit in ductbanks for field interconnection of equipment or buildings.
- Raceways will be a combination of concealed and exposed in process areas.
- Raceways will be concealed in walls and ceilings in control rooms, offices, and areas that have finished interiors.
- PVC-coated rigid galvanized steel conduit will be used for the transition from underground direct burial and under-slab PVC conduit and concrete-encased (in-floor slab) PVC and rigid galvanized steel conduit to exposed rigid galvanized steel conduit. The transition section will extend from 1 foot below grade or top of floor slab or the last foot of conduit in the floor slab, to 6 inches out of the floor slab, concrete encasement, or above grade.
- The number of conduit bends will be limited to an equivalent of 270 degrees on long runs without pull boxes.
- PVC-coated rigid galvanized steel conduit and fittings that are resistant to direct sunlight and include an interior urethane coating will be used in exposed corrosive interior and exterior areas. This conduit will also be used for underground direct-burial. Direct buried conduit will have a 3-inch red colored concrete cap.
- PVC Schedule 40 conduit and fittings will be used for under-slab and concrete-encased ductbanks.
- Rigid galvanized steel conduit and fittings will be used when exposed in interior non-corrosive process and non-process areas, pre-cast concrete utility trenches, and in non-corrosive areas outdoors.
- Flexible, nonmetallic, liquid-tight conduit 4 inches or smaller in size will be used for connections to motors, transformers, etc., as required. Fittings will be PVC-coated in wet or corrosive areas. Length of flexible conduit will be limited to 36 inches.
- Underground conduit routes will be identified with nonmetallic warning tape and tracer wire above underground direct-burial conduits.
- Raceways will be tagged with a engraved plastic or nonferrous metal embossed tag attached to the raceway with a stainless steel wiring. Raceway tags as defined in the plans and conduit schedule will be located at each terminus, pullbox, and at minimum intervals of every 50 feet on exposed raceways (in ceiling spaces and surface-mounted).
- Cable trays will be evaluated for use where appropriate.

C.6.3.3 Wire and Cable

- Stranded copper conductors will be used for all except lighting and receptacle wiring. Solid conductors No. 10 AWG and smaller will be used for lighting and receptacle wiring.
- A minimum conductor size of No. 12 AWG will be used for power and lighting branch circuits. Type THHN/THWN-2 insulation will be used for No. 10 AWG and smaller conductors (conduit will be sized for Type THW conductors). Type XHHW-2 insulation will be used for No. 8 AWG and larger conductors (conduit will be sized for THW conductors). Conductor ampacity ratings of 75°C will be used for sizing conductors.
- A minimum conductor size of No. 14 AWG will be used for individual 120-volt control circuits.
- A minimum conductor size of No. 14 AWG will be used for 120-volt control circuits routed in a common conduit with the power conductors to the motor circuit controls. Combining individual motor power and control conductors in a common conduit will be done up to a maximum power conductor size of No. 2 AWG.
- Power and control conductors will be color-coded. Conductors No. 8 AWG and smaller will have colored insulation. Conductors No. 6 AWG and larger will be color-coded with tape at each end and at accessible intermediate points.
- Conductors and control cables will be tagged with a permanent sleeve or nylon marker plate attached with a nylon strap. Conductor tags with an approved tag number will be provided by the Contractor and will be located in accessible locations at each termination.
- Under normal conditions, the maximum wire size will be limited to 500 kcmil. Parallel conductors will be used for circuits requiring greater capacity.
- The 120-volt control circuits will be combined in control cables containing multiple No. 14 AWG stranded copper conductors with type THHN insulation and a common PVC outer jacket.
- A 600-volt multi-circuit control cable will be used where grouping control circuits is practical, and the number of individual wires exceeds six conductors. When selecting control cable size, 25 percent spare (plus or minus 10 percent) conductors will be used.
- Multi-conductor control cable color-coding will be ICEA S-61-402 Appendix K, Method 1, Table K-2.
- Low-voltage analog signal circuits will be routed in 600-volt single twisted shielded pair instrumentation control cables. The cables will consist of No. 16 AWG stranded copper conductors with combination PVC/nylon insulation, drain wire, shield, and PVC outer jacket. Signal circuits may be combined in multi-twisted shielded pair instrumentation control cables with common overall shield. The cables will consist of No. 18 AWG minimum stranded copper conductors, with a combination PVC/nylon insulation, pair and common drain wires, pair and common shields, and PVC outer jacket. Instrumentation control cables will be in accordance with ICEA S-82-552. Low-voltage analog signal circuits will not be routed in the same control cable or conduit with 120-volt control or power circuits.
- Adequate separation of power and instrumentation and control (I&C) wiring will be provided to avoid signal interference.
- Shielded power cables will be used between adjustable-frequency drives and the driven motor.

C.6.3.4 Color Coding

Conductor insulation colors will be as shown in Exhibit C.6-3.

EXHIBIT C.6-3

System Color Coding

Groundwater Remedy Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

System	Conductor	Color
All Systems	Ground	Green
208Y/120 Volts	Neutral	White
	Phase A	Black
	Phase B	Red
	Phase C	Blue
240/120 Volts	Neutral	White
	Phase L1	Black
	Phase L2	Red
480Y/277 Volts	Neutral	White
	Phase A	Brown
	Phase B	Orange
	Phase C	Yellow
12.47 kV	Phase A	Phase A
	Phase B	Phase B
	Phase C	Phase C

C.6.3.5 Circuit Identification

Circuit names will be assigned based on the device or equipment at the load end of the circuit. Circuits will be identified at each termination and in accessible manholes and pull boxes. Plastic sleeves for conductor No. 3 AWG or smaller and plastic marker plates for larger conductors will be used. For lighting circuits, the panel and circuit number will be identified for each fixture.

C.6.3.6 Enclosures

NEMA 1 enclosures will be used for equipment in electrical rooms and finished areas, while NEMA 12 enclosures will be used for electrical equipment in dry industrial locations. NEMA 3R enclosures will be used for outside and in wet locations, and NEMA 4X enclosures will be used for corrosive locations. NEMA 4 enclosures will be used for underground and in wet locations.

C.6.3.7 Fiber Optic Cabling

Where used, fiber optic cabling will be installed either in conduit (4-inch-diameter minimum with three 1 ¼-inch inner ducts), or in a cable tray. Routing of the raceway system will provide for large-radius turns to prevent breaking of the fiber optic cable.

C.6.3.8 Convenience Receptacles

General-service duplex receptacles will not be spaced more than 25 feet apart in process areas. Receptacles will be surface-mounted on walls or columns. Weatherproof receptacles will be installed in damp areas or areas subject to washdown.

Outlet-mounted ground-fault circuit-interrupters (GFCIs) will be provided where required by the NEC. Panelboard or feed-through-type devices will not be used.

C.6.3.9 Low Voltage AC Induction Motors

Enclosures for both horizontal and vertical motors 25 hp and smaller will be totally enclosed, fan-cooled (TEFC) severe-duty for indoor and outdoor locations. In wet and/or corrosive locations, chemical industry severe-duty (CISD-TEFC) motors will be used. Motors larger than 25 hp will be open drip-proof, unless TEFC or CISD-TEFC is required for specific conditions (evaluated on a case-by-case basis considering cost and required physical protection). Submerged motors will be totally submersible, air- or oil-sealed. Bearings will be rated for 100,000-hour Anti-Friction Bearings Manufacturers' Association (AFBMA) B-10 life.

Alternating current (AC) induction motors will be the premium efficiency type with the following:

- Motors will have a 1.15 service factor at 50 degrees Celsius ambient, except where inverter-duty rated.
- NEMA design letter to fit the application (usually NEMA design B), and locked rotor kV-amps kVA Code G or lower.
- Motor windings will be copper wire.
- Motors 15 hp and larger located in damp or wet areas will be provided with 115-volt space heaters to prevent moisture condensation.
- TEFC motors will be equipped with weep holes and drain plugs to withdraw condensed moisture.
- Motors operated by variable frequency drives (VFDs) will be specified with special provisions for inverter duty operation.

C.6.4 Electrical Systems Analysis

An analysis of the fault current will be made during the 90% design. Maximum fault current will be analyzed with sufficient accuracy to establish the required interrupting ratings of circuit protective devices specified.

During construction, a final load flow, short circuit, coordination, and arc flash hazard analysis will be performed by the Project Engineer, based on actual equipment purchased, to establish protective device settings that will result in reasonable selectivity of device operation for both three-phase and ground faults, while minimizing the arc flash hazard to workers. The following protective device characteristics will be specified:

- Protective relay model, pickup, and time delay settings
- Circuit breaker model, frame size, trip unit, trip settings, and time delay settings
- Current transformer ratios

Arc flash labels will be placed on the installed electrical equipment.

C.6.5 Grounding System

An integrated grounding system will be installed throughout the new remedial facilities and interconnected with the existing grounding system at the Compressor Station. A lightning protection system will be connected to the facility ground ring as well as to any exposed metallic surfaces.

Grounding electrode ground mats or embedded rods and cables will be designed for a maximum resistance to ground of 25 ohms. Where more than one rod is required, rods will be installed at least 20 feet apart. A minimum of No. 4/0 AWG stranded bare copper cable will be used for interconnecting to ground rods and footing rebar.

A lightning protection system will be designed with air terminals and separate grounding system on buildings or structures used for operations and maintenance and chemical storage, including shade structures. Shade structures, if isolated from electrical equipment, may not be required to have lightning protection.

Equipment Grounding

A separate ground conductor sized in accordance with NEC requirements will be installed in raceways for power feeders and branch circuit raceways for motor control, lighting, and receptacle loads.

Shields of shielded instrumentation cables will be grounded to the ground bus at the power supply for the analog or low-voltage discrete signal circuit. Shielded instrumentation cables will not be grounded at more than one point.

C.6.6 Hazardous and Corrosive Area Definition

Area classification will be shown on the drawings and will be defined at the 90% design stage.

C.6.7 Energy Efficiency and Lighting

Energy efficiency will be a factor in equipment selection. Motors will be specified to be Premium Efficient per latest NEMA MG 1 standard where possible. Lighting equipment and facilities for safe operations will be designed to be energy efficient and comply with California Title 24 and county lighting ordinances. In compliance with EIR mitigation measure CUL-1a-7, to minimize construction and operations-related lighting impacts, the lighting for the remedy will include the following features: (1) shrouding/shielding for portable lights during construction and operational activities; (2) installation of portable lights at the lowest allowable height and in the smallest number feasible to maintain adequate night lighting for safety; and (3) shielding and orientation of lights such that off-site visibility of light sources, glare, and light from construction activities are minimized to the extent feasible. In addition, no additional permanent poles will be installed for lighting.

C.6.7.1 General Lighting Requirements

Since CUL-1a-7 is not meant to replace or subsume any actions required by the County or state or federal entities with regard to lighting required for minimum security and safety purposes, the following specifications will also be met:

- Construction Industry 29 CFR 1926.56 (lighting safety requirements)
- General Industry 29 CFR 1910.120 (HAZWOPER) (lighting safety requirements)
- San Bernardino County Code Title 8 Section § 83.07.040 Glare and Outdoor Lighting - Mountain and Desert Regions
- Mohave County Outdoor Light Control Ordinance 87-1
- Specific requirements from land owners, if feasible and is not in conflicting with the mitigation measures and county codes

The San Bernardino County lighting requirements are divided into two categories: residential and commercial/industrial. Remedy facilities are located both on and outside of PG&E-owned land, as follows:

- PG&E parcel (zoned industrial) – Compressor Station and Transwestern Bench
- Outside of PG&E parcel (zoned recreational) – Federally-owned land (including MW-20 Bench), the Havasu National Wildlife Refuge, and Fort Mojave Indian Tribe-owned land

PG&E will apply industrial requirements on the PG&E parcel and residential requirements outside of the PG&E parcel. The rationale for installing lights outside of the PG&E parcel is as follows:

Well Sites

- Nighttime access is not necessary; therefore no permanent lights will be installed. No new permanent light poles will be installed.
- Portable or truck-mounted lights can be brought in the event that an emergency or unforeseen condition occurs and plugged in locally.

MW-20 Bench

- Similar to the IM-3 Brine Storage Facilities located at the MW-20 bench, nighttime access is not normally required. Exterior lights will be installed but activated manually.
- No new permanent light poles will be installed.

In both Mohave and San Bernardino Counties, the lighting requirements are intended to reduce glare or other light emissions on adjacent properties. Exhibit C.6-4 lists San Bernardino County shielding requirements for different types of fixtures in residential and commercial areas.

EXHIBIT C.6-4
Shielding Requirements For Outdoor Lighting In the Mountain Region and Desert Region
Groundwater Remedy Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Fixture Lamp Type	Residential Area Shielded	Commercial/Industrial Area Shielded
Low pressure sodium	Fully	Fully
High pressure sodium	Prohibited except fully shielded on streets	Fully
Metal halide	Prohibited	Fully
Fluorescent	Fully	Fully
Quartz	Prohibited	Fully
Incandescent > 60 watts	Fully	Fully
Incandescent 60 watts or less	No requirement	No requirement
Glass tubes filled with neon, argon, or krypton	No requirement	No requirement
Mercury vapor	Prohibited	Fully
Halogen	Prohibited	Fully
Searchlights for advertising purposes	Prohibited	Prohibited
Laser source light or similar light intensity light for advertising purposes	Prohibited when projected above the horizontal	Prohibited when projected above the horizontal

Source: San Bernardino County Development Code, Ch. 83.07.040 Table 83-7. Note that LED lights (a low energy form) may be suitable for the Remedy. This technology is not covered in the County Code.

Fixtures prohibited by the County Code will not be used on the project. Fixtures planned for use in the remedy project are listed in Exhibit C.6-5. Fixtures used at the Compressor Station will comply with County requirements and follow PG&E standards for energy efficiency and lighting at operating facilities.

EXHIBIT C.6-5
Planned Fixtures for Remedy and Associated County Requirements For Outdoor Lighting
Groundwater Remedy Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Fixture Lamp Type	Shielding Requirement	Type Used in Remedy Project?
Low pressure sodium	Fully	Indoors/Outdoors
Fluorescent	Fully	Indoors
Incandescent > 60 watts	Fully	Indoors
Incandescent 60 watts or less	No requirement	Indoors
LED	No requirement (not covered in the County Code)	Indoors

Source: San Bernardino County Development Code, Ch. 83.07.040 Table 83-7.

The amount of light or the illumination level is based on having sufficient light to do the expected tasks safely. OSHA sets standards for construction activities as shown on Exhibit C.6-6 below.

EXHIBIT C.6-6
Minimum Illumination Intensities
Groundwater Remedy Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Level (foot-candles)	Area of Operation
5	General construction area lighting.
3	General construction areas, concrete placement, excavation and waste areas, access ways, active storage areas, loading platforms, refueling, and field maintenance areas.
5	Indoors: warehouses, corridors, hallways, and exit ways.
5	Tunnels, shafts, and general underground work areas. (Exception: minimum of 10 foot-candles is required at tunnel and shaft heading during drilling, mucking, and scaling. Bureau of Mines approved cap lights shall be acceptable for use in the tunnel heading.)
10	General construction plant and shops (e.g., batch plants, screening plants, mechanical and electrical equipment rooms, carpenter shops, rigging lofts and active store rooms, mess halls, and indoor toilets and workrooms.)
30	First aid stations, infirmaries, and offices.

Source: Safety Lighting Levels During Construction – OSHA 29 CFR 1926.56(a) Table D-3.

For activities and areas not included under the OSHA standard, the ANSI/IES has established recommended illumination levels under Recommended Practice RP-07-01 (see Exhibit C.6-7 below).

EXHIBIT C.6-7
Recommended Illumination Levels per ANSI/IES RP-07-01
Groundwater Remedy Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Category	Description	Level
A	Public spaces	3 fc (30 lux)
B	Simple orientation for short visits	5 fc (50 lux)
C	Working space where simple visual tasks are performed	10 fc (100 lux)
D	Performance of visual tasks of high contrast and large size	30 fc (300 lux)
E	Performance of visual tasks of high contrast and small size, or tasks of low contrast and large size	50 fc (500 lux)
F	Performance of visual tasks of low contrast and small size	100 fc (1,000 lux)
G	Performance of visual tasks of critical importance	300 – 1,000 fc (3,000 – 10,000 lux)

Notes:
fc=foot-candles
1 fc ≈ 10 lux

C.6.7.2 Lighting Calculations

The recommended illumination level (foot-candles) for each space will be calculated in accordance with IES procedures. The following assumptions will be made, unless specific information is available:

Reflectances for finished rooms:

- Ceilings 80 percent reflectance
- Walls 50 percent reflectance
- Floors 20 percent reflectance

Reflectances for unfinished rooms:

- Ceilings 50 percent reflectance
- Walls 30 percent reflectance
- Floors 10 percent reflectance

Maintenance factor (light loss factor):

- Fluorescent lighting 0.80

C.6.7.3 Emergency Lighting System

- Emergency illumination will be provided in appropriate spaces, as required by code to provide life safety, property, and equipment protection.
- Adequate lighting levels will be provided to maintain safe building egress and critical process plant functions. Emergency lighting will be located near MCCs and any equipment locations that need to be monitored on a continuing basis.
- In large process areas, emergency standby lighting units with a battery pack and two lamps and lighted exit signs with a battery pack will be provided. The battery pack will power the lights for at least 90 minutes.

- In non-process and finished areas, continuous-on lights with emergency ballast and battery pack, and exit signs with a battery pack will be provided. The continuous-on light battery pack will power one fluorescent lamp and the exit sign battery pack will power the exit sign for at least 90 minutes.

C.6.7.4 Explosion-Proof Luminaires

Any room or space listed as a hazardous atmosphere area will have explosion-proof-type luminaires UL listed for installation in the hazardous area classifications, as required by Article 500 of the NEC.

C.6.7.5 Nighttime Construction Lighting

The first step will be to determine whether nighttime construction work is required. Nighttime construction-related activities will be limited to work that cannot be disrupted or suspended until the following day, such as, but not limited to, well drilling and development or decommissioning activities. If nighttime construction is required, the following principles will be applied:

- Identify the active area for construction and the applicable lighting standards. Only areas of active construction may be illuminated.
- Obtain portable lighting (including solar-powered). Lights must include shielding/shrouding (e.g., downward facing fixtures with cutoff shields to reduce light diffusion). No permanent poles will be installed for nighttime lighting.
- Install the minimum lighting feasible to maintain adequate night lighting for safety at the lowest allowable height. Orient the lights such that off-site visibility of light sources, glare, and construction activities is limited.
- Assign a responsible member of the construction crew, such as foreman or crew boss, to extinguish the lighting as soon as the nighttime construction work is completed.

C.6.8 Communications

Fiber optic cable or conventional copper wire will be used for sending signals via cable. Wireless communications devices like radio, satellite, or cellular, may be used as appropriate.

C.6.9 Existing Utilities

All existing utilities will be potholed for actual depth prior to construction following Compressor Station or utility owner methods and requirements, including maintaining a minimum 25-foot right-of-way for the L300 gas pipelines located near occupied buildings. Existing engineering drawings have been reviewed to identify areas of potential conflict, but are for planning purposes only, not solely relied upon. A utility survey was conducted in early 2012 to support the remedy design. See also Section C.2.2, Earthwork.

C.7 Instrumentation and Control

The I&C system for the project will utilize a stand-alone SCADA system and local PLCs. The SCADA system will be located at the Central Maintenance Facility (Transwestern Bench) and will provide monitoring, supervisory control, alarming, and control functions. Historian software will collect, archive and distribute project-wide raw data and provide access to historical data.

In general, emergency shutdown of equipment due to alarm conditions (low discharge flow, high discharge pressure, motor overload, pump seal water failure, high level vault alarms, etc.) will be hardwired and will occur remotely or be executed locally. These alarm conditions will require manual reset at the SCADA or the local digital controller. In conformance with the EIR mitigation measure CUL-1a-6, all additional phone calls and alarms associated with remediation activities or facilities will not be routed through PG&E's existing alarm system utilized at the Compressor Station. The notification system for remediation-related alerts and/or phone calls will not introduce additional noise to the project area, to the maximum extent feasible, provided there is ongoing compliance with applicable safety regulations or standards of the Federal Energy Regulatory Commission, Occupational Safety and Health Administration, and other agencies.

Local PLCs will have operator interface terminals. The operator interface will include sufficient access to modify system set-points, parameters, alarms limits, and indication of associated process variables and instruments. This data will also be available to the SCADA system for full remote control, alarming, trending, archiving, etc.

Each PLC switch will be connected to the Maintenance Building's gigabit capable Ethernet backbone switch. The fiber cable will be run from the Maintenance Building communication panel to remote communication panels and onto each remote PLC. The fiber cable will be multimode or single mode as applicable, consisting of 12 fibers per cable. All fiber cables will be color coded, labeled and terminated at a fiber interconnect panel.

The system has been designed to allow for isolation/removal of components that could fail from operational sequencing, thereby minimizing downtime. Full redundancy of the control system was determined to be unnecessary. System outage in individual area is expected to be repaired and put back into service within two to three days given an appropriate inventory of parts and skilled staff availability.

Power Distribution to Instrument Power Panel

All control power for each area PLC will be supplied by control panel. The control panel shall be fed from the area primary distribution transformer. All I&C power for field devices or panels will be sourced from the control.

Uninterruptible Power Supply

The UPS will be double conversion "true online" and configured with an automatic bypass switch for battery maintenance. The UPS will provide power to the PLC, 24-volt DC power supply, Digital Input/Digital Output (DI&DO) cards, and analyzer power.

Power System Monitoring/Control from SCADA

Power distribution panels, motor control centers, and communications panels will be supplied with digitally networked power metering devices for remote energy monitoring and control. Primary distribution equipment and selected secondary equipment will be supplied with electrically actuated circuit breakers or contactors which will be available for remote position monitoring and alarming as well as remote manual and automatic control via the SCADA system. Automatic sequencing for restarting of equipment after restoration of power will be provided through SCADA.

C.8 Architectural

Building and all infrastructure components will conform to the following:

- Exterior finishes: In conformance with the EIR mitigation measure AES-1d and AES-2e, the color of the wells, pipelines, reagent storage tanks, control structures, and utilities shall consist of muted, earth-tone colors that are consistent with the surrounding natural color palette. Matte finishes shall be used to prevent reflectivity along the view corridor. Integral color concrete should be used in place of standard gray concrete.
- The design, location, and physical appearance and character of new construction at the Topock Compressor Station will be consistent with existing buildings in scale, form, materials, and architectural detail.
- For new construction within the Compressor Station fenceline: In keeping with the Secretary of the Interior's Standards for the Rehabilitation of Historic Buildings, the new construction will be differentiated from existing historic architecture on the property, but will be compatible with the historic materials, features, size, scale and proportion, and massing to protect the integrity of the Topock Compressor Station and its environment.
- Floors: Floors will be reinforced cast-in-place concrete and steel grates where required for water containment. Six-inch housekeeping pads at equipment locations.
- Doors and frames: Heavy-gauge hollow metal doors and frames will be used. Doors from the exterior into the facility and the interior door into the groundwater sampling equipment room will receive a tempered glass window. Hardware to be of heavy gauge and made of stainless steel where practical.

- Overhead sectional doors: A 12-foot wide by 12-foot high heavy-gauge steel overhead sectional door with perforations to allow for air movement. Overhead door to be manually operated.
- Exterior wall assemblies: Exposed concrete and painted concrete masonry unit (CMU) on the lower floor. Insulated metal siding on the upper floor with Kynar finishes to match existing adjacent buildings.
- Interior walls and ceilings: Metal studs with Batt insulation where separating conditioned and non-conditioned spaces. Wall to be built on a concrete curb and receive moisture resistant gypsum board on both sides.
- Windows: Aluminum framed windows with a clear anodized finish. Energy efficient insulated tempered glass with a low-E coating. Extensive use of day lighting through windows.
- Louvers: Aluminum drainable louver with a clear anodized finish.
- Roof: Insulated metal roof with continuous ridge vent and Kynar light colored finishes to match existing adjacent buildings.
- Fire protection: Fire extinguishers as required per building and fire codes including NFPA 10.
- Interior finishes: Epoxy paint over gypsum board and CMU. Clear sealer at concrete. All paint to be off-white to promote a bright space where light can reach areas behind equipment.
  - Cabinetry: Wood cabinets with chemical-resistant countertops and stainless steel pulls.
  - Floors: Smooth texture and finished with a clear surface sealer to increase the durability of the concrete surface and to maintain a clean, dust-free environment.
  - Framing: Steel framing to be finished with an epoxy primer and polyurethane finish coating.
  - Interior walls: Epoxy paint over gypsum board in laboratory room and MCC room, light colored vinyl backed insulation at metal roof, painted concrete at lower floor ceiling to improve light reflectivity.
  - Pedestrian doors: Field finished with polyurethane and epoxy finish coating.

C.9 PG&E Personnel Requirements

PG&E personnel will perform the following activities during construction:

- PG&E personnel, or their designee, will lead TCS-specific safety and biological and cultural sensitivity training for contractors and employees.
- Serve as liaison and primary contact for any agency, tribal, or other third party personnel inspecting and/or monitoring construction and O&M activities.
- Serve as liaison and primary contact for community, stakeholders, agencies, Tribes, members of the press, and others requesting site tours or project-related information.
- Initiate communications with/notifications to agencies, land owners, and others, as required, in the event of emergencies or contingency triggers.
- Attend stand-up tailboard (safety) meetings before the start of work each day to review safety policies and specific hazards likely to be encountered in the day's activities.
- Sign waste manifest forms and compliance documents that require PG&E certification.
- Monitor for compliance with PG&E safety standards and requirements and contract specifications, terms, and conditions.

Additional criteria may be added for the pre-final (90%) design submittal.

C.10 Health and Safety

The project falls under federal Occupational Safety and Health Administration (OSHA) Hazardous Waste Operations and Emergency Response (HAZWOPER) requirements (29 CFR 1910.120) so these procedures must be followed in addition to California and Arizona state requirements.

These requirements will be embodied in project-specific health and safety plan(s) for construction and O&M that will be prepared and submitted to DTSC and DOI for review prior to ground disturbance activities. In addition, health and safety work plans will be prepared or amended by construction, drilling and other service contractors working on the project. Existing health and safety plans will be reviewed and amended, as needed, to suit new project requirements and/or conditions. PG&E personnel similarly work under PG&E's own health and safety requirements. These health and safety plans will describe such things as training, site control, medical surveillance, safety personnel roles and responsibilities, personnel protective equipment, exposure monitoring and air sampling programs, heat and cold stress, and site work rules and procedures.

Project-specific health and safety plans will be provided with the Pre-Final (90%) Design submittals.

C.11 Noise

- A design margin of 3 to 5 A-weighted decibels (dB[A]) will be considered in all noise design criteria.
- In conformance with the EIR mitigation measures NOISE-3 and CUL-1a-10, the operational noise design criteria for the project will be per San Bernardino County Development Code 83.01.080 for acceptable exterior noise standards for place of worship, which is 55 dB(A) Leq daytime (7 a.m.-10 p.m.) and 45 dB(A) Leq nighttime (10 p.m.-7 a.m.) (Leq is the equivalent average hourly noise level) (see page 4.9-24 of the EIR [DTSC 2011]). The noise measurement locations will be at the edge of the Maze closest to the subject facilities and at the short-term ambient noise measurement locations (ST-1, ST-2, and ST-3) in Exhibit 4.9-2 of the certified EIR (DTSC 2011).
- For remedy facilities in Arizona, the operational noise design criteria will be 60 dB daytime and 50 dB nighttime average at closest residences (per current Mohave General Plan, Exhibit V-5, Maximum Noise Levels for Various Land Use).
- For remedy facilities on the Refuge, the operational noise design criteria will be 60 dB.
- For remedy facilities located on the Compressor Station and within PG&E property, the operational noise design criteria will be consistent with the noise environment at the Station, per San Bernardino County Development Code 83.01.080 for industrial land use, 70 dB(A).
- The construction noise criteria will conform to San Bernardino Development Code and Mojave County standards, as well as the EIR mitigation measures NOISE-1, -2, and -3. Per San Bernardino County Code Division 3 Chapter 83.01.080, temporary construction, maintenance, repair, or demolition activities between 7:00 a.m. and 7:00 p.m., except Sundays and federal holidays, are exempt from noise limits.

C.12 References

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Attachment A
Carbon Substrate Selection and Degradation Pathways Design Bulletin (*on CD-ROM only*)

ARCADIS	TOPIC: **Carbon Substrate Selection and Degradation Pathways Design Bulletin**	
Revision 2 (8/1/12)	REPORT SECTION: Appendix C	BULLETIN No.:

1. Purpose

The objective of this Design Bulletin is to detail the basis of design for the selection and usage of carbon substrates and their degradation pathways for the In-Situ Reactive Zone (IRZ) at the Pacific Gas & Electric (PG&E) Topock site. There is a wide spectrum of organic carbon substrates available for anaerobic in-situ reactive zone (IRZ) applications including fermentable soluble substrates such as molasses, lactate, and whey; alcohols such as ethanol and methanol; semi-soluble substrates such as emulsified vegetable oil; and solids such as chitin and bark mulch.

Selection of the appropriate substrate depends on the balance between the mode of delivery, the substrate properties, and the rate of carbon utilization. Substrates considered for use in the Topock Compressor Station final remedy will be discussed in this appendix, as well as general degradation pathways. Some information on carbon substrate dosing design is also provided in this appendix to supplement the thorough treatment of the dosing design in the groundwater modeling Appendix B.

2. References

ARCADIS 2007. *Floodplain Reductive Zone In Situ Pilot Test, Final Completion Report.* Pacific Gas and Electric Company Topock Compressor Station, Needles, California. March 5.

ARCADIS 2009. *Upland In-Situ Pilot Test, Final Completion Report.* Pacific Gas and Electric Company Topock Compressor Station, Needles, California. March 3.

ARCADIS 2010. *Central Area In-Situ Remediation Pilot Study Second Quarter 2010 Monitoring Report.* Pacific Gas and Electric Company Hinkley Compressor Station. Hinkley, California. July 29.

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3. Definitions

C-1	Single carbon compounds
CH_4	Methane
$C_2H_3O_2^-$	Acetate
C_2H_6O	Ethanol
$C_3H_5O_3^-$	Lactate
$C_3H_5O_2^-$	Propionate

$C_{12}H_{22}O_{11}$	Lactose
CO_2	Carbon dioxide
$Cr(III)$	Trivalent chromium
$Cr(VI)$	Hexavalent chromium
$Cr(OH)_3$	Chromium hydroxide
e^-	Electrons
$Fe(II)$	Ferrous iron
$Fe(III)$	Ferric Iron
$Fe(OH)_3$	Ferrihydrite
H^+	Hydronium ion
H_2	Hydrogen
H_2O	Water
H_2S	Hydrogen sulfide
HS^-	Bisulfide ion
$Mn(IV)$	Tetravalent manganese
$Mn(II)$	Divalent manganese
MnO_2	Manganese dioxide
NO_3^-	Nitrate
NO_2^-	Nitrite
N_2	Nitrogen
O_2	Oxygen
SO_4^{2-}	Sulfate

4. Carbon Substrate Selection

Based on the results of the preliminary evaluation, the carbon substrates that were carried forward into remedy design included ethanol (used in the Uplands In-Situ Pilot Test [ARCADIS 2009]), sodium lactate (used in the Floodplains In-Situ Pilot Test [ARCADIS, 2007]), emulsified vegetable oil, and liquid whey. Each of these carbon substrates were evaluated in the Final Environmental Impact Report (FEIR, DTSC, 2011). The selection of the appropriate substrate depended on the balance between the mode of delivery, the substrate properties, and the rate of carbon utilization.

It is anticipated that for most of the final remedy operational period, substrates that are soluble with short biodegradation half lives (i.e., 5 to 20 days), like lactate and ethanol, will be used to facilitate effective distribution and establishment of reducing conditions across the IRZ, with the highest degree of distribution control, given the utilization of the carbon substrates and by-products (discussed below) to completion (i.e. to complete degradation to carbon dioxide and methane). During the 60% design stage, ethanol was selected for use in the ongoing design and for initial use in the final remedy based on additional considerations including substrate cost and PG&E's greater experience and past successes with ethanol (e.g., at the PG&E Hinkley Compressor Station site). However, carbon substrate selection may change over the lifetime of the project as substrate costing varies. In addition, alternative substrates could be useful for certain situations that arise over the life of the project. For example, emulsified vegetable oil may be used during future operational stages of the remedy if a low dosage, slow release reservoir of carbon would be advantageous.

5. Organic Carbon Degradation Pathways

Within an active IRZ, periodic injection activities support the development of a diverse microbial community that utilizes the augmented organic carbon supply via a complex network of degradation pathways. In general, there are two types of processes by which organic carbon substrates are consumed: respiratory processes and fermentation processes. Regardless of the carbon substrate used and the complex network of degradation

pathways stimulated, the resultant end products of degradation will include carbon dioxide, methane, and biomass. Eventually, biomass will also decay into carbon dioxide and methane. The following provides an overview of the various degradation pathways that will be stimulated within the IRZs, identifies the typical intermediates that may form, and includes several balanced oxidation-reduction reactions. This list may not be inclusive, considering the complex microbial ecology that will develop within the IRZ, but is intended to provide a basic framework for understanding the carbon degradation pathways.

In respiratory processes, organic carbon substrates are oxidized to carbon dioxide, releasing electrons that in turn reduce terminal electron acceptors (oxygen, nitrate, hexavalent chromium, iron, manganese, and sulfate). In fermentation processes, the organic carbon substrates are both oxidized and reduced via the metabolic pathways. The general pathways and intermediates for organic carbon degradation are shown on Figure 1. As shown on the figure, in the respiratory pathways coupled to reduction of oxygen, nitrate, chromium, iron, manganese and sulfate, the carbon substrate is completely oxidized to carbon dioxide. Consequently, total organic carbon concentrations return to ambient concentrations following IRZ injections.

Fermentation reactions produce additional intermediates such as fatty acids, alcohols, lactate, succinate, and hydrogen from primary fermentation of more complex organic carbon substrates, and acetate and single carbon (C-1) compounds, like formate, from less complex substrates or the intermediates of primary fermentation.

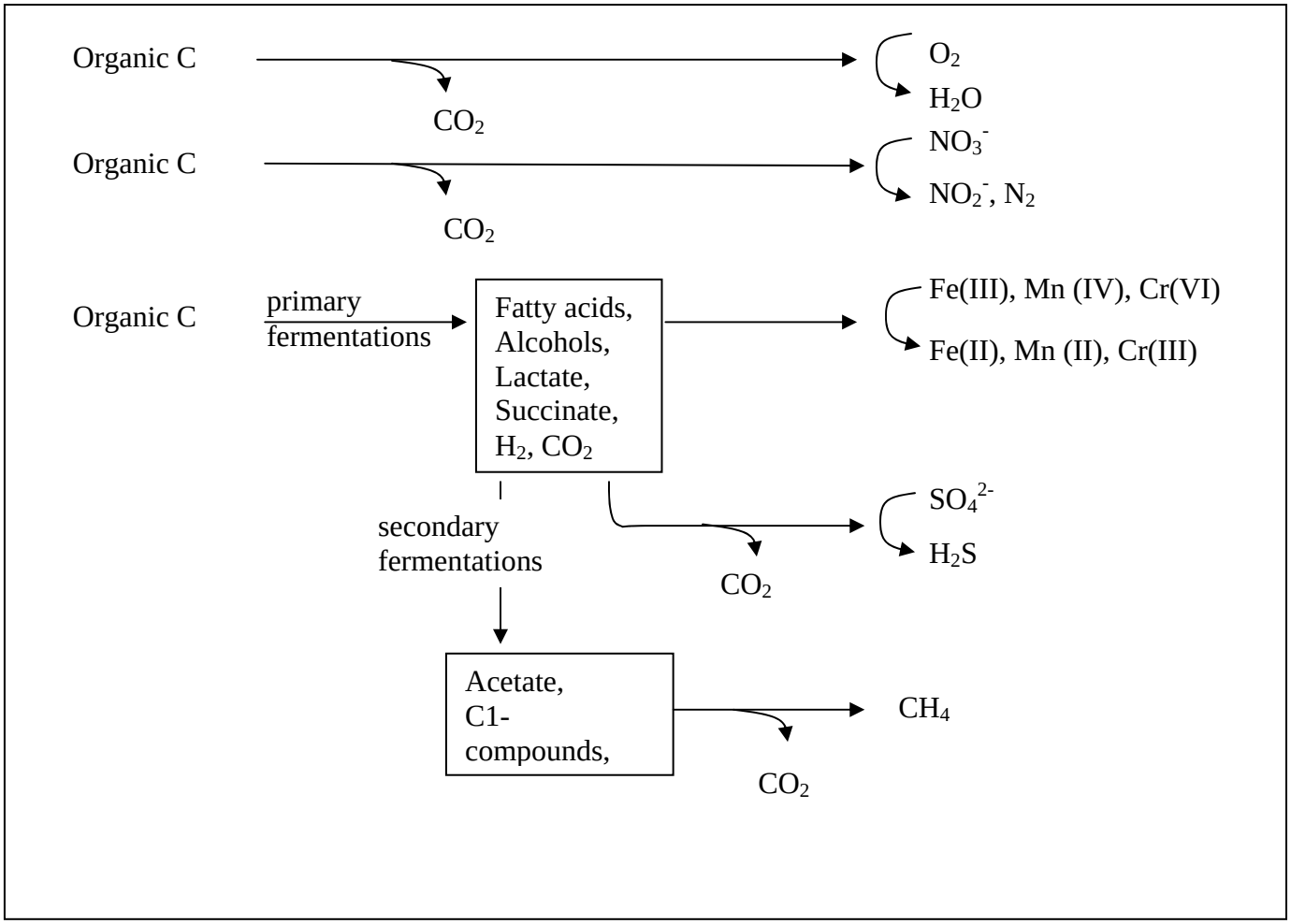


Figure 1: General Degradation Pathways for Organic Carbon Substrates (adapted from Lengeler et al., 1999)

For the IRZs that are part of the final groundwater remedy at the Topock Compressor Station, several organic carbon substrates were considered. For the purposes of this discussion, however, only the four most likely

substrates are considered, ethanol, lactate, liquid whey, and emulsified vegetable oil (EVO). For reference, liquid whey is composed primarily of the disaccharide lactose, and EVO is a triglyceride.

EVO is a slightly different substrate than the others being discussed, because it is delivered as a separate phase oil that will sorb to aquifer soils. The triglycerides are first hydrolyzed, releasing glycerol and long chain fatty acids (IES, 2006). As the long chain fatty acids are degraded by beta-oxidation, smaller molecules are generated which more easily dissolve into groundwater, such as butyric acid, and acetate (IES, 2006), as shown on Figure 2.

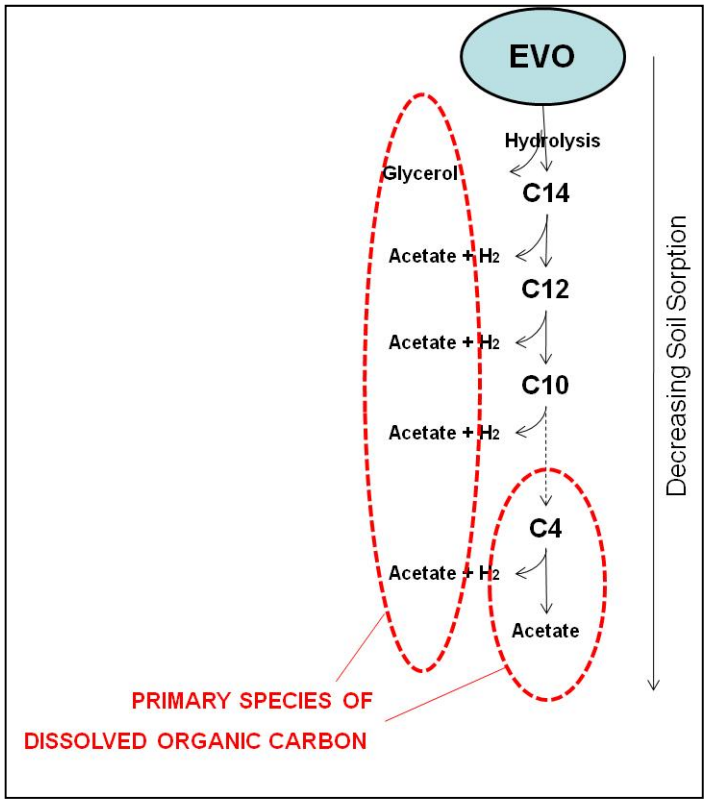


Figure 2. Degradation and Dissolution of EVO.

In the next few sections, the general breakdown pathways and balanced reactions for the respiration and fermentation of the various organic carbon substrates are presented. For the purpose of EVO, acetate will be discussed as an example of a dissolved organic compound.

a. Respiratory Processes

In respiratory processes, the oxidation of organic carbon substrates to carbon dioxide is coupled to the reduction of a terminal electron acceptor. Respiratory processes stimulated within an IRZ include aerobic respiration, denitrification, chromium reduction, iron reduction, manganese reduction, and sulfate reduction. The following discussion will provide an overview of the reactions for these respiratory processes.

The following are balanced oxidation half-reactions that release electrons for ethanol, lactate, lactose (from whey), and acetate (a degradation intermediate and one of the primary dissolved constituents released from EVO).

Ethanol	$1/12\ C_2H_6O + 1/4\ H_2O \rightarrow 1/6\ CO_2 + H^+ + e^-$	(1)
Lactate	$1/12\ C_3H_5O_3^- + 1/4\ H_2O \rightarrow 1/4\ CO_2 + 11/12\ H^+ + e^-$	(2)
Lactose	$1/48\ C_{12}H_{22}O_{11} + 13/48\ H_2O \rightarrow 1/4\ CO_2 + H^+ + e^-$	(3)
Acetate	$1/8\ C_2H_3O_2^- + 1/4\ H_2O \rightarrow 1/4\ CO_2 + 7/8\ H^+ + e^-$	(4)

The release of electrons from the oxidation of each substrate is coupled to the reduction of the various terminal electron acceptors. Below are the reduction half reactions for the various terminal electron acceptors. Note, for iron and manganese reduction (Reaction 8 and 9), various mineral phase reactants are possible and one example of each is shown. Similarly for chromium (Reaction 7), several mineral phase products are possible and one example is shown, chromium hydroxide.

Oxygen	$1/4\ O_2 + H^+ + e^- \rightarrow 1/2\ H_2O$	(5)
Nitrate	$1/5\ NO_3^- + 6/5\ H^+ + e- \rightarrow 1/10\ N_2 + 3/5\ H_2O$	(6)
Chromium	$1/3\ Cr^{6+} + H_2O + e^- \rightarrow 1/3\ Cr(OH)_3 + H^+$	(7)
Iron	$Fe(OH)_3 + 3H^+ + e^- \rightarrow Fe^{2+} + 3H_2O$	(8)
Manganese	$1/2\ MnO_2 + 2H^+ + e^- \rightarrow 1/2\ Mn^{2+} + H_2O$	(9)
Sulfate	$1/8\ SO_4^{2-} + 9/8\ H^+ + e^- \rightarrow 1/8\ HS- + 1/2\ H_2O$	(10)

For each substrate being considered, bacteria within the IRZ would couple the oxidation of the organic carbon substrate with the reduction of various electron acceptors. For example, balanced reactions for the coupling of ethanol oxidation with oxygen, iron and sulfate reduction (Reactions 11, 12 and 13, respectively) are as follows:

Ethanol/Oxygen	$1/12\ C_2H_6O + 1/4\ O_2 \rightarrow 1/6\ CO_2 + 1/4\ H_2O$	(11)
Ethanol/Iron	$1/12\ C_2H_6O + Fe(OH)_3 + 2H^+ \rightarrow Fe^{2+} + 2\ 3/4\ H_2O + 1/6\ CO_2$	(12)
Ethanol/Sulfate	$1/12\ C_2H_6O + 1/8\ SO_4^{2-} + 1/8\ H^+ \rightarrow 1/8\ HS- + 1/4\ H_2O + 1/6\ CO_2$	(13)

The utilization of electron acceptors in the system will generally be governed by the principles of thermodynamic equilibrium and redox kinetics. Dissolved oxygen and nitrate are thermodynamically more favorable electron acceptors than Cr(VI), while Cr(VI) is thermodynamically a more favorable electron acceptor than manganese oxides, iron oxides, and sulfate. However, given the relative availability of the electron acceptors and spatial heterogeneities of the subsurface aquifer environment, many of these reactions can occur simultaneously under field conditions. For example, iron and manganese reduction can proceed concurrently and sulfate reduction can begin before iron oxides are depleted, depending on the strength of the reducing environment. The strength of the reducing environment can be tuned by adjusting the concentration of organic carbon injected. To a large extent, this can help minimize the reduction of manganese, iron, and sulfate while still achieving adequate Cr(VI) reduction and removal. However, in order to create a reducing environment sufficient for the sustained removal of Cr(VI), some manganese, iron, and sulfate reduction will occur. Some iron reduction is actually desirable, as it provides stored Cr(VI) reduction capacity within the aquifer. In fact, abiotic pathways, such as reduction by Fe(II), may be faster than direct biotic mechanisms for Cr(VI) reduction (e.g., Wielinga et al., Environmental Science and Technology, 2001). Iron reduction is expected to occur under active Cr(VI) reducing conditions, producing mixed Fe/Cr precipitates that sequester Cr(VI). Thus, it is anticipated that both Cr(VI) reduction mechanisms will occur simultaneously. These principles are discussed in more detail in Appendix B of the Basis of Design (BOD)/60% Design Report.

The oxidation-reduction (redox) reactions fostered in the IRZ may temporarily mobilize certain naturally-occurring metals within the treatment zone, including manganese and arsenic. An adaptive operations approach, outlined in Volume 2 of the Operations and Maintenance Manual will be used to balance carbon dosing to treat

Cr(VI) while minimizing manganese and arsenic generation.

b. Fermentative Processes

Fermentative conditions will also develop within the IRZ, as indicated by increased methane concentrations in groundwater in IRZs at the PG&E Hinkley Site (ARCADIS 2010). As shown in Figure 1, various organic intermediates and hydrogen can be produced from the fermentation of the organic carbon substrates, but the ultimate end products of reaction are carbon dioxide and methane.

For example, fatty acids have been monitored during IRZ implementation at Hinkley. The most prominent fatty acids detected in IRZ groundwater during both lactate and ethanol applications have been acetate and propionate (ARCADIS 2010). The production of acetate and propionate from lactate and ethanol are well documented fermentation processes.

Propionibacteria produce acetate and propionate from the fermentation of lactate (Lengeler et al., 1999) as follows:

$$3\ C_3H_5O_3^- \rightarrow C_2H_3O_2^- + CO_2 + 2\ C_3H_5O_2^- + H_2O \qquad (14)$$

Ethanol ferments to produce acetate and propionate as follows (Schink et al., 1987):

$$3\ C_2H_6O + 2\ HCO_3^- \rightarrow C_2H_3O_2^- + 2\ C_3H_5O_2^- + H^+ + 3\ H_2O \qquad (15)$$

Finally, the products of fermentation will be used by methanogens to make methane. Acetoclastic methanogens will produce methane from acetate (Lengeler et al., 1999):

$$C_2H_3O_2^- + H^+ \rightarrow CH_4 + CO_2 \qquad (16)$$

Hydrogenotrophic methanogens will produce methane from carbon dioxide and hydrogen (Lengeler et al., 1999):

$$CO_2 + 4\ H_2 \rightarrow CH_4 + 2\ H_2O \qquad (17)$$

6. Dosing Design

The primary design consideration for carbon substrate dosing is the adequate (lateral) distribution of the substrate in the subsurface while minimizing byproduct (reduced manganese and arsenic) production. Concentrations of total organic carbon will be highest at the injection point and will decrease with distance, and the arsenic and manganese generated is a consequence of that distribution of organic carbon, as discussed in detail in Appendix B of the BOD/60% Design Report. As such, the hydraulic, fate and transport, and geochemical models, as well as pilot test data, are being used to guide reagent dosing design, as discussed in Appendix B (BOD/60% Design Report). To optimize the tradeoff between organic carbon distribution and byproduct generation, design parameters such as well spacing, recirculation flow rates, and injection concentrations can be varied. The first step of this process was taken with the reactive transport modeling that supported the IRZ design (Appendix B, BOD/60% Design Report). This optimization process will continue during operation as monitoring data are collected, evaluated, and used to modify operations of the system.

The semi-soluble substrate, EVO is a special case and is discussed further in this section. As EVO is injected, significant portions of the oil will be retained on the soil. The amount of oil that will be retained per unit volume of aquifer varies with soil type as documented in the Protocol for Enhanced In Situ Bioremediation (IES, 2006) and is a lower bound on the amount of oil that will be required to achieve distribution within a given

target volume. However, the amount of EVO required to achieve sufficient distribution can be up to an order of magnitude greater than the amount of oil retention reported in the literature, based on field implementation at a number of sites (Schnobrich et al., 2011). In practice, the required EVO loading must be evaluated on a case-by-case basis to confirm the site-specific degree of droplet retention and to ensure sufficient organic carbon distribution for treatment within the targeted area.

Attachment B
Calculations (*On CD-ROM only*)

- Remedy-produced water pump calculations – Recirculation; filter feed; conditioned water transfer
- Remedy-produced water conditioning process - Eductor sizing
- Remedy-produced water conditioning process - Caustic usage
- Remedy-produced water conditioning building – Structural calculations
- Freshwater injection/remedy-produced water collection/conditioned remedy water distribution and disposal hydraulic network modeling calculations from EPANET software
- Hydraulic calculations for NTH IRZ, Inner Recirculation Loop, and TCS Recirculation Loop Wells
- Structural calculations for the MW-20 Bench Carbon Amendment Building

Remedy-produced Water Pump Calculations—Recirculation; Filter Feed; Conditioned Water Transfer

PMP 201-204
Influent Tank Recirculation Pump 1 through 4

DESIGN DATA

DGN FLOW	492.4	GPM	FROM
SG @DT	1.0		TNK-201
DEN @ DT	62.4	Lb/ft3	
VISC. @ D T	1	cP	TO
VAP P @ D T	0.7	PSIA	TNK-201
DGN TEMP	150.0	F	

PUMP SUCTION INPUT DATA CONDITIONS

MINIMUM SYSTEM INITIAL PRES.		14.7	psia
STATIC HEAD (+) OR LIFT (-)		1.0	ft
EQUIPMENT LOSS			psia
MISC LOSS		0.0	psia

PUMP DISCHARGE INPUT DATA CONDITIONS

MAX. SYSTEM TERMINAL PRES.		14.7	psia
STATIC HEAD DIFFERENCE		1.0	ft
EQUIPMENT LOSS (2) Eductors		30.0	psi
EQUIPMENT LOSS		0.0	psi
MISCELLANEOUS LOSS		0.0	psi
MISCELLANEOUS LOSS		0.0	psi
ALLOWED CONTROL VALVE PRES. DROP		0.0	psi

RESULTS

CORRECTED DIFFERENTIAL HEAD		82	ft
CORRECTED DIFFERENTIAL PRESS		35.1	psi
MIN. PUMP CASING DESIGN PRESSURE		42.5	psig
DESIGN SUCTION PRES.		14.2	psia
CORRECTED DISCHARGE PRESS.		49.3	psia
CORRECTED NPSHa		28.7	ft

Required Input
Optional Input

PUMP CALCULATION SHEET

Pump2K Version 1.2

PROJECT NO. :	435062.00	BY:	RCH	DATE:	
CLIENT:	PG&E	CHECKED:	WLR/JP	DATE:	
EQUIPMENT NO(S):	PMP-201-204	REVISION NO.:	0	DATE:	13-Jul-12 BY: RCH
SERVICE:	Remedy Water	FLUID:	Remedy Water	PFD #:	G-1201
LOCATION:	Influent Tank Farm	NO. PUMPS REQ'D:	4	P&ID #:	I-1101-1104

DESIGN DATA

DGN FLOW, GPM	492.4	PUMPS FROM:	
SG, DESIGN TEMP	0.98604	TNK-201	
DEN @ D T, LB/FT3	61.528896		
VISC. @ D T, CP	1	PUMPS TO:	
VAP P @ D T, PSIA	0.65	TNK-201	
DGN TEMP, DEG F	150		

NORMAL OPERATING DATA

NORMAL FLOW,GPM	0
SG, NORMAL TEMP	0
DEN @ N T, LB/FT3	0
VISC. @ N T, CP	0
VAP P @ N T, PSIA	0
NORM. TEMP, DEG F	0

PUMP SUCTION CONDITIONS

MINIMUM SYSTEM INITIAL PRES., PSIA		14.7
STATIC HEAD (+) OR LIFT (-), FT		1
STATIC HEAD (+) OR LIFT (-), PSI		0.4
LINE FRICTION LOSS, PSI		0.9
EQUIPMENT LOSS, PSI		0.0
MISC LOSS, PSI	0	0.0
DESIGN SUCTION PRES., PSIA		14.2

INPUT: SUCTION PIPING DATA / DISCHARGE PIPING DATA

	Suction			Discharge		
NOMINAL SIZE, IN.	6.00	<-enter piping		6.00	<-enter piping	
SCHEDULE	40	& fitting data		40	& fitting data	
ACTUAL I.D., IN.	6.065			6.065		
FITTINGS	NO.	K *	DP, PSI	NO.	K *	DP, PSI
ELBOWS, 90 LR	4	0.24	0.19	8	0.24	0.37
ELBOWS, 45 LR		0.18	0.00		0.18	0.00
TEES, THRU	1	0.58	0.12	3	0.58	0.35
TEES, BRANCH		0.94	0.00	2	0.94	0.37
BALL VALVES		0.18	0.00		0.18	0.00
BUTTERFLY VALVES	1	0.29	0.06	4	0.29	0.23
GATE VALVES		0.12	0.00		0.12	0.00
GLOBE VALVES		4.67	0.00		4.67	0.00
CHECK VALVES		1.75	0.00	1	1.75	0.35
PLUG VALVES		0.30	0.00		0.30	0.00
PIPE ENTRANCE	1	0.50	0.10			
PIPE EXIT				1	1.00	0.20
OTHER			0.00			0.00
LIN. FT OF PIPE	58		0.39	80		0.54
OTHER, EQ FT			0.00			0.00
CONTINGENCY, %	20%			20%		
CONTINGENCY, FT	11.6		0.08	16		0.11
TOTAL EQ FT	137			371		
DP TOTAL, PSI			0.93			2.52

PUMP DISCHARGE CONDITIONS

MAX. SYSTEM TERMINAL PRES., PSIA		14.7
STATIC HEAD DIFFERENCE, FT		1
STATIC HEAD DIFFERENCE, PSI		0.4
TOTAL FIXED LOSSES, PSIA		15.1
LINE FRICTION LOSS, PSI		2.5
EQUIPMENT LOSS, PSI	(2) Eductors	30.0
EQUIPMENT LOSS, PSI	0	0.0
MISCELLANEOUS LOSS, PSI	0	0.0
MISCELLANEOUS LOSS, PSI	0	0.0
TOTAL VARIABLE LOSS, PSI		32.5
TOTAL FIXED AND VARIABLE LOSS, PSIA		47.6
ALLOWED CONTROL VALVE PRES. DROP , PSI		0.0
DISCHARGE PRESSURE, PSIA		47.6
CORRECTED DISCHARGE PRESSURE, PSIA		**49.3**

DIFFERENTIAL HEAD AND POWER CALCULATION

DESIGN SUCTION PRESSURE, PSIA	14.2
TOTAL DIFFERENTIAL PRESSURE, PSI	33.5
TOTAL DIFFERENTIAL HEAD, FT	78
OVERALL LOSS SAFETY FACTOR, % (e.g., 10 %)	5%
CORRECTED DIFFERENTIAL HEAD, FT	**82**
CORRECTED DIFFERENTIAL PRESS, PSI	**35.1**
HYDRAULIC HORSEPOWER, HP	10.1
PUMP EFFICIENCY, % (e.g., 50%)	50%
BRAKE HORSEPOWER, BHP (water only)	20.2
MIN. PUMP CASING DESIGN PRESSURE, PSIG	42.5

CALCULATED SUCTION DATA / CALCULATED DISCHARGE DATA

	Suction	Discharge
PIPE I.D., IN	6.065	6.065
X-SECT AREA,FT2	0.2006	0.2006
DGN FLOW, LB/HR	242,763	242,763
VELOCITY, FT/SEC	5.46	5.46
REYNOLDS NUM	252,577	252,577
DARCY FRI FACT	0.01733	0.01733
FRICT DP, PSI/100'	0.68	0.68

NET POSITIVE SUCTION HEAD CALCULATION (NPSHa)

MINIMUM SYSTEM INITIAL PRESSURE, PSIA	14.7
MINIMUM STATIC HEAD, PSI	0.4
LINE FRICTION LOSS AT DESIGN FLOW, PSI	0.9
OTHER LOSSES, NET, PSI	0.0
LIQUID VAPOR PRESSURE, PSIA	0.7
NET POSITIVE SUCTION HEAD AVAILABLE, PSIA	13.5
NET POSITIVE SUCTION HEAD AVAILABLE, FT.	32
NPSHa SAFETY FACTOR, FT.	3
CORRECTED NPSHa, FT.	**28.7**

* CALCULATION OF K FACTOR BASED ON 2-K METHOD.

NOTES:

Updated to add analyzers on inlet to eductors. Change eductor to 30 dp and add inlet stream of chemicals to pump suction (T). Added 25 gph to flow for chemicals and updated flow for 3' -30 dP

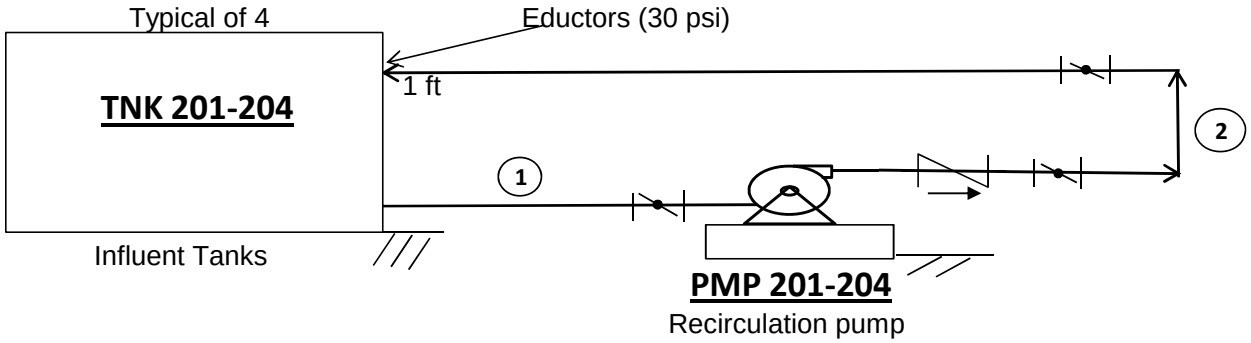
CH2MHILL

Job Name: Topock 60% Design **Sheet No.:** 3 of 3

Subject: Pump Calculation **Date:** 8/3/2012

Job No.: 435062 **Computed By:** RCH

Checked By: JP



Section 1: Suction

6" pipe
1 entrance
1 butterfly
4 elbows
58'
1' static lift

Section 2: Discharge

6" pipe
1 exit
1 check
4 butterfly
2 branch T
eductors (30 psi)
8 elbows
80'
3 thru T

PMP-310, 320, 330, 340
Filter Feed Pumps 1 and 2 (A side and B Side)

DESIGN DATA

DGN FLOW	35.0	GPM	FROM
SG @DT	1.0		Influent Tank Farm
DEN @ DT	62.4	Lb/ft3	
VISC. @ D T	1	cP	TO
VAP P @ D T	0.7	PSIA	Filters & Conditioned Water Tank Farm
DGN TEMP	150.0	F	

PUMP SUCTION INPUT DATA CONDITIONS

MINIMUM SYSTEM INITIAL PRES.		14.7	psia
STATIC HEAD (+) OR LIFT (-)		0.0	ft
EQUIPMENT LOSS		0.0	psia
MISC LOSS		0.0	psia

PUMP DISCHARGE INPUT DATA CONDITIONS

MAX. SYSTEM TERMINAL PRES.		14.7	psia
STATIC HEAD DIFFERENCE		55.0	ft
EQUIPMENT LOSS	Filters Loss	10.0	psi
EQUIPMENT LOSS	FM-572	2.0	psi
MISCELLANEOUS LOSS		0.0	psi
MISCELLANEOUS LOSS		0.0	psi
ALLOWED CONTROL VALVE PRES. DROP			psi

RESULTS

CORRECTED DIFFERENTIAL HEAD	112	ft
CORRECTED DIFFERENTIAL PRESS	47.7	psi
MIN. PUMP CASING DESIGN PRESSURE	56.0	psig
DESIGN SUCTION PRES.	13.4	psia
CORRECTED DISCHARGE PRESS.	61.1	psia
CORRECTED NPSHa	26.9	ft

Required Input
Optional Input

PUMP CALCULATION SHEET

Pump2K Version 1.2

PROJECT NO. :	435062.00	BY:	RCH	DATE:	
CLIENT:	PG&E	CHECKED:	WLR/JP	DATE:	
EQUIPMENT NO(S):	PMP-310,320,330,340	REVISION NO.:	0	DATE:	30-Jul-12 BY: RCH
SERVICE:	Remedy Water	FLUID:	Remedy Water	PFD #:	G-1201
LOCATION:	Influent Tank Farm	NO. PUMPS REQ'D:	4	P&ID #:	I-1201,1202

DESIGN DATA

DGN FLOW, GPM	35
SG, DESIGN TEMP	0.98604
DEN @ D T, LB/FT3	61.528896
VISC. @ D T, CP	1
VAP P @ D T, PSIA	0.65
DGN TEMP, DEG F	150

PUMPS FROM: Influent Tank Farm

PUMPS TO: Filters & Conditioned Water Tank Farm

NORMAL OPERATING DATA

NORMAL FLOW,GPM	0
SG, NORMAL TEMP	0
DEN @ N T, LB/FT3	0
VISC. @ N T, CP	0
VAP P @ N T, PSIA	0
NORM. TEMP, DEG F	0

PUMP SUCTION CONDITIONS

MINIMUM SYSTEM INITIAL PRES., PSIA		14.7
STATIC HEAD (+) OR LIFT (-), FT		0
STATIC HEAD (+) OR LIFT (-), PSI		0.0
LINE FRICTION LOSS, PSI		1.3
EQUIPMENT LOSS, PSI		0.0
MISC LOSS, PSI	0	0.0
DESIGN SUCTION PRES., PSIA		13.4

INPUT:

	SUCTION PIPING DATA			DISCHARGE PIPING DATA		
NOMINAL SIZE, IN.	2.00	<-enter piping		2.00	<-enter piping	
SCHEDULE	40	& fitting data		40	& fitting data	
ACTUAL I.D., IN.	2.067			2.067		
FITTINGS	NO.	K *	DP, PSI	NO.	K *	DP, PSI
ELBOWS, 90 LR	3	0.31	0.07	10	0.31	0.23
ELBOWS, 45 LR		0.23	0.00		0.23	0.00
TEES, THRU	5	0.74	0.28		0.74	0.00
TEES, BRANCH	2	1.20	0.18	5	1.20	0.45
BALL VALVES	2	0.23	0.03	7	0.23	0.12
BUTTERFLY VALVE	1	0.39	0.03	1	0.39	0.03
GATE VALVES		0.15	0.00		0.15	0.00
GLOBE VALVES		5.96	0.00		5.96	0.00
CHECK VALVES		2.25	0.00	1	2.25	0.17
PLUG VALVES		0.39	0.00		0.39	0.00
PIPE ENTRANCE	1	0.50	0.04			
PIPE EXIT				3	1.00	0.22
OTHER			0.00	2	1	0.15
LIN. FT OF PIPE	55		0.56	605		6.15
OTHER, EQ FT			0.00			0.00
CONTINGENCY, %	20%			20%		
CONTINGENCY, FT	11.0		0.11	121		1.24
TOTAL EQ FT	127			860		
DP TOTAL, PSI			1.30			8.75

PUMP DISCHARGE CONDITIONS

MAX. SYSTEM TERMINAL PRES., PSIA		14.7
STATIC HEAD DIFFERENCE, FT		55
STATIC HEAD DIFFERENCE, PSI		23.5
TOTAL FIXED LOSSES, PSIA		38.2
LINE FRICTION LOSS, PSI		8.8
EQUIPMENT LOSS, PSI	Filters Loss	10.0
EQUIPMENT LOSS, PSI	FM-572	2.0
MISCELLANEOUS LOSS, PSI	0	0.0
MISCELLANEOUS LOSS, PSI	0	0.0
TOTAL VARIABLE LOSS, PSI		20.8
TOTAL FIXED AND VARIABLE LOSS, PSIA		58.9
ALLOWED CONTROL VALVE PRES. DROP , PSI		0.0
DISCHARGE PRESSURE, PSIA		58.9
CORRECTED DISCHARGE PRESSURE, PSIA		**61.1**

DIFFERENTIAL HEAD AND POWER CALCULATION

DESIGN SUCTION PRESSURE, PSIA	13.4
TOTAL DIFFERENTIAL PRESSURE, PSI	45.5
TOTAL DIFFERENTIAL HEAD, FT	107
OVERALL LOSS SAFETY FACTOR, % (e.g., 10 %)	10%
CORRECTED DIFFERENTIAL HEAD, FT	**112**
CORRECTED DIFFERENTIAL PRESS, PSI	**47.7**
HYDRAULIC HORSEPOWER, HP	1.0
PUMP EFFICIENCY, % (e.g., 50%)	50%
BRAKE HORSEPOWER, BHP (water only)	1.9
MIN. PUMP CASING DESIGN PRESSURE, PSIG	56.0

CALCULATED SUCTION DATA / CALCULATED DISCHARGE DATA

	SUCTION	DISCHARGE
PIPE I.D., IN	2.067	2.067
X-SECT AREA,FT2	0.0233	0.0233
DGN FLOW, LB/HR	17,256	17,256
VELOCITY, FT/SEC	3.34	3.34
REYNOLDS NUM	52,679	52,679
DARCY FRI FACT	0.02363	0.02363
FRICT DP, PSI/100'	1.02	1.02

NET POSITIVE SUCTION HEAD CALCULATION (NPSHa)

MINIMUM SYSTEM INITIAL PRESSURE, PSIA	14.7
MINIMUM STATIC HEAD, PSI	0.0
LINE FRICTION LOSS AT DESIGN FLOW, PSI	1.3
OTHER LOSSES, NET, PSI	0.0
LIQUID VAPOR PRESSURE, PSIA	0.7
NET POSITIVE SUCTION HEAD AVAILABLE, PSIA	12.8
NET POSITIVE SUCTION HEAD AVAILABLE, FT.	30
NPSHa SAFETY FACTOR, FT.	3
CORRECTED NPSHa, FT.	**26.9**

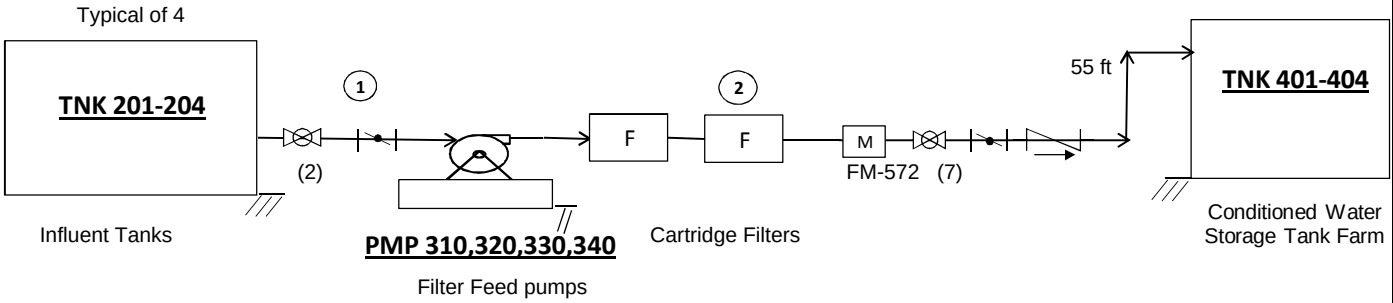
* CALCULATION OF K FACTOR BASED ON 2-K METHOD.

NOTES:

Discharge pipe length includes: 60' to remedy building, 60 ft in building , 460' to conditioned water tanks (further distance than to TNK-510).

4 Feed Filter Pumps were sized for wast case scenario user/destination

Job Name:	Topock 60% Design	**Sheet No.:**	3 of 3
Subject:	Pump Calculation	**Date:**	8/3/2012
Job No.:	435062	**Computed By:**	RCH
		Checked By:	JP



Section 1: Suction
2" pipe
2 ball
1 butterfly
2 branch T's
5 straight T's
55'
3 elbows
1 entrance

Section 2: Discharge
2" pipe
1 check
7 ball
1 butterfly
5 branch
2 Filters (#10)
Filter System Flow Meter (FM-572)
3 exit
2 entrance
55' elevation change
10 elbows
605'

PMP-405/406
Conditioned Water Transfer Pump A/B

DESIGN DATA

DGN FLOW	35.0	GPM	FROM
SG @DT	1.0		Conditioned Water
DEN @ DT	62.4	Lb/ft3	Storage Tank Farm
VISC. @ D T	1	cP	TO
VAP P @ D T	0.7	PSIA	Cooling Tower
DGN TEMP	150.0	F	Blowdown

PUMP SUCTION INPUT DATA CONDITIONS

MINIMUM SYSTEM INITIAL PRES.		14.7	psia
STATIC HEAD (+) OR LIFT (-)		0.0	ft
EQUIPMENT LOSS		0.0	psia
MISC LOSS		0.0	psia

PUMP DISCHARGE INPUT DATA CONDITIONS

MAX. SYSTEM TERMINAL PRES.		14.7	psia
STATIC HEAD DIFFERENCE		30.0	ft
EQUIPMENT LOSS		0.0	psi
EQUIPMENT LOSS	FM-771	2.0	psi
MISCELLANEOUS LOSS		0.0	psi
MISCELLANEOUS LOSS		0.0	psi
ALLOWED CONTROL VALVE PRES. DROP		0.0	psi

RESULTS

CORRECTED DIFFERENTIAL HEAD		52	ft
CORRECTED DIFFERENTIAL PRESS		22.0	psi
MIN. PUMP CASING DESIGN PRESSURE		27.0	psig
DESIGN SUCTION PRES.		13.6	psia
CORRECTED DISCHARGE PRESS.		35.6	psia
CORRECTED NPSHa		27.4	ft

Required Input
Optional Input

PUMP CALCULATION SHEET

Pump2K Version 1.2

PROJECT NO. :	435062.00	BY:	RCH	DATE:	
CLIENT:	PG&E	CHECKED:	JP	DATE:	
EQUIPMENT NO(S):	PMP-405/406	REVISION NO.:	0	DATE:	30-Jul-12 BY: RCH
SERVICE:	Remedy Water	FLUID:	Treated Water	PFD #:	G-1201
LOCATION:	Conditioned Water Storage Tank Farm	NO. PUMPS REQ'D:	2	P&ID #:	I-1401

DESIGN DATA

DGN FLOW, GPM	35
SG, DESIGN TEMP	0.98604
DEN @ D T, LB/FT3	61.528896
VISC. @ D T, CP	1
VAP P @ D T, PSIA	0.65
DGN TEMP, DEG F	150

PUMPS FROM:	Conditioned Water Storage Tank Farm
PUMPS TO:	Cooling Tower Blowdown

NORMAL OPERATING DATA

NORMAL FLOW,GPM	0
SG, NORMAL TEMP	0
DEN @ N T, LB/FT3	0
VISC. @ N T, CP	0
VAP P @ N T, PSIA	0
NORM. TEMP, DEG F	0

PUMP SUCTION CONDITIONS

MINIMUM SYSTEM INITIAL PRES., PSIA		14.7
STATIC HEAD (+) OR LIFT (-), FT		0
STATIC HEAD (+) OR LIFT (-), PSI		0.0
LINE FRICTION LOSS, PSI		1.1
EQUIPMENT LOSS, PSI		0.0
MISC LOSS, PSI	0	0.0
DESIGN SUCTION PRES., PSIA		13.6

INPUT:	SUCTION PIPING DATA			DISCHARGE PIPING DATA		
NOMINAL SIZE, IN.	2.00	<-enter piping		2.00	<-enter piping	
SCHEDULE	40	& fitting data		40	& fitting data	
ACTUAL I.D., IN.	2.067			2.067		
FITTINGS	NO.	K *	DP, PSI	NO.	K *	DP, PSI
ELBOWS, 90 LR	3	0.31	0.07	10	0.31	0.23
ELBOWS, 45 LR		0.23	0.00		0.23	0.00
TEES, THRU	3	0.74	0.17	1	0.74	0.06
TEES, BRANCH	1	1.20	0.09	1	1.20	0.09
BALL VALVES		0.23	0.00		0.23	0.00
BUTTERFLY VALVES	1	0.39	0.03	1	0.39	0.03
GATE VALVES		0.15	0.00		0.15	0.00
GLOBE VALVES		5.96	0.00		5.96	0.00
CHECK VALVES		2.25	0.00	1	2.25	0.17
PLUG VALVES		0.39	0.00		0.39	0.00
PIPE ENTRANCE	1	0.50	0.04			
PIPE EXIT				1	1.00	0.07
OTHER			0.00			0.00
LIN. FT OF PIPE	55		0.56	380		3.87
OTHER, EQ FT			0.00			0.00
CONTINGENCY, %	20%			20%		
CONTINGENCY, FT	11.0		0.11	76		0.77
TOTAL EQ FT	104			519		
DP TOTAL, PSI			1.06			5.28

PUMP DISCHARGE CONDITIONS

MAX. SYSTEM TERMINAL PRES., PSIA		14.7
STATIC HEAD DIFFERENCE, FT		30
STATIC HEAD DIFFERENCE, PSI		12.8
TOTAL FIXED LOSSES, PSIA		27.5
LINE FRICTION LOSS, PSI		5.3
EQUIPMENT LOSS, PSI	0	0.0
EQUIPMENT LOSS, PSI	FM-771	2.0
MISCELLANEOUS LOSS, PSI	0	0.0
MISCELLANEOUS LOSS, PSI	0	0.0
TOTAL VARIABLE LOSS, PSI		7.3
TOTAL FIXED AND VARIABLE LOSS, PSIA		34.8
ALLOWED CONTROL VALVE PRES. DROP , PSI		0.0
DISCHARGE PRESSURE, PSIA		34.8
CORRECTED DISCHARGE PRESSURE, PSIA		**35.6**

DIFFERENTIAL HEAD AND POWER CALCULATION

DESIGN SUCTION PRESSURE, PSIA	13.6
TOTAL DIFFERENTIAL PRESSURE, PSI	21.2
TOTAL DIFFERENTIAL HEAD, FT	50
OVERALL LOSS SAFETY FACTOR, % (e.g., 10 %)	10%
CORRECTED DIFFERENTIAL HEAD, FT	**52**
CORRECTED DIFFERENTIAL PRESS, PSI	**22.0**
HYDRAULIC HORSEPOWER, HP	0.4
PUMP EFFICIENCY, % (e.g., 50%)	50%
BRAKE HORSEPOWER, BHP (water only)	0.9
MIN. PUMP CASING DESIGN PRESSURE, PSIG	27.0

	CALCULATED SUCTION DATA	CALCULATED DISCHARGE DATA
PIPE I.D., IN	2.067	2.067
X-SECT AREA,FT2	0.0233	0.0233
DGN FLOW, LB/HR	17,256	17,256
VELOCITY, FT/SEC	3.34	3.34
REYNOLDS NUM	52,679	52,679
DARCY FRI FACT	0.02363	0.02363
FRICT DP, PSI/100'	1.02	1.02

NET POSITIVE SUCTION HEAD CALCULATION (NPSHa)

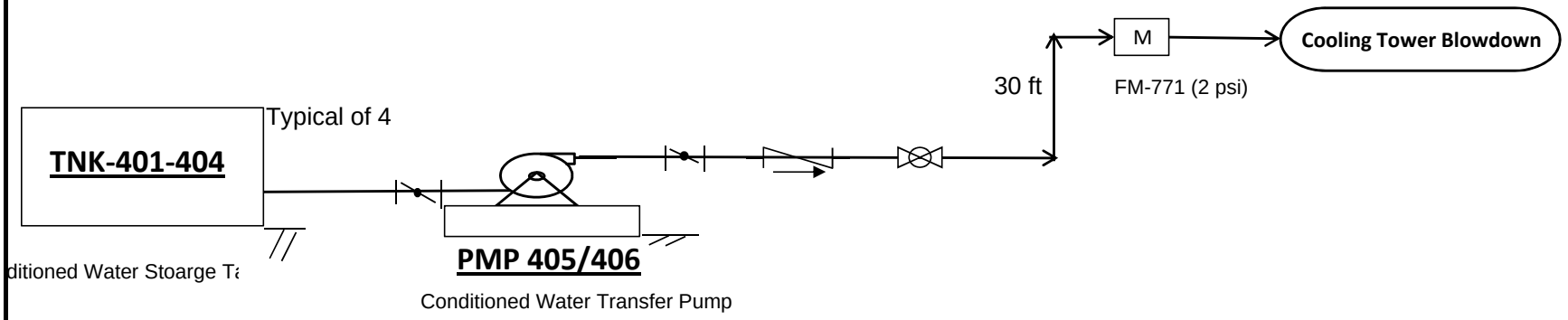
MINIMUM SYSTEM INITIAL PRESSURE, PSIA	14.7
MINIMUM STATIC HEAD, PSI	0.0
LINE FRICTION LOSS AT DESIGN FLOW, PSI	1.1
OTHER LOSSES, NET, PSI	0.0
LIQUID VAPOR PRESSURE, PSIA	0.7
NET POSITIVE SUCTION HEAD AVAILABLE, PSIA	13.0
NET POSITIVE SUCTION HEAD AVAILABLE, FT.	30
NPSHa SAFETY FACTOR, FT.	3
CORRECTED NPSHa, FT.	**27.4**

* CALCULATION OF K FACTOR BASED ON 2-K METHOD.

NOTES:

Pump was sized for worst case scenario user/destination

Job Name:	Topock 60% Design	**Sheet No.:**	3 of 3
Subject:	Pump Calculation	**Date:**	8/3/2012
Job No.:	435062	**Computed By:**	RCH
		Checked By:	JP



Section 1: Suction

2" pipe
1 butterfly
3 straight T's
1 branch T
55'
3 elbows
1 entrance

Section 2: Discharge

1 check
1 butterfly
1 branch T
1 straight T
1 FM 771 (2 psi)
1 ball
30' elevation change
2" pipe
380'
10 elbows
1 exit

Remedy-produced Water Conditioning Process—Eductor Sizing

CH2MHILL Lockwood Greene

— CALCULATION SHEET —

COMPUTED BY:	R. Harris		
REVISION No.:		DATE:	02-Jul-2012
REV. COMMENT			
CHECKED BY:	W.L. Ross		
LOCATION:	Needles, CA		
CLIENT:	PG&E	PROJECT NAME	Topock Groundwater Remediation
SUBJECT:	Influent Tank Eductor and Recirc Pump Sizing	PROJECT No:	435062

Eductor Sizing Basis:

Tank Diameter is 8'
Tank Volume: 21,000 gal
Tank Volume: 2,807 ft^3
Assume 30 minute mix and 3 tank turnovers *check of mix time =* *25.7 minutes*
Induced flow = 2100 gpm
Volume for 3 Tank Turnovers = 63,000 per 2 eductors (or 31,500 gal/eductor)

Eductor Sizing:

Scenarios: 2", 3", and 4" Eductors
20 psi, 30 psi, 40 psi, and 50 psi drop across Eductors

Eductor Size*	DP*	Max Plume*	Motive Liq. In*	Out of Eductor*	Complete Mix**
2 in	20 psi	23 ft	87.2 gpm	436 gpm	1200 gpm
3 in	20 psi	34 in	201 gpm	1003 gpm	1200 gpm
2 in	30 psi	34 in	107 gpm	534 gpm	1200 gpm
3 in	**30 psi**	**51 in**	**246 gpm**	**1228 gpm**	**1200 gpm**
4 in	30 psi	60 in	427 gpm	2136 gpm	1200 gpm
2 in	40 psi	48 in	123 gpm	616 gpm	1200 gpm
3 in	40 psi	73 in	283 gpm	1417 gpm	1200 gpm
3 in	50 psi	99 in	317 gpm	1585 gpm	1200 gpm
4 in	40 psi	95 in	493 gpm	2448 gpm	1200 gpm

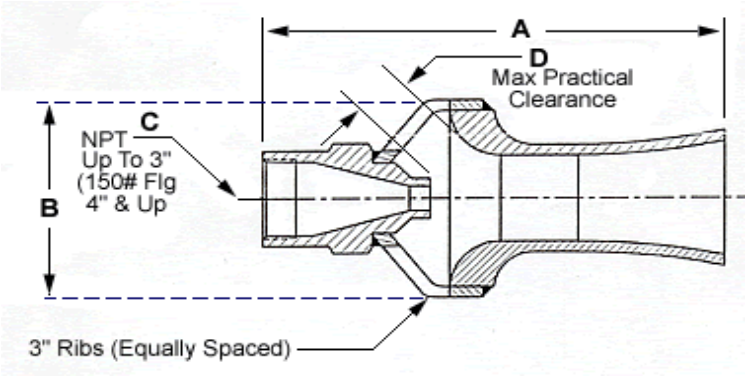
* Data from www.jrgjt.com
** Complete mix assumed after 3 tank turnovers per Bill Ross.

Tank width is 8ft (96")
Using a 3" eductor
Nozzles Needed = 2
Pump to handle 492 gpm at 82 psi
Check Mix time =
Based on data above, we can use two 3" nozzles per tank.
Recirculation pump to handle 492 gpm at 82 psi (See pump Calc)

CH2MHILL Lockwood Greene

— CALCULATION SHEET —

COMPUTED BY	R. Harris
REVISION No.:	DATE: 02-Jul-2012
REV. COMMENT	
CHECKED BY:	W.L. Ross
LOCATION:	Needles, CA
PROJECT NAME	Topock Groundwater Remediation
PROJECT No:	435062
CLIENT:	PG&E
SUBJECT	Influent Tank Eductor and Recirc Pump Sizing



* Data from www.jrgjt.com

Based on data above, we can use two 3" nozzle. Vendor to clarify Dimension B for PVC eductor and Tank nozzle sizes. for outboard access.

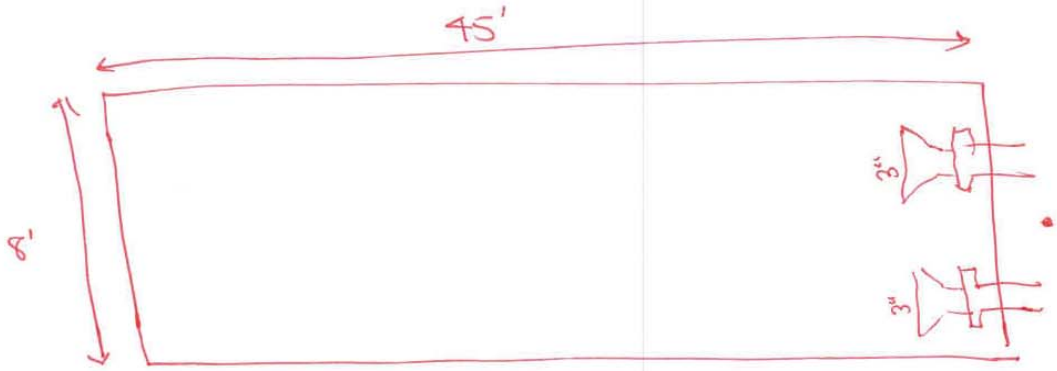
Size IPS		Pressure Difference, PSI											
		10	20	30	40	50	60	70	80	90	100	120	140
	Motive Flow (GPM)	7.1	10.0	12.3	14.2	15.8	17.4	18.7	20.1	21.3	22.4	24.6	26.5
3/8" mnpt	Outlet Flow (GPM)	35	50	61	71	79	87	88	90	91	92	94	96
	Max. Plume Length	4	8	12	16	22	29	36	43	50	58	72	86
3/4" mnpt	Motive Flow (GPM)	15.4	21.8	26.7	30.8	34.5	37.8	40.8	43.6	46.3	48.8	53.4	57.7
	Outlet Flow (GPM)	77	109	134	154	172	189	192	195	197	200	204	209
	Max. Plume Length	5	11	17	24	33	42	53	64	74	85	106	127
	Motive Flow (GPM)	30.8	43.6	53.4	61.6	68.9	75.5	81.5	87.2	92.5	97.5	107	115
1-1/2" fnpt	Outlet Flow (GPM)	154	218	267	306	345	378	384	389	395	400	409	417
	Max. Plume Length	7.5	16	24	34	46	60	75	90	105	120	150	180
2" fnpt	Motive Flow (GPM)	61.6	87.2	107	123	138	151	163	174	185	195	214	231
	Outlet Flow (GPM)	308	436	534	616	689	755	767	778	789	799	818	835
	Max. Plume Length	11	23	34	48	65	85	106	12	148	170	212	255
	Motive Flow (GPM)	142	201	246	283	317	347	375	401	426	449	491	531
3" fnpt	Outlet Flow (GPM)	708	1,003	1,228	1,417	1,585	1,737	1,764	1,790	1,815	1,836	1,880	1,920
	Max. Plume Length	16	34	51	73	99	129	161	193	225	257	322	386
4" flg	Motive Flow (GPM)	246	349	427	493	551	604	652	698	740	780	856	920
	Outlet Flow (GPM)	1232	1744	2136	2448	2760	3024	3072	3112	3160	3200	3272	3336
	Max. Plume Length	22	41	60	95	132	164	196	228	260	295	360	424
6" flg	Motive Flow (GPM)	493	698	854	986	1102	1208	1304	1395	1480	1560	1712	1840
	Outlet Flow (GPM)	2464	3488	4272	4896	5520	6048	6144	6224	6320	6400	6544	6672
8" flg	Motive Flow (GPM)	986	1395	1709	1971	2205	2416	2608	2790	2960	3120	3424	3680
	Outlet Flow (GPM)	4928	6976	8544	9792	11040	12096	12384	12448	12640	12800	13088	13344
10" flg	Motive Flow (GPM)	1971	2790	3418	3942	4410	4832	5216	5581	5920	6240	6848	7360
	Outlet Flow (GPM)	9856	13952	17088	19584	22080	24192	24576	24896	25344	25600	26176	26688

rgjt.com

** Pressure is in PSI and Plume Length shown in Feet

Option 2

Portable Frac Tanks
(sloped bottom)



- (2) 3" (30psi) eductors
- side mounted ~1' from bottom of tank on 8' side
- requires 492 gpm @ ~76' (10hp) recirc pump

Remedy-produced Water Conditioning Process—Caustic Usage

Calculation Cover Sheet

CH2MHILL

Project Name/Title:	PG&E Topock Final Groundwater Remedy Design	Project Number:	415087.01.05.02
Document Name:	Basis of Design Report - Appendix C	Preparer Name:	John Porcella
Project Manager:	Christina Hong	Design Manager:	John Porcella

Calculation Title:		Remedy WW Treatment Plant - Caustic Feed Usage				
Calculation Identifier:						
Date Prepared	Rev. No.	Preparer Signature/Date		Checker Signature/Date		*For Professional Seal When Required*
26-Oct	1	*John Porcella*	26-Oct-11	*Ken Martins*	10-Nov-11	
4/4/2013	2	*John Porcella*	4-Apr-13			
STC/SME Signature/Date						
LTR Signature/Date (if required)						

Comments:

Total usage revised to 13,840 gal/year based on increase in flow from 0.7 million gallons per year to 0.78 million gallons per year.

Information Requiring Confirmation:

Problem Statement

Calculate caustic usage to neutralize first flush well rehabilitation water to 1) calculate caustic usage

Given/Assumptions

1. 700,000 gallons per year of first flush water (Table F-1)
2. First flush water is pH 2.1 and final pH is 7.0
3. Hydrochloric acid (32%) is used for acidifying well water from ambient conditions to dissolve precipitated minerals
4. Ambient concentrations based on IW-3 backwash water chemical analysis of samples collected 10/5/11 ("Raw Data")

Method

Use Stream Analyzer by OLI Systems to perform pH adjustment (http://www.olisystems.com/new-streamanalyzer.shtml)
Uses electrolyte thermodynamic equations to calculate equilibrium concentrations.
Results shown on "Stream Analyzer Modeling" worksheet
Screenshot 1 - Starting conditions
Screenshots 2/3 - acidifying process in two different pH ranges (pH on y-axis; ratio of acid volume (L) to million liters of water)
Screenshots 4/5 - neutralizing process in two different pH ranges (pH on y-axis; ratio of NaOH volume (L) to million liters of water)

Caustic Usage

1850 L	25% caustic
to	
1e6 L	well water

700,000	gallons/year first flush water
3.7854	L/gal
2,649,788	Liters/year first flush water
4,902	Liters/year of 25% caustic
1,295	gal/year of 25% caustic
1.15	specific gravity 25% caustic
8.34	lbs/gal
12,420	lbs/year caustic

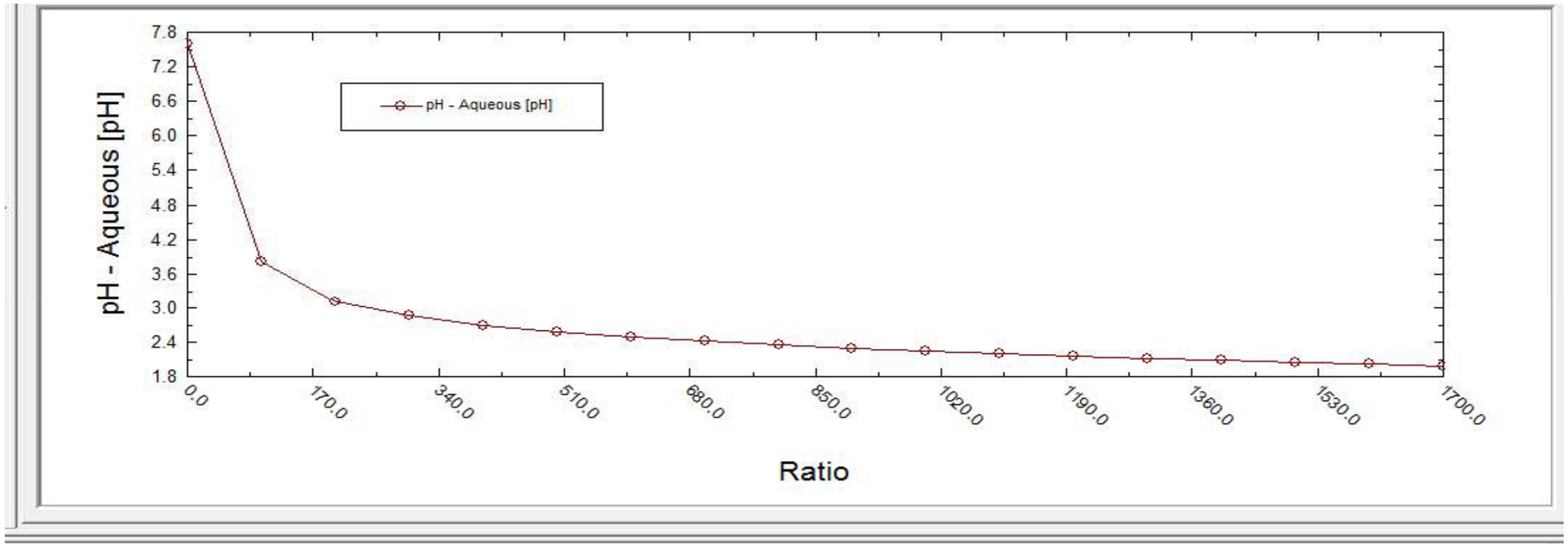
Rev. 2	Total Flow	780,000	gallons/year first flush water
		13,840	lbs/year caustic

SCREEN SHOT #1

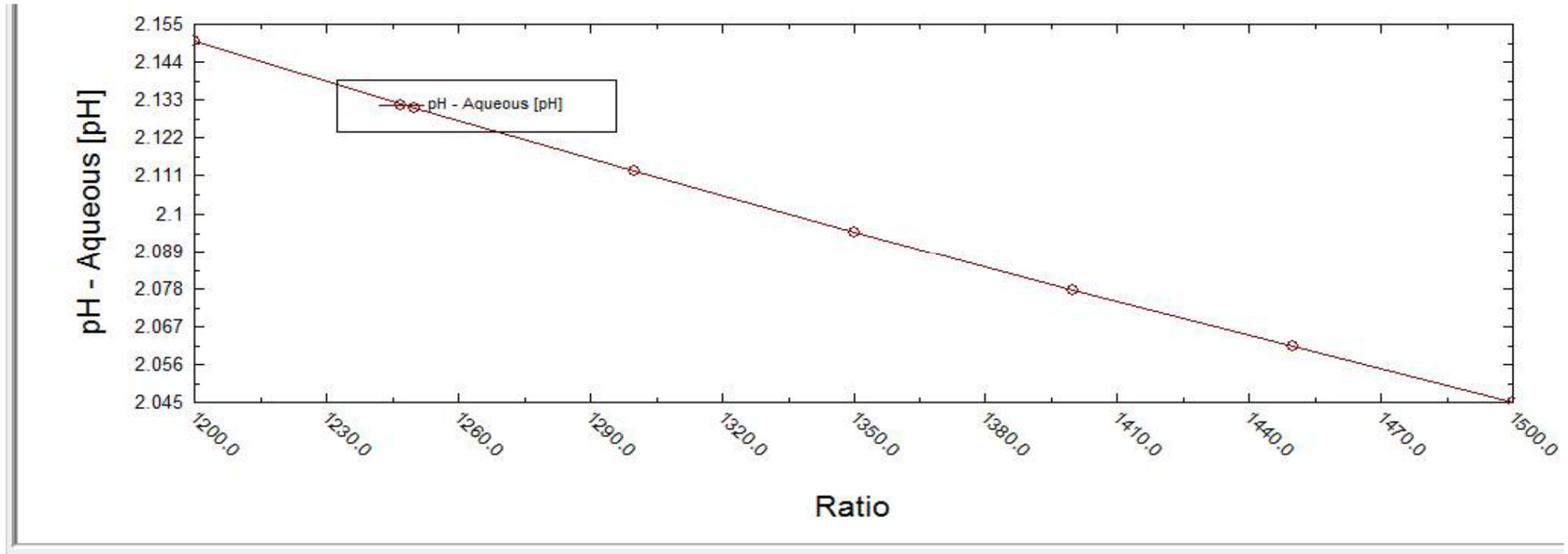
Description | Reconciliation | Molecular Basis | Report

Variable	Unit	Value
Known: pH - Aqueous	pH	7.60000
pH Acid Titrant: Carbon dioxide		
pH Base Titrant: Sodium hydroxide		
Neutrals		
Water		
Carbon dioxide	mg/L	0.0
Sodium hydroxide	mg/L	0.0
Cations		
Calcium ion(+2)	mg/L	95.0000
Magnesium ion(+2)	mg/L	22.0000
Sodium ion(+1)	mg/L	940.000
Strontium ion(+2)	mg/L	3.20000
Potassium ion(+1)	mg/L	10.0000
Anions		
Chloride ion(-1)	mg/L	2200.00
Nitrate ion(-1)	mg/L	2.60000
Sulfate ion(-2)	mg/L	490.000
Bicarbonate ion(-1)	mg/L	40.0000

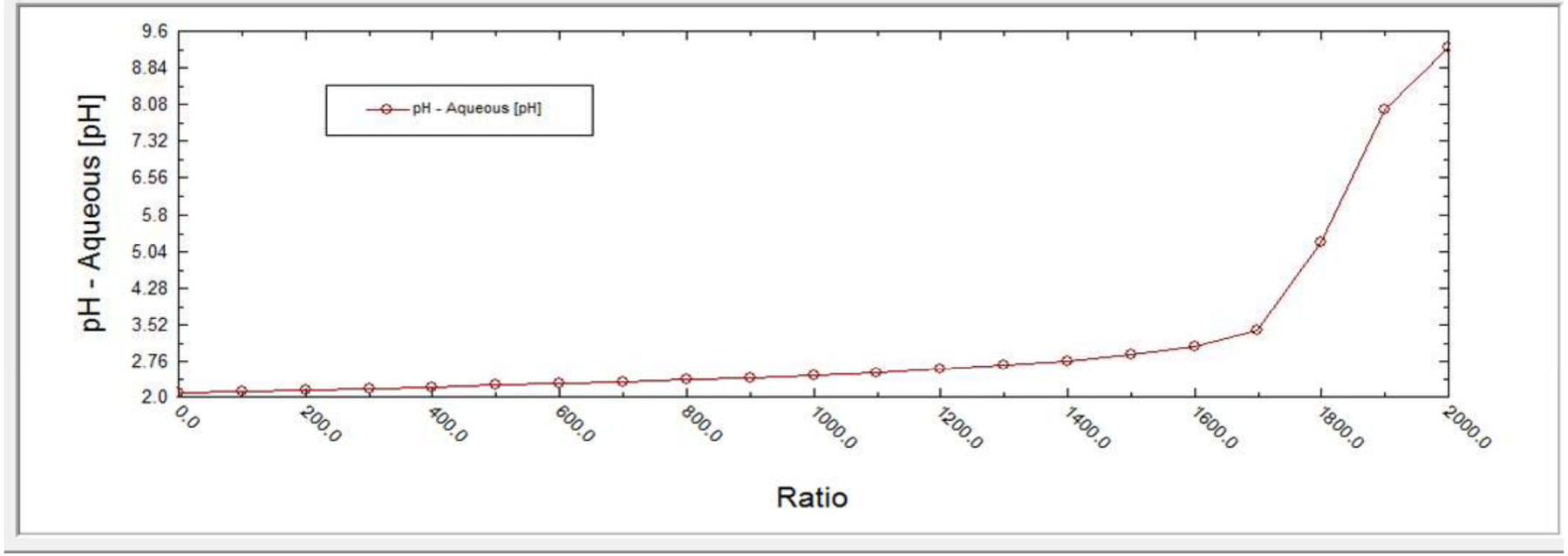
SCREEN SHOT #2



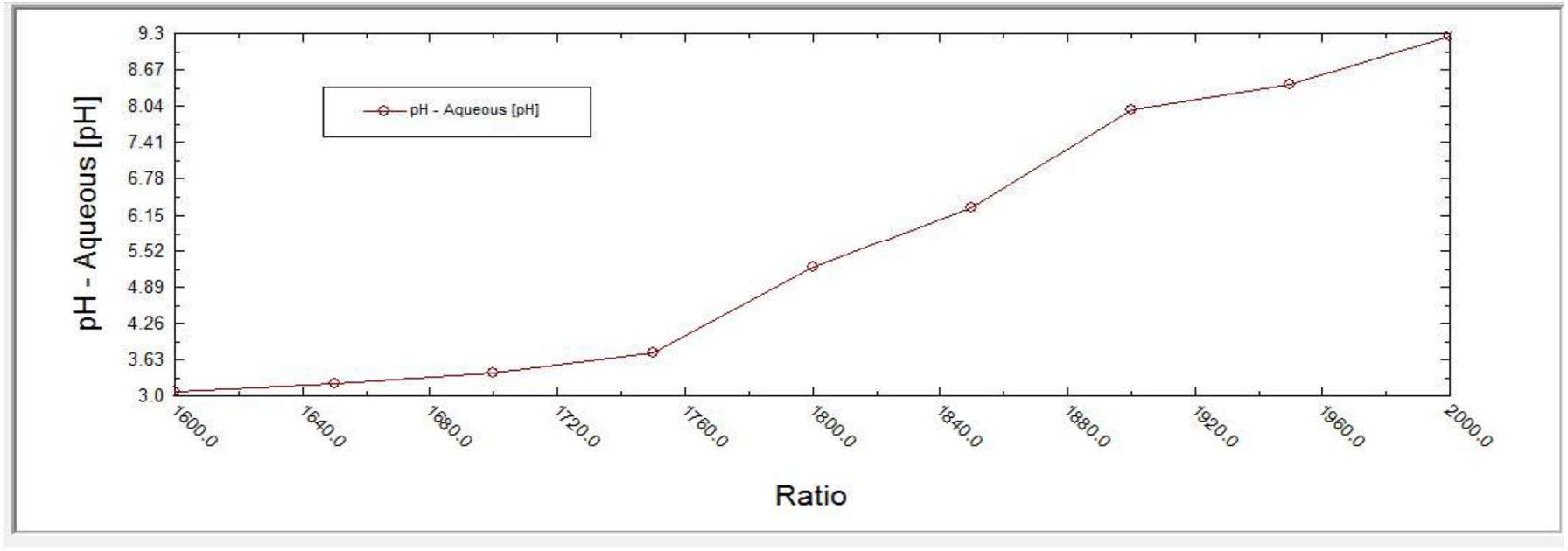
SCREEN SHOT #3



SCREEN SHOT #4



SCREEN SHOT #5



Method	Analyte	Final Result	Final Validation Flag	Reporting Limit	Units
E120.1	EC	7200		0.1	µmhos/cm
E180.1	Turbidity	0.1		0.1	NTU
E218.6	Hexavalent Chromium	1	U	1	ug/L
E300.0	Chloride	2200		250	mg/L
E300.0	Fluoride	5	U	5	mg/L
E300.0	Nitrate as N	2.6		1	mg/L
E300.0	Nitrogen, Nitrite	25	U	25	mg/L
E300.0	Sulfate	490		50	mg/L
E365.3	Phosphorus, Total (As P)	0.02	U	0.02	mg/L
SM2320B	Alkalinity	40		5	mg/L
SM2320B	Alkalinity, Bicarbonate (As CaCO3)	40		5	mg/L
SM2320B	Alkalinity, Carbonate (As CaCO3)	5	UJ	5	mg/L
SM2320B	Alkalinity, Hydroxide (As CaCO3)	5	U	5	mg/L
SM2540C	Total Dissolved Solids	3700		50	mg/L
SM2540D	Suspended Solids (Residue, Non-Filterable)	10	U	10	mg/L
SM4500-HB	pH	7.6	H=	0.1	pH Units
SM4500NH3C	Nitrogen, Ammonia (As N)	0.1	U	0.1	mg/L
SM5310C	Total Organic Carbon	1	U	1	mg/L
SW6010B	Aluminum	50	U	50	ug/L
SW6010B	Antimony	10	U	10	ug/L
SW6010B	Barium	7.6		3	ug/L
SW6010B	Beryllium	1	U	1	ug/L
SW6010B	Boron	740		100	ug/L
SW6010B	Cadmium	3	U	3	ug/L
SW6010B	Calcium	95000		500	ug/L
SW6010B	Chromium	1	U	1	ug/L
SW6010B	Cobalt	3	U	3	ug/L
SW6010B	Copper	5	U	5	ug/L
SW6010B	Iron	20	U	20	ug/L
SW6010B	Iron, dissolved	20	U	20	ug/L
SW6010B	Lead	10	U	10	ug/L
SW6010B	Magnesium	22000		100	ug/L
SW6010B	Manganese	10	U	10	ug/L
SW6010B	Manganese, dissolved	10	U	10	ug/L
SW6010B	Molybdenum	9.2		5	ug/L
SW6010B	Nickel	5	U	5	ug/L
SW6010B	Potassium	10000		5000	ug/L
SW6010B	Silver	3	U	3	ug/L
SW6010B	Sodium	940000		50000	ug/L
SW6010B	Strontium	3200		2500	ug/L
SW6010B	Vanadium	3	U	3	ug/L
SW6010B	Zinc	10	U	10	ug/L
SW6020A	Arsenic	0.12		0.1	ug/L
SW6020A	Selenium	2.8		0.5	ug/L
SW6020A	Thallium	0.5	U	0.5	ug/L
SW7470A	Mercury	0.2	U	0.2	ug/L

Remedy Project Structural Calculations—
Remedy-produced Water Conditioning Building;
Conditioned Water Tank;
Injection Well and Valve and Meter Vaults;
Pipe Bridge Deflection

APPENDIX A - CALCULATION COVER SHEET

CALCULATION ID NUMBER	
REVISION NUMBER	
JOB NUMBER	

TITLE	Topock Water Conditioning Plant, Needles, CA

PAGE NO.	Item
1	Design Criteria & Loads
2 To 4	Roof Framing
5 To 9, 9A	Concrete Floor Framing
10, 11	Basement Concrete Walls For Earth Loads
12 To 17	Lateral loads and Analysis upper steel Frames
18 To 22	Lateral loads, Analysis, shear Walls, lower building
23, 24	Footings
25	Meter Vaults
26 - 26-6	Steel Moment Frame
27 - 27-6	Col. line-B Braced Frame
28 - 28-5	Col. line-A Braced Frame
29 - 29-6	Concrete Moment Frame line (2) & (4)

	Initial	date
PREPARED	KD	8/11/12
TITLE		
REVIEWED		
TITLE		

REVISION NOTES	

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	Checked By:	Date:
	Revised By:	Date:
Project No. WW-PEB-2174-043062		Sheet No. 1

Project Description Topock Ground water Remediation proj. Design Criteria

All Buildings including
- Water treatment & maintenance facility (water conditioning
- Hazardous waste Storage & operations Bldg. plant)

References
AWAA Standard D-100-11 For Tank Design
IBC 2009/CBC 2010 As amended by San Bernardino County
ASCE 7-10 For loads & load combinations
ACI 318-11 For concrete
AISC 13nth Edition For Steel
Moments & Reactions for Rectangular plates, U.S Dept of interior

Seismic Data
$S_S = .434$ $S_1 = .205$ $F_a = 1.4$, $F_v = 2.0$
$S_{MS} = F_a S_S = 1.4 \times .434 = .608$ $S_{M1} = F_v S_1 = 2 \times .205 = .41$
$S_{DS} = .667 \times .608 = .406$ $S_{D1} = .667 \times .41 = .273$
Seismic category - D (Table 1613.5.6 IBC) Occupancy Type III (Table 1604.5, IBC)

Concrete Data
$f'_c = 5.0^{ksi}$ $f_y = 60^{ksi}$ Table 1.5.1 ASCE 7/10

Structural Steel
$F_y = 50^{ksi}$ (WF shapes) $F_y = 36^{ksi}$ (For channels, plates etc)

Soil Data
No Soil Report available.
Allow. Bearing Pressure for Ftg = 4.0 ksf
~~Capacity of drilled piers: axial = 30k~~
~~friction factor = .30~~ ~~uplift = 25k~~
~~lateral = 13k~~

Design Loads Floor

1ST Flr	DL 12" Conc. Slab	=	150 PSF
	LL	=	500
	TL		650 PSF
2nd Flr	DL 12" Conc. Slab	=	150 PSF
	LL	=	200
	TL		350 PSF

In addition the floors shall be checked for concentrated loads from equipments, Cranes or trucks

Misc. All Basement walls
Design for 60 pcf at rest press.
Design for 2'-0" Soil Surcharge (For trucks)

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Project No. WW-PEG-2124-043062		Sheet No. 2

Project Description Topock Water Conditioning Plant Roof Framing

Roof Loads

DL = 10.0 PSF
Mech. etc. = 20.0 (USE 50% of this for Seismic DL)
LL = 20.0 PSF
TL = 50.0

Decking

For Roof purlins @ 5'-0" w/ 1½" HSB 36 Deck by Verco (22 GA.) OK FOR EQ
Allow load = 120 PSF > 50 PSF ok
USE 22GA. 1½" Decking

Purlins P-1
Between ① & ②

$\ell = 29.5'$ $W_{TL} = (.05) \times 5 + .02 = .27^{K/'}$

$R = \frac{.27 \times 29.5}{2} = 3.98^{K}$

$M = \frac{.27 \times 29.5^2}{8} = 29.87^{'K}$ $S_y = \frac{29.37 \times 12}{.6 \times 50} = 11.75^{in^3}$

Try W 12x19 $I_x = 130^{in^4}$

$\Delta_{TL} = \frac{5}{384} \times \frac{.27 \times 29.5^4}{29000 \times 130} \times 1728 = 1.22" = \frac{\ell}{290} < \frac{\ell}{240}$

USE W 12x19 purlins w/ ½ span filler strut inbetween purlins

Purlins P-2 (Bet.'n ② & ③)

$\ell = 21.5'$ P-2 $W_{TL} = .27^{K/'}$ $R = .27 \times 21.5 \times .5 = 2.9^{K}$

$M = \frac{.27 \times 21.5^2}{8} = 15.6^{'K}$ Try W 12x14 $I = 88.6$

$\Delta_{TL} = \frac{5}{384} \times \frac{.27 \times 21.5^4}{29000 \times 88.6} \times 1728 = .505" = \frac{\ell}{510} < \frac{\ell}{240}$ ok

USE W 12x19

$\ell_x = 21.5$ $\ell_y = 12.5$ Purlins P-3 @ Ⓐ & Ⓑ

$W_y = .02 \times 4 = .08^{K/'}$ $M_y = \frac{.08 \times 17.5^2}{8} = 3.06^{'K}$

$W_x = .05 \times 2.5 + .02 + .01 \times 7 = .22^{K/'}$ $M_x = \frac{.22 \times 29.5^2}{8} = 23.93^{'K}$

W 12x22 $S_x = 25.4^{in^3}$ $S_y = 2.31$

$f_{bx} + f_{by} = \frac{23.93 \times 12}{25.4} + \frac{3.06 \times 12}{2.31} = 11.31 + 15.9 = 27.22^{ksi} < 30^{ksi}$ USE W 12x22

USE W 12x40 @ Braced Frame (See pg 16)

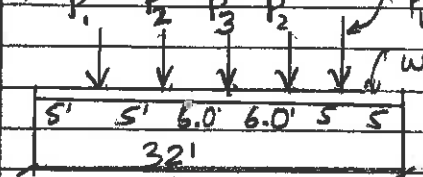
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Project No.	WW-PEG-2124-043062		Sheet No. 3
Project Description	Topock Water Conditioning plant Roof framing		

Roof

Girders

$\ell = 32'$

Col line ② & ④



$P_1 = 3.93 + 2.9 = 6.83^k$

$P_3 = 3.93\times\frac{6}{5} + 2.9\times\frac{6}{5} = 8.2^k$

$P_2 = 3.93\times\frac{5.5}{5} + 2.9\times\frac{5.5}{5} = 7.51^k$

$W_{TL} = .01\times\frac{14}{2} + .07 = .14^{k/'}$

$R = 6.83 + 7.51 + \frac{8.2}{2} + .14\times16 = 19.56^k$

$M_{max} = 19.56\times16 - 6.83\times11 - 7.51\times6 - .14\times\frac{16^2}{2} = 174.85^{'k}$

Try W 18×60 $S = 108\ in^3$ $I = 984\ in^4$

$f_{bx} = \frac{175\times12}{108} = 12^{ksi} < 50^{ksi}$ $w_{eq.} = \frac{175\times8}{(32)^2} = 1.367^{k/'}$

$\Delta_{TL} = \frac{5}{384}\times\frac{1.367\times32^4}{29000\times984}\times1728 = 1.13'' = \frac{\ell}{340} < \frac{\ell}{240}$ OK

USE W 18×60

Col. line ⑤ Girder ($\ell = 32'$)

P_1', P_2' & P_3' are 58% of P_1, P_2, P_3 for interior girders

Design for 60% of Moment for girders col. line ② & ③

$M_x = .6\times175 = 105^{'k}$ $P_y = .02\times16\times7 = 2.24^k$

Also Design for My due to wind $w_y = .02\times7 = .14^{k/'}$

$M_y = \frac{.14\times32^2}{8} = 17.92^{'k}$ OR $M_y = \frac{P_y\ell}{4} = \frac{2.24\times32}{4} = 17.92^{'k}$

W 18×60 $S_y = 13.3\ in^3$ $I_y = 50.1\ in^4$

$f_b = f_{bx} + f_{by} = \frac{105\times12}{108} + \frac{17.92\times12}{13.3} = 11.67 + 16.17 = 27.84^{ksi} < 30^{ksi}$

$\Delta_{TL} = \frac{105}{175}\times1.13 = 0.68''$

USE W 18×60

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Project No.	WW-PEA-2124-043062		Sheet No. 4

Project Description Topock Water Conditioning plant Roof framing -

Girt
G-1A
Line ①,⑤

$l = 16.0'$ Try MC 10 Girts @ 4'-3" o/c

$w_w = .02 \times 4.25 = .085^{k/l}$

$M_w = (.085 \times 16^2)/8 = 2.72^{'k}$ $R = .085 \times 8 = .68^{k}$

MC 10x22 For $l_u = 16$ $M_A = (28.4)/1.67 = 17.0^{'k} >> 2.72^{'k}$ OK

Lines Ⓐ & Ⓑ

G-1B $l = 21.5'$ $M_w = (.085 \times 21.5^2)/8 = 4.91^{'k}$ USE MC 10x22 $M_A = 12^{'k} > 4.91^{'k}$

G-1 $l = 29.5'$ $M_w = \frac{.085 \times 29.5^2}{8} = 9.25^{'k}$ $R = \frac{.085 \times 29.5}{2} = 1.254^{k}$

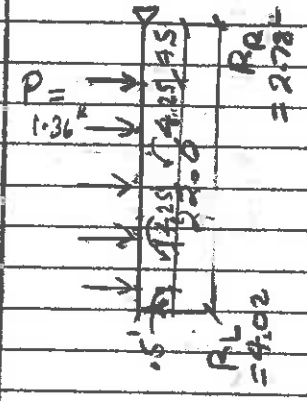
Try MC 10x28.5 $l_u = 29.5'$ $M_A = \frac{24.4}{1.67} = 14.6^{'k} > 9.25^{'k}$ OK

USE MC 10x28.5 for $l = 29.5'$

USE MC 10x22 for $l = 21.5'$ And $l = 16'$

Middle Column @ lines ③ & ⑤

$h = 22.0'$ Try W 10x22 Col. $S_x = 23.2\ in^3$



$P = .68 \times 2 = 1.36^{k}$

$R_L \times 22 = 1.36(4.5 + 8.75 + 13 + 17.25 + 21.5)$

$R_L = 4.02^{k}$ $R_R = 6.8 - 4.02 = 2.78^{k}$

$M_{max} = 2.78 \times 8.75 - 1.36 \times 4.25 = 18.55^{'k}$ say $19^{'k}$

$f_{bx} = (19 \times 12)/23.2 = 9.82\ ksi < .6 \times 50$ OK

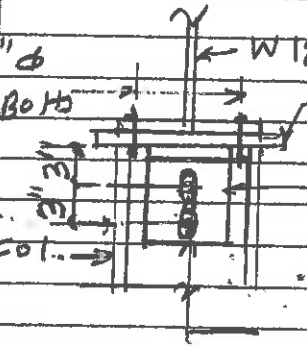
Col does not take vertical loads

See Conn. below to beam above

P_{MAX} due to weight of Siding + Framing

$= .015 \times 16 \times 20 = 4.8^{k}$ say 5^{k} $f_a = \frac{5}{6.49} = .77\ ksi$ small

5^{k} is transferred to W10 thru Girts



USE W 10x45

See pg. 16 (Mom. Fr. Analysis)

L 8x6x3/8 Ea. Side LLV Vert. welded to Col-

W/ 2 - 7/8" x 1 1/2" Vert. holes

2 - 3/4" ϕ A-325 Bolts

For Mom. frame columns see pg. 15 and 16 (W10x45).

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Project No. WW-PEG-2124-043062		Sheet No. 5
Project Description Topock Water Conditioning Plant / Beams 2nd flr.		

Design Structural slab (2nd Floor)

Note: All conc. beams except conc. frame designed for $\frac{wl^2}{8}$ and checked @ Ends for $\frac{wl^2}{12}$ fixed moment

Clear span = 5'-6"

$w_u = (1.4 \times .15 + 1.7 \times .20) = .21 + .34 = .55^{k}/_{l}$

$M_u = \frac{.55 \times 5.5^2}{10} = 2.08^{'k}$ $\quad R = \frac{.55 \times 5.5}{2} = 1.51^{k}$

$\phi M_n = A_s f_y (d - \frac{a}{2})$ $\quad f_y = 60^{ksi}$ $\quad f_c' = 4^{ksi}$

Try #5 @ 12" o/c

$a = \frac{A_s f_y}{.85 f_c' b} = \frac{.31 \times 60}{.85 \times 4 \times 12} = .456$ $\quad d = 12 - 1.5 - .5 = 10"$

$\phi M_n = \frac{.31 \times 60}{12}(10 - \frac{.456}{2}) = 15.15^{'k} > 2.08^{'k}$ ok

For Future Bays, LL = 750 PSF (Equalization Tank)

$w_u = (1.4 \times .15 + 1.7 \times .75) = .21 + 1.275 = 1.49^{k}/_{l}$

$M_u = \frac{1.49 \times 5.5^2}{8} = 5.63^{'k} < 15.15^{'k}$ ok

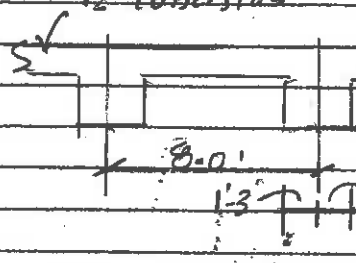
USE 12" Tk conc. slab w/ #5 @ 12" Ea. Way

$\phi V_n = .85 \times 2\sqrt{5000} \times 12 \times 10 = 14.4^{k} > 1.49 \times 5.5 = 4.1^{k}$ ok

Beams: Assume simple support for +ve M (BOT.) / Assume fixed support for -ve Mom (Top)

Interior Beam B-1 (l = 29.5) $\quad l_c = 29.5 - 1.25 - .75 = 27.5$

12" conc slab



$w_u = 1.4(.15 \times 5.5 + 2.5 \times 2.5 \times .15) + 1.7(2.5 \times .5)$

$= 1.4(1.7625) + 1.7(1.1)$

$= 4.27^{k}/_{l}$

$M_u = \frac{4.27 \times 27.5^2}{8} = 403.65^{'k}$

For $b = 30"$ $\quad d = 30 - 1.5 - .5 = 28"$

$F = 1.96$

$V_u = 4.27 \times 27.5 \times .5 = 58.7^{k}$

$\frac{M_u}{F} = \frac{404}{1.96} = 206$ $\quad A_s = .004 \times 30 \times 28 = 3.36^{in^2}$

USE 5-#8 Bars @ T & B

B-1A / l = 25'

For Future Beams $w_u = 1.4(1.7625) + 1.7(.50 \times 5.5) = 7.14^{k}/_{l}$

$l_c = 25 - 2 = 23'$ $\quad +M_u = (7.14 \times 23^2)/8 = 473^{'k}$ 4.337

$-M_u = (7.14 \times 23^2)/12 = 315^{'k}$

$+\frac{M_u}{F} = \frac{472}{1.96} = 241$ $\quad A_s = .0047 \times 30 \times 28 = 3.95^{in^2}$

USE 5-#8 bars @ T & B

$V_u = 7.14 \times 23 \times .50 = 82.1^{k}$

$V_n = 2\sqrt{5000} \times 30 \times 28 \times 10^{-3} \times .85 = 101^{k}$ $\quad V_u = 82.1^{k}) \frac{101}{2}$

provide stirrups

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Project No. WW-PEB-2174-043062		Sheet No. 6

Project Description Topock plant / Beams 2nd Flr.

Check Shear

Bm. B-1 $\ell = 29.5$

For 29'-6" Span

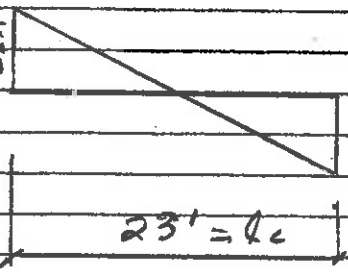
V_Q dist. d = 58.7 − 9.90 = 48.8 k (Pg.) $\quad 2\sqrt{5000} \times 30 \times 28 \times 10^{-3} = 101$ k

provide Min. stirrups

$A_{v\,min.} = \frac{50 b_w s}{f_y} = \frac{50 \times 30 \times 12}{60000} = .3\ in^2$

USE #5 stirrups @ 12" o/c ($\frac{d}{2} = 14$)

Bm. B-1A $\ell = 25'$



V_u @ dist. d = 82.1 − 7.14 $(\frac{28}{12})$ = 65.4 k

$V_s = \frac{A_v f_y d}{s}$ #3 Bars Stirrups s = 12

$= \frac{.22 \times 60 \times 28}{12}$

$= 30.8$ k

$V_n = \phi (V_c + V_s)$ $= .85\,(101 + 30.8) = 112.03$ k

$V_n = 112.03$ k > 65.4 k

USE 30"×30" Beam w/ 5-#8 @ T & B & #3 Stirrups @ 12" o/c

Exterior $\ell = 29.5'$

Beam B-1B ($\ell_c = 27.5'$)

$W_{u_1} = 1.4\,(.15 \times 5.5 \times .5 + 2.5 \times 2.5 \times .15 + .015 \times 14) + 1.7\,(.2 \times \frac{5.5}{2})$ (Siding + misc)

$= 1.4\,(1.56) + 1.7\,(.55) = 3.12$ k/l USE 3-2 k/l.

$\ell = 25'$ $\quad W_{u_2} = 1.4 \times 1.56 + 1.7\,(.05 \times \frac{5.5}{2}) = 4.52$ k/l

$\ell_c = 23'$ $\quad M_{u_1} = \frac{3.12 \times 27.5^2}{8} = 295$ k $\quad M_{u_2} = \frac{4.52 \times 23^2}{8} = 299$ k

$\frac{M_{u_2}}{F} = \frac{299}{1.96} = 152.5$ $\quad A_s = .0029 \times 30 \times 28 = 2.44\ in^2$

4-#8 Bars @ T & B ok

Check Shear

$\ell = 25$ $\quad V_{u_2} = 4.52 \times 23 \times .50 = 52$ k

$V_n = 2\sqrt{5000} \times 30 \times 28 \times 10^{-3} \times .85 = 101$ k > 52 k

provide min. Stirrups - #3 @ 12" o/c

Int. Bm. $\ell = 21.5'$

B-2 ($\ell_c = 21.5 - 2.5 = 19'$)

$W_u = 4.27$ k/l $\quad M_u = \frac{4.27 \times 19^2}{8} = 192.7$ k $\quad \frac{M_u}{F} = \frac{192.7}{1.96} = 98$

$V_u = 4.27 \times 19 \times .50 = 40.6$ k $\quad A_s = .002 \times 30 \times 28 = 1.68\ in^2$ 3-#8 Bars ok @ T & B

$V_n = 101$ k > 40.6 k #3 Stirrups @ 12" o/c

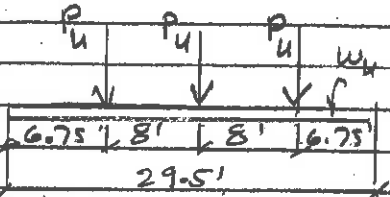
USE 30"×30" Bm. w/ 3-#8 T & B

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Project No.	WW-PEG-2174-043062		Sheet No. 7

Project Description: Todock Water Conditioning Plant / Girders 2nd Flr

G-1 Interior 30"x30"

Girders (ℓ = 32.0') ℓ_c = 32 - 2.5 = 29.5'



(B-1) (B-2) USE

P_u = 58.7 + 40.6 = 99.3^k USE 100^k

w_u = 1.4 (2.5x2.5x.15) + 1.7 (.2x1x2.5)

= 1.31 + .86 = 2.16^k/' USE 2.2^k/'

$$R = \frac{2.2 \times 29.5}{2} + \frac{3 \times 100}{2} = 32.45 + 150 = 182.45^k$$

$$+M_u = 182.45 \times \frac{29.5}{2} - 2.2 \times \frac{(29.5)^2}{2} \times .5 - 100 \times 8 = 1652^{'k}$$

Try 30"x30" Bm. $W_{eq} = \frac{1652 \times 8}{(29.5)^2} = 15.19^k/'$, $M_{u_1} = \frac{8}{12} \times 1652 = 1101^{'k}$ ← USED FOR CONC. FRAME PG 16

BOT $F = 1.82$ $\frac{M_u}{F} = \frac{1652}{1.82} = 908$ $d = 30 - 1.5 - 1.5 = 27"$

$A_s = .0178 \times 30 \times 27 = 14.42^{in^2}$ 12 - #10 Bars

6 - #10 w/ two layers @ BOT. $A_{s_u} = 1.27 \times 12 = 15.24^{in^2}$

$M_u = (15.19 \times 29.5^2)/12 = 1102^{'k}$

$(M_u)/F = (1102)/1.82 = 605$ $A_s = .0124 \times 30 \times 27 = 10^{in^2}$ 8 - #10 Top

Check shear

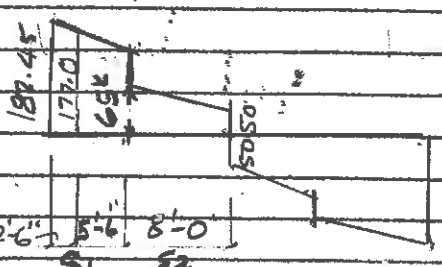
V_{max} V_u = 182.45^k V_u @ dist d = $182.45 - 2.2 \times \frac{27}{12} = 177.5^k$

$V_c = 2\sqrt{5000} \times 30 \times 27 \times 10^{-3} = 114.6^k$

$V_n = \phi V_c = .85 \times 114.6 = 97.4^k$

$V_{s_1} = \frac{A_v f_y d}{S_1} = \frac{.4 \times 60 \times 27}{6} = 108^k$

$V_{n_1} = \phi (V_c + V_{s_1}) = .85 (114.6 + 108) = 189.2^k$



S_1 - #4 @ 6" o/c Cap. V_n = 189.2^k

S_2 - #4 @ 12" o/c

S_3 - #4 @ 24" o/c

$V_{s_2} = \frac{.4 \times 60 \times 27}{12} = 54^k$

$V_{n_2} = .85 (114.6 + 54) = 143.3^k > 65^k$ OK

G-1	S_1 = 6" S_2 = 12"	12 - #10 bot & 8 #10 @ Top
G-2	S_1 = 4" S_2 = 12"	12 - #11 bot. & 8 - #11 @ Top
G-2B	S_1 = 8 S_2 = 16"	10 #10 @ bot. & 6 - #10 @ Top
G-2A	S_1 = 12"	3 - #8 @ T & B

For Girders G-2, G-2B etc See pg. 8 & 9

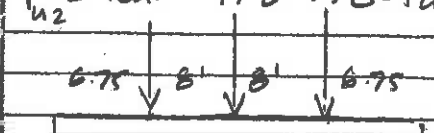
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Project No. | WW-PEG-2124-043062		Sheet No. 8

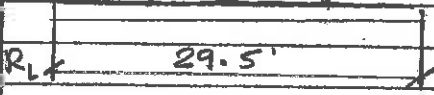
Project Description Topock Water Conditioning Plant / Future Girders / 2nd Flr.

G-2 Interior Future

Girders (ℓ = 32.0')

P_{u_2} = 132.0 99.8 99.8 = P_{u_1}





ℓ_c = 29.5'

P_{u_1} = 49.9 + 49.9 = 99.8 k

P_{u_2} = 82.1 + 49.9 = 132.0 k

w_u = 1.4 (2.5×2.5×.15) + 1.7×.2×2.5

= 2.16 k/ft Say 2.2 k/ft

$R_L \times 29.5 = 132 \times 22.25 + 99.8 (14.75 + 6.75) + 2.2 \times \frac{29.5^2}{2}$

R_L = 207.0 k R_R = 396.5 − 207.0 = 189.5 k

$M_u = 207 \times \frac{29.5}{2} - 132 \times 8 - 2.2 \left(\frac{29.5}{2}\right)^2 \times .50 = 1757.9$ k-ft

$\frac{M_u}{F} = \frac{1758}{1.82} = 966$ $A_s = .0209 \times 30 \times 27 = 16.93$ in²

14 - #10 Bars (12 - #11 OK)

6 - #11 Bars two layers @ Bot. $A_{s_A} = 12 \times 1.56 = 18.72$

8 - #11 Bars @ Top (4 - #11 in each layer total 2 layers @ Top)

Check Shear

S_1 = #4 @ 4" $V_{s_1} = \frac{.4 \times 60 \times 27}{4} = 162$ k

$V_{n_1} = \phi (114.6 + 162) = 235$ k > $207 - 2.2 \times \frac{27}{12} = 202$ k

S_2 = #4 @ 8" $V_{s_2} = \frac{.4 \times 60 \times 27}{8} = 81$ k

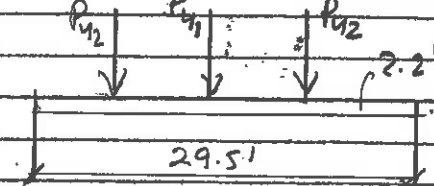
$V_{n_2} = .85 (114.6 + 54) = 143.3$ k > 75 k ok

#4 @ 12" o/c

USE 30"x30" Girders w/ 12-#11 Bars @ bot, 8-#11 @ Top

G-2B Exterior Future

Girders (ℓ = 32.0') ℓ_c = 29.5



P_{u_1} = 82.1 k (B-1A) P_{u_2} = 50 k

w_u = 2.2 k/ft $R = \frac{(2 \times 50 + 82)}{2} + \frac{2.2 \times 29.5}{2}$

R = 123.45 k = 125.45 k

$M_u = 125.45 \times 29.5 - 50 \times 8 - 2.2 \times \frac{(29.5)^2}{2} \times .5$

= 1211 k-ft

$\frac{M_u}{F} = \frac{1211}{1.82} = 665$ $A_s = .0136 \times 30 \times 27 = 11.0$ in² A_s = 1.27 × 10 = 12.7 in²

USE 10 #10 Bars @ bot & 4 - #11 @ Top

Shear S_1 = #4 @ 8" $V_{s_1} = (.4 \times 60 \times 27)/8 = 81$ k

$V_{n_1} = .85 (114.6 + 81.0) = 143.3$ k > $123.45 - 2.2 \times \frac{2}{12} = 118.5$ k

#4 @ 16" $V_{n_2} = .85 (114.6 + 40.5) = 131.8$ > 123.45 − 50 − 2.2 × 8 = 55.9

USE 30"x30" Girders w/ 10 #10 @ bot, & 6 #10 @ Top

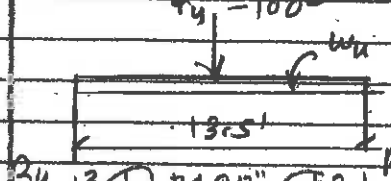
(two layers 5 #10) (Two layers 3-#10 ea.)

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Project No. WW-PEB-2124-043062		Sheet No. 9

Project Description Topock plant / Girders line ① & ③

G1-2C **Girders** ($\ell = 16.0'$) $\quad \ell_c = 16 - 2.5 = 13.5'$

$P_u = \frac{4.27 \times 21.5}{2} + \frac{4.27 \times 25}{2} = 99.3^k$ USE 100^k



$w_u = 1.4(1.5 \times 1.5 \times .15) = .47^{k/'}$ SAY $.5^{k/'}$

$R_u = \frac{100}{2} + \frac{.5 \times 13.5}{2} = 53.4^k$

$M_u = \frac{100 \times 13.5}{4} + \frac{.5 \times 13.5^2}{8} = 98.9^{k'}$ SAY $100^{k'}$

Try Girder 18" W x 30" +/- $\quad d = 30 - 2 - .5 = 27.5"$

$F = \frac{18 \times 27.5}{12000} = 1.13$

$\frac{M_u}{F} = \frac{100}{1.13} = 88$ $\quad A_s = .0017 \times 18 \times 27.5 = .842\ in^2$

USE 3-#8 bars T & B

Shear $V_c = 2\sqrt{5000} \times 18 \times 27.5 \times 10^{-3} = 70.0^k > 53.4^k$ OK

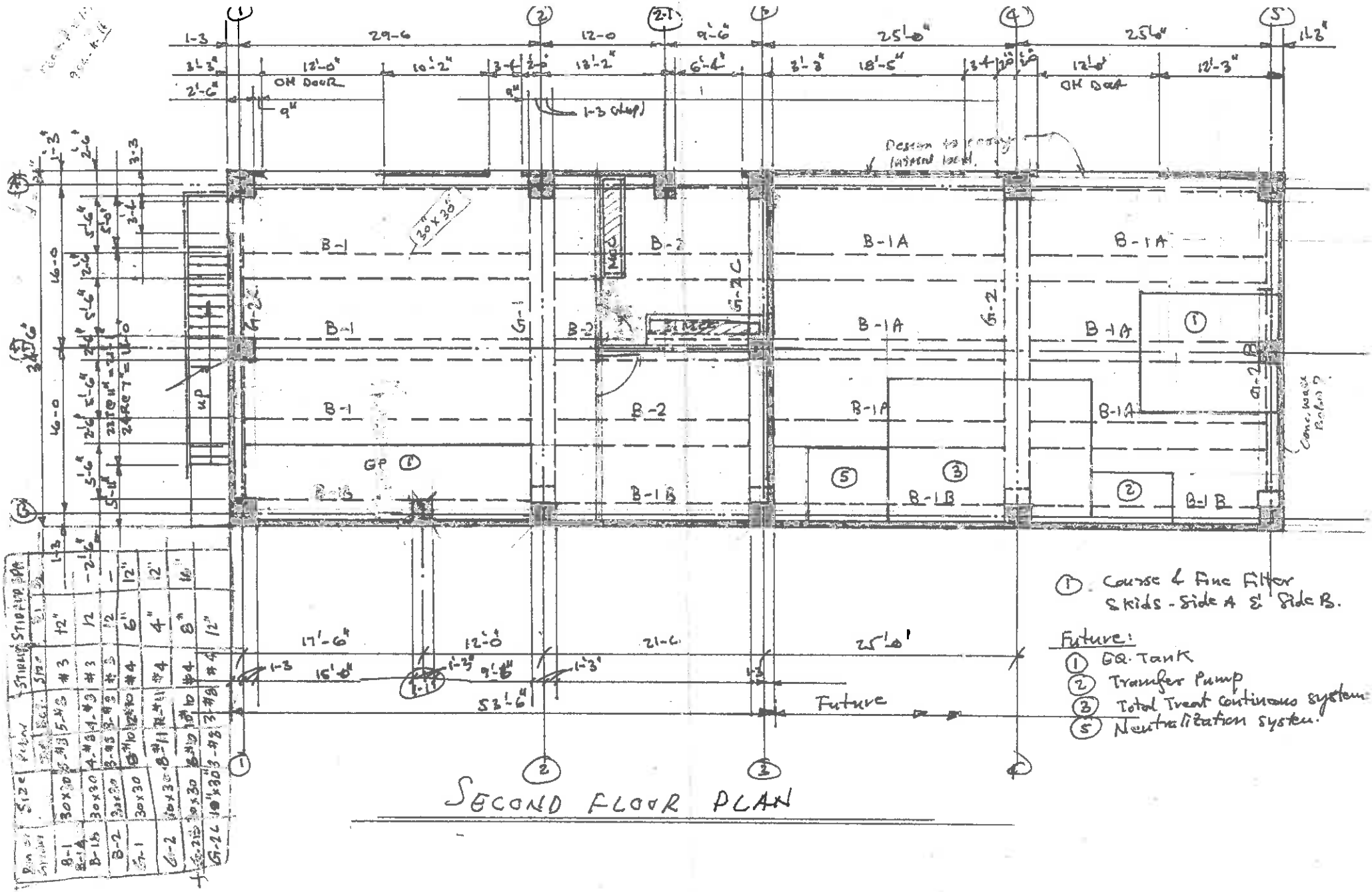
Provide stirrups #4 @ 12" o/c (2'-0 from support)

$V_s = \frac{A_v f_y d}{s} = \frac{.40 \times 60 \times 27.5}{12} = 62.0^k$

$\phi(V_c + V_s) = .85(70 + 62.0) = 112.2^k$

$V_u = 53.4 - 2 \times .50 = 52.4 < \frac{112.2}{2}$

USE 18" x 30" Girder W/ 3-#8 @ T & B



SECOND FLOOR PLAN

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Project No. WW-PEG-2124-043062		Sheet No. 10

Project Description Basement Wall Design / Concrete Wall Supports

Wall W-1 @ line-B

South wall (Bet'n line ③ & ⑤)

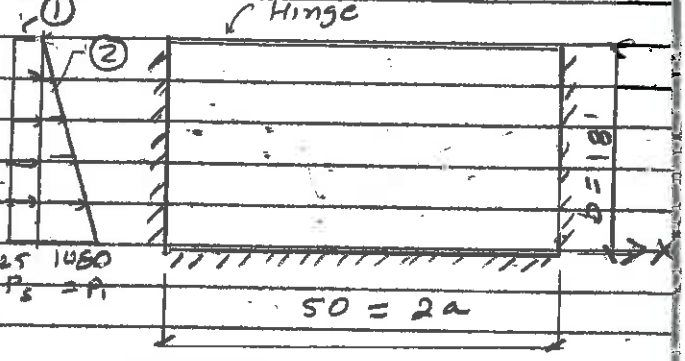
Assume wall hinged on Top, two sides & bottom fixed

For wall designation see sketch pg. 21

P_s = Surcharge = $250 \times .50 = 125$ PSF

$P_1 = .5 \times 120 \times 18 = 1080$ PSF

$\frac{a}{b} = \frac{25}{18} = 1.39$ Say 1.50



Loading Type — Calculate Mom. & Reactions

① $M_{1x} = .0531 \times .125 \times 18^2 = 2.15^{1K}$

$R_{1x} = .5302 \times .125 \times 18 = 1.193$

$M_{1y} = .1194 \times .125 \times 18^2 = 4.84^{1K}$

$R_{1y} = .6852 \times .125 \times 18 = 1.407$

② $M_{2x} = .0262 \times 1.08 \times 18^2 = 9.17^{1K}$

$R_{2x} = .2208 \times 1.08 \times 18 = 4.292^{K}$

$M_{2y} = .0637 \times 1.08 \times 18^2 = 22.29^{1K}$

$R_{2y} = .3997 \times 1.08 \times 18 = 7.77^{K}$

$M_{Tx} = 2.15 + 9.17 = 11.32^{1K}$ $R_{Tx} = 1.193 + 4.292 = 5.485^{K}$

$M_{Ty} = 4.84 + 22.29 = 27.13^{1K}$ $R_{Ty} = 1.407 + 7.77 = 9.177^{K}$

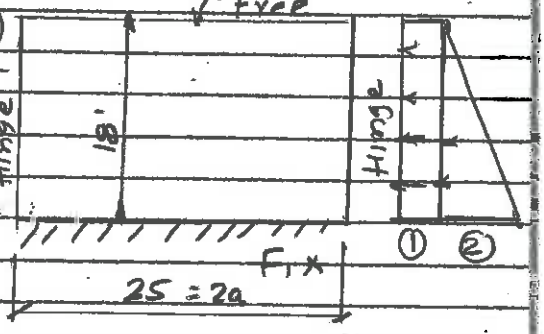
$M_{Uy} = 1.7(27.12) = 46.10^{1K}$ $R_{Uy} = 1.7(9.177) = 15.6^{K}$

$d_y = \frac{15600}{.85 \times 141 \times 12} = 10.85"$ 15" Tk. wall OK USE 18" Tk walls

Wall W-2

South Wall (Future Bldg. bet'n ① & ②)

$\frac{a}{b} = \frac{12.5}{18} = .694$ USE .75



① & ② $M_{1x} = .1217 \times .125 \times 18^2 = 4.93^{1K}$

$M_{2x} = .0337 \times 1.08 \times 18^2 = 11.79$

$R_{1x} = 1.4911 \times .125 \times 18 = 3.355$

$R_{1y} = .9187 \times .125 \times 18 = 2.067$

$M_{1y} = .2136 \times .125 \times 18^2 = 8.65$

$M_{2y} = .0871 \times 1.08 \times 18^2 = 30.48$

$R_{2x} = .3017 \times 1.08 \times 18 = 5.865$

$R_{2y} = .4816 \times 1.08 \times 18 = 9.362$

$M_{Tx} = 4.93 + 11.79 = 16.72^{1K}$ $M_{Ty} = 8.65 + 30.48 = 39.13^{1K}$

$R_{Tx} = 3.355 + 5.865 = 9.22$ $R_{Ty} = 2.067 + 9.362 = 11.429^{K}$

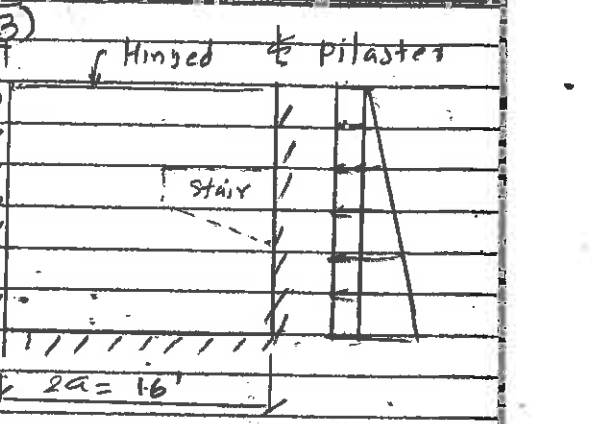
$M_{Uy} = 1.7 \times 39.13 = 66.52^{1K}$ $R_{Uy} = 1.7 \times 11.429 = 19.429^{K}$

$d_y = \frac{19429}{.85 \times 12 \times 141} = 12.5"$ USE 18" Tk Walls

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Project No. WW-PEG-2124-043062		Sheet No. 11

Project Description Basement Wall Design

Wall W-3 East Wall (col-line 5.)



$\frac{a}{b} = \frac{8}{18} = .44$ USE .50

① $M_{1x} = .0572 \times .125 \times 18^2 = 2.32^{k}$

$R_{1x} = .4751 \times .125 \times 18 = 1.069^{k}$

$M_{1y} = .0512 \times .125 \times 18^2 = 2.07^{k}$

$R_{1y} = .4525 \times .125 \times 18 = 1.02^{k}$

② $M_{2x} = .0269 \times 1.08 \times 18^2 = 9.413^{k}$

$R_{2x} = .2450 \times 1.08 \times 18 = 4.763^{k}$

$M_{2y} = .0320 \times 1.08 \times 18^2 = 11.20^{k}$

$R_{2y} = .3225 \times 1.08 \times 18 = 6.269$

$M_{Tx} = 2.32 + 9.413 = 11.733^{k}$ $M_{Ty} = 2.07 + 11.20 = 13.27^{k}$

$M_{uy} = 13.27 \times 1.7 = 22.56^{k}$ $R_{uy} = (1.02 + 6.27) \times 1.7 = 12.39^{k}$

$d_r = \frac{12390}{.85 \times 141 \times 12} = 8.62"$ Try 12" wall $d = 12 - 2 - .5 = 8.5"$ ok

Reinforcements

W-1 & W-2 @ line-B: $d = 18 - 2 - .50 = 15.5"$ $b = 12"$ $F = .24$

M_{ux} $M_{uy} = 66.52^{k}$ $k_n = \frac{66.52}{.24} = 277$

$f_c' = 5 ksi$ $f_y = 60 ksi$

$A_{sv} = .0052 \times 12 \times 15.5 = .967 in^2$ #9 @ 12" o/c Vert. outside face

$M_{ux} = 1.7 \times 16.72 = 28.42^{k}$ $k_n = \frac{28.42}{.225} = 126$

for $b = 12$ & $d = 18 - 2 - 1 = 15"$

$A_{sh} = .0025 \times 12 \times 15.0 = .45 in^2$ #7 @ 15" o/c (towards earth)

USE 18" TK walls w/ #9 @ 12" vert. bars outside face
#9 @ 18" vert. bars inside face
#7 @ 15" Horiz bars ea. face

(Line-5) W-3 $d = 18 - 2 - .50 = 15.5$ $b = 12"$ $F = .24$

Vert. → Rebars $k_n = \frac{22.56}{.24} = 94$ $A_{sv} = .0018 \times 12 \times 15.5 = .335 in^2$
#6 @ 12" Vert. outside face

Horiz → Rebars $d = 18 - 2 - 1 = 15"$ $b = 12"$ $F = .225$ $M_{ux} = 1.7 \times 9.413 = 16.0^{k}$

$k_n = (16)/.225 = 71$ $A_{sh} = .0017 \times 12 \times 15 = .306 in^2$ #7 @ 15"

USE #6 @ 12" ea. face vert. bars & #6 @ 15" horiz. bars

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Project No. WW-PEA-2124-043062		Sheet No. 12

Project Description: Lateral Loads, Topock Water Conditioning plant

Lateral Loads

Seismic: Moment frames above El. 14.0' are primarily single story frames carrying 20 PSF Dead Load from Roof

Lower portion from El. 14'-0" to El. 0'-0" shall be analysed as separate building from above using different seismic factors. All forces from above including vertical loads & horizontal shear acting at el. 14'-0"

Slope of Roof is 4:1

12.3.3.4 Design forces for all connections & collectors shall be 1.25 times the seismic forces for above frames (covered in 14'-0")

Redundancy factor ρ

ρ = 1.3 for all moment & Braced frames

Load combinations (ASCE 7-10)

For Mom. Frames & Braced frames Combinations w/ Allowable Stress Design

12.4.3.2 Comb. 5 = $(1.0 + .14 S_{DS})D + .7 \Omega_0 Q_E$ or $(1 + .057)D + 2.1 Q_E$

Mom. Fr's Comb. 8 = $(.6 - .14 S_{DS})D + .7 \Omega_0 Q_E$ or $(.6 - .057)D + 2.1 Q_E$

Ordinary Moment frames NS DIR

R = 3.5 Ω_0 = 3 C_d = 3 $\delta_x = \frac{C_d \delta_{xe}}{I} = \frac{3}{1.25} \delta_{xe} = 2.4 \delta_{xe}$

Braced Frames

R = 3.25 Ω_0 = 2 C_d = 3.25

Braced Fr's Comb. 5 $(1 + .057)D + 1.40\, Q_E = 1.057 D + 1.4 Q_E$

Comb 8: $(.6 - .057)D + 1.40\, Q_E = .543 D + 1.4 Q_E$

Using Equivalent Lateral procedure

$V = C_S W$; I = 1.25 R = 3.5 (Ordinary Mom. Fr.)

$C_S = \frac{S_{DS}}{(R/I)} = \frac{.406}{(3.5/1.25)} = .145$ $C_{S\,max} = \frac{S_{D1}}{T(R/I)}$

$T = C_t h_n^x$ (Mom. Fr) $= .028 \times (21)^{.8} = .82$ $T_{Br.Fr} = .02 \times (21)^{.75} = .196$ sec.

$C_{S\,max} = \frac{.5 \times .271}{.32 (2.8)} = .152$ (Mom. Fr's) crane $C_{S\,max}$ (For Braces) $= \frac{.5 \times .271}{.196 (3.25/1.25)} = .265$

NS DIR $W = .02 \times 25 \times 35 + .75 \times 4.0 + .01 \times 10.5 \times 25 = 23.12^K$

$V_{NS} = .152 \times 23.12 \times 1.3 = 4.6^K$ USE 4.6^K / Mom. Fr. Say 5^K

E W DIR $V_{EW} = .265 \times 23.12 \times 1.3 = 9.1^K$ USE 9.1^K / Br. Fr.

Wind See pg. 16 for wind pressure calc. $V_{NS} = .024 \left(\frac{21}{2} + 5.4\right) \times 25 = 9.5^K = P_W$ $V_{EW} = .024 \times 23.7 \left(\frac{84}{2}\right) = 4.83^K = P_W$

Design for Seismic in both directions. Check w/ Wind loads applied in separate load cases See pg. 14

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Project No. WW-PEG-2124-043062		Sheet No. 13

Project Description Lateral Loads Topock W.C. plant

Lateral Loads Contd

Seismic

Lower Structure is concrete slab & beam at 2nd flr and concrete shear walls under 2nd flr resisting lateral loads. Shear walls shall be designed to carry loads from
- Moment Frames & braced frames (all lateral loads)
- Columns Supporting Roof DL + LL as well as Crane loads

From Table 12.2-1 Get design factors for Ordinary Reinforced concrete shear Walls

$R = 4 \quad \Omega_o = 2.50 \quad C_d = 4$

$V = C_s W \qquad C_s = \frac{S_{DS}}{(R/I)} = \frac{.406}{(4/1.25)} = .127$

$C_{s\,max.} = \frac{.5 S_{D1}}{T(R/I)} = \frac{.5 \times .271}{T \times 3.2} = \frac{.0424}{T} = \frac{.0424}{.1448} = .293$

Sect. 12.8.2.1 (Eq. 12.8-7) $T_a = C_t h_n^{.75} = .02 \times 14 = .1448$; $T_{max} = .1 \times 1.5 = .15$ sec. (C_t walls)

$V = .293\ W \qquad W \approx .15 \times 2 \times 50 \times 34 + .15 \times 34 \times 2 \times \frac{14}{2} \times 1.5$

$\approx 510 + 1071 = 617^K$

$V = .293 \times 617 = 180.8^K$ USE 190^K

Wall Line 3 & Line A

$V_{Tot.} = \underset{\text{Main Ex's}}{\text{Upper Struct. Shear}} + \text{Lower Struct. Shear}$

$V_{3\,Tot.} = 5.0 \times 2 + 180.8 = 190.8^K$ USE 191^K

12.4.3.2 For Conc. Structure Combinations w/ Strength Design

$5\ (1.2 + .2 S_{DS})D + \Omega_o Q_E = (1.2 + .2 \times .406)D + 2.5 Q_E$

$7\ (.9 - .2 S_{DS})D + \Omega_o Q_E = (.9 - .2 \times .406)D + 2.5 Q_E$

Final equations are

Comb. 5 $(1.2 + .0812)D + 2.5 Q_E = 1.281\ D + 2.5 Q_E$

Comb. 7 $(.9 - .0812)D + 2.5 Q_E = 0.819\ D + 2.5 Q_E$

Calculate T_a based on Eq. 12.8-7 ASCE 7-10

Walls line ③ $D_i = 17$, $h_n = 14$, $A_b = 7$, Fdn. Area $A_b = 76.5$, Bldg Area $A_b = 1100$

Eq. 12.8-10 $T_a = \frac{.0019}{\sqrt{C_w}} \times h_n \qquad C_w = \frac{100}{A_B} \sum_{i=1}^{n} \left(\frac{h_n}{h_i}\right)^2 \frac{A_i}{\left[1 + .83\left(\frac{h_i}{D_i}\right)^2\right]}$; A_i = Shear Area

$= \frac{.0019}{\sqrt{6.384}} \times 14 = \frac{100}{2 \times 34 \times 10.5} \left[\frac{1.5 \times 17 + 1.5 \times 34}{\left(1 + .83\left(\frac{14}{17}\right)^2\right)}\right]$

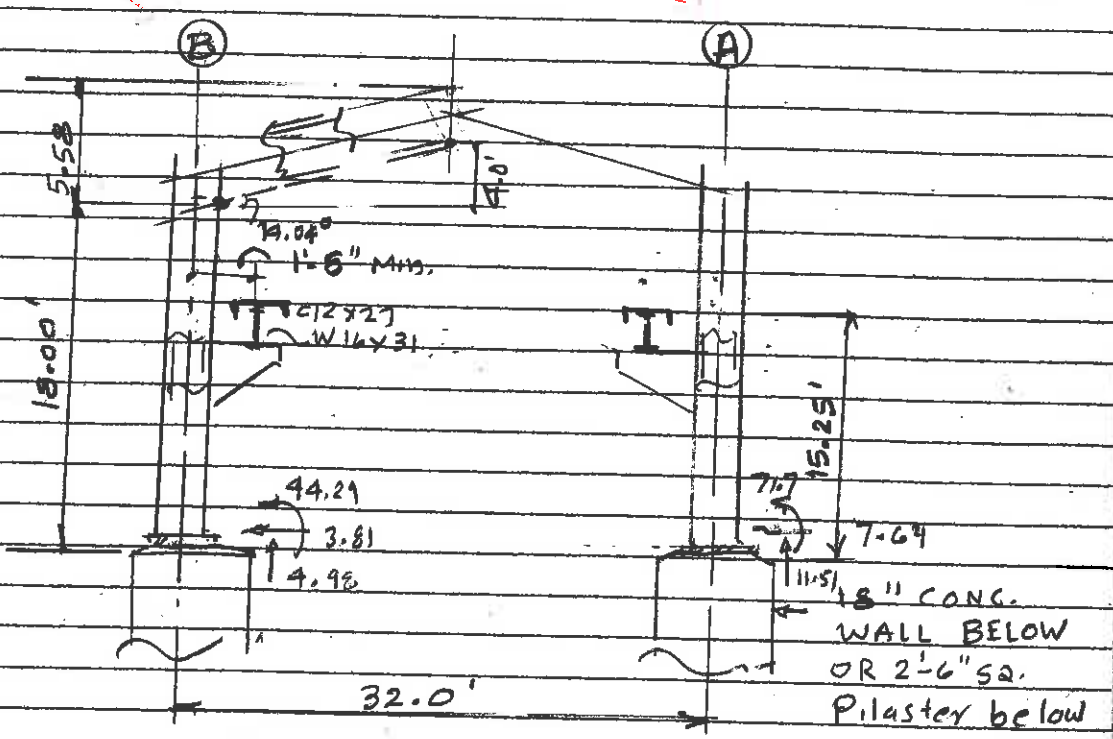
$= .0105$ sec. $= 6.384$

$T = .0105 \times 1.5 = .016$ sec. Too small use other method

$T_a = .1N = .1 \times 1 = .1$ sec. $T = C_u T_a = 1.5 \times .1 = 1.5$ sec. (Eq. 12.8-8) (C_u Table 12.8-1)

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Project No. WW-PEG-2174-043062		Sheet No. 14

Project Description: Frame @ col. line (3) Load combinations



Following Load combinations for Exonic Design considered

$Q_E = Q_L$ = Seismic P_W = wind

Include Roof DL

DL = .02 x 25 = .50 k/'

1	D + L	Q_E See pg. 12 for Seismic (Q_L) & Wind (P_W)
2	1.057 D + 2.1 Q_L	Q_L = 5.0 (Mom. Fr.), Q_L = 9.1 k (Br. Fr.)
3	.543 D + 2.1 Q_L	
4	Roof D + WIND P_W	P_W = 5 (Br. Fr.), P_W = 10.0 (Mom. Fr.)
5	Roof D + .75 L + .75 P_W	
6	Roof D + Crane (D+L) + 2.1 Q_L	

Assume crane is not operating during earthquake
Hence no impact nor horiz. loads due to operation

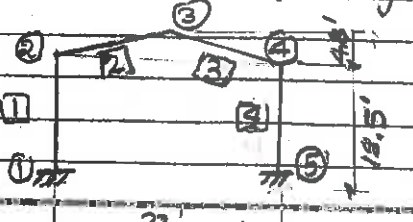
Crane Loads (2 T capacity) Single Girder Wheel Crane

Assume DL = 1k (including bridge girder & crane)

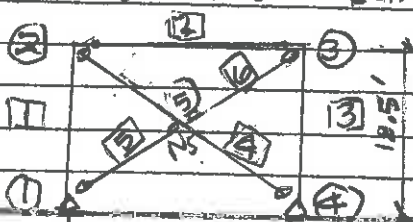
Crane D+L = 1 + 4 = 5k

1 wheel to crane runway = .2 x 5 = 1.0k 0.5k ea. beam

1 wheel to crane runway = .1 x 5 = 0.5k ea. runway bm.



ALL MOM. CONN.'s



Col. line B ALL PIN CONN.'s

Col. line A

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Project No. WW-PEG-2174-043062		Sheet No. 15

Project Description Crane Runway Design.

Single Bridge (Girder) $\ell = 32 - 2\times1.5 = 29'$

$P = (10.0 + 4)\times1.25 = 6.25^k$ $\quad R = \frac{6.25\times27.5}{29} = 5.93^k$ (MAX.)

$M = \frac{6.25\times29}{4} = 45.31^{IK}$

for $\ell_H = 27.5'$ Bm W 14x48 $M_A = \frac{84}{1.67} = 51.5^{IK}$

Try W 14 x 61 $I_x = 640$ $I_y = 107$

$S_x = 92.1$ $S_y = 21.5$

$\Delta_A = \frac{29\times12}{600} = 0.58''$ $\quad \Delta_a = \frac{Pl^3}{48EI} = \frac{6.25\times29^3}{48\times29000\times640}\times1728 = .30'' < .58''$

Note: Crane Bridge Girder size for reference only however it shall be designed by Crane Manufacturer.

Crane Runway Beam

Max. Span = 29.5' $\quad P_{max} = 5.93^k$ Say 6^k

$M_{x\,max} = \frac{6\times29.5}{4} = 44.25^{IK}$ $\quad R = 6^k$ (MAX) $\quad M_{y\,max} = \frac{1.2\times29.5}{4} = 8.85^{IK}$

C 12x27 — Try W 16 x 36 w/ C 12 x 27 LH. (AISC pg. 1-112)

W16x36

$I = 670\ in^4$, $\quad S_1 = 62.8$ (BOT.) $\quad S_2 = 123$ (TOP) $\quad S_y = 25.6$ $\quad I_y = 153$

$r = 6.34$

f_{bx} (BOT.) $= \frac{44.25\times12}{62.8} = 8.45^{KSI}$ $\quad f_{by}$ (TOP) $= \frac{8.85\times12}{25.6} = 4.15^{KSI}$

$\Delta_{max} = \frac{6\times(29.5)^3}{48\times29000\times670}\times1728 = .285'' < \frac{\ell}{600} = .59''$ ok

Crane col. (WIND pg. 3 Crane + Crane + Roof DL + SNOW)

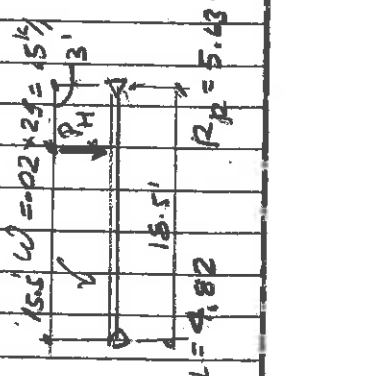
Vert. $P_{max} = 6^k + \frac{20}{2} = 16^k = P_V$

Horiz. $P_H = .2\times6 = 1.2^k$ $\quad W_W = .5^{k/l}$

$R_R = \frac{.5\times18.5}{2} + \frac{1.2\times15.5}{18.5} = 5.63^k$ $\quad R_L = 4.82^k$

$M_{max} = 4.82\times\frac{9.64}{2} = 23.23^{IK}$

$P_D = 16^k$



Include Crane LL — Crane col. - W10x45

See Computer output for various combinations.

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Project No. WW-PE4-2124-043062		Sheet No. 16

Project Description: Topock W.C. plant, Frames sizes & checks (outputs)

N-S Dir — Typical Mom. Fr.

(Topock gwr. mom. fr.)

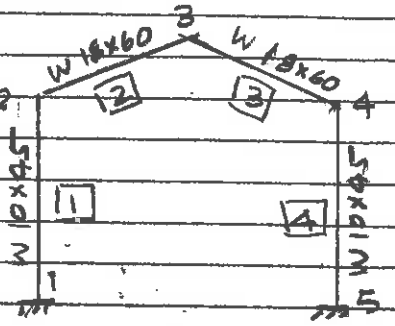
For size checks see page 26

Steel code checks (outputs)

Displacement (See Joint Deflections)

Max. Defl. (JT. 4, load case 6)

= 1.26" = δ_{xe} = Defl. by elastic An.



Max. Defl. $\delta_e = 2.4\,\delta_{xe}$ (pg. 12)

$= 2.4 \times 1.26 = 3.024"$ < $.015 \times 18.5 \times 12 = 3.33"$ (Table 12-12-#SCE 7/10)

Assume $R_I = 1.0$ for Drift Calculations.

Design pilaster below for

Mom. Fr. Only — $M = 7167^{K}$ $V_{max} = 7.69^{K}$ $R_{max} = 11.51^{K}$

(Topock wcp. braced frame A)

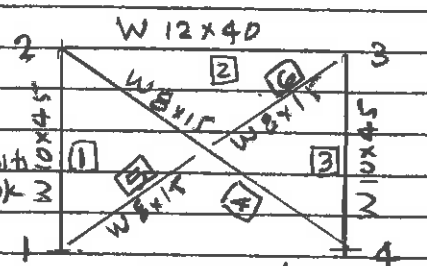
E-W Dir — Braced Frames

Line A — $V_{max} = 19.26^{K}$ $R_{max} = 21.13^{K}$

$R_{uplift} = 16.62^{K}$ ↓ 12-1¼" ϕ A-36 Bolts & 24"x24" Base pl. OK

Line B — $V_{max} = 19.28^{K}$ $R_{max} = 16.62^{K}$

$R_{uplift} = 12.11^{K}$ 12-1¼" ϕ A 36 A.B.'s w/ 24"x24"x1½" pl. OK (See page 22)



Wind Loads (see chapter 28, Part 2

Sect. 28.5 — Risk category II $V = 110$ mph,

Table 28.1-1 (pg. 304) — Exp C, V = 110 mph $P_{S30} = 17.5$ PSF ($\theta = 18.4°$)

Wind press. — $P_W = P_S = \lambda K_{zt} P_{S30}$ (Eq. 28.6-1 pg. 306)

(P_{S30} (Table 28.3.1)* = 17.5; λ = 1.35 (pg. 305) (Mean ht. 25'); $K_{zt} = 1.0$

$P_S = 1.35 \times 1 \times 17.5 = 23.6$ PSF Use 24 PSF

Topock comp. Frame (A)

Stiffness of Fr. = $\frac{1}{\Delta} = \frac{1}{1.861} = .54$ (Load comb. -2)

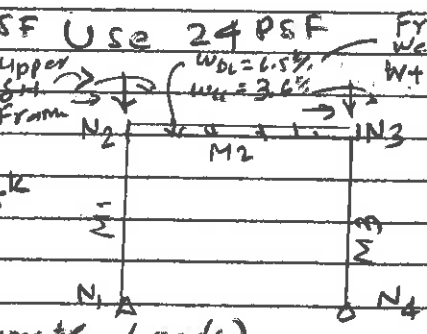
Max. Reactions (+DL+LL) $V_{Hmax} = 89.7^{K}$ $R_{Hmax} = 243.5^{K}$

Seismic $V_{Hmax} = 52.7^{K}$ $R_{Hmax} = 114.5^{K}$

Max. Defl. of Frame = .833"

Max. Bm. Defl. (DL+LL) = 1.336" (ultimate Loads)

For Working Loads Defl. = $\frac{1.336}{1.6} = 1.16" < \frac{l}{}$ OK



E2 Consulting Engineers, Inc. 1900 Powell Street, Suite 250 Emeryville, CA 94608	Designed By: KD	Date: 8/09/12
	Checked By:	Date:
	Revised By:	Date:
Project No. WW-PEG-2174-043062		Sheet No. 17

Project Description: Topock Steel Mom. Fr. Base pl. & Anchor Bolts

Loads from pg. ~26 Computer output for Stl. Mom. frame
Also see Braced frame line-B

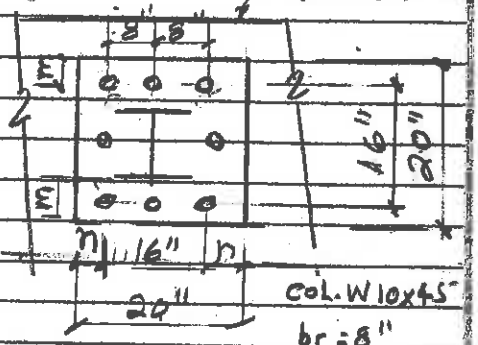
Load comb (5)

$P_{max} = 22.55^{k}$ $M_{max} = 70.46^{'k}$ $V_{max} = 8.32^{k}$

Base pl. (20" x 20" x 1" tk trial size)

$\frac{P}{A} = \frac{22.6}{20\times20} = .0565^{ksi}$ $\frac{M}{S} = \frac{70.46\times12}{\frac{1}{6}\times20\times20^2} = .634^{ksi}$

$f_p = .0565 + .634 = .69^{ksi}$



$n = \frac{B - .8\,b_f}{2} = \frac{20 - .8\times8}{2} = 6.8"$

$m = \frac{N - .95\,d}{2} = \frac{20 - .95\times10}{2} = 5.25"$

$t_{min.} = 2\,m\sqrt{\frac{f_p}{F_y}}$ $F_y = 36^{ksi}$

↓ is used since this comp'n occurs in that direction.

$= 2\times5.25\sqrt{\frac{.69}{36}} = 1.45"$ (See calc.'s below for 24"x24" pl.)

$f'_c = 5^{ksi}$
$f_y = 60^{ksi}$

Anchor Bolts

Steel Mom. Frame

Max. Ten./Bolt = $T = \frac{70.46\times12}{16\times3} = 17.62^{k}$

Max Shear/Bolt = $V = \frac{8.32}{8} = 1.04^{k}$

Try $1\frac{1}{4}"\phi$ x 9" A-36 Anchor Bolts [Table 3,5,6 Attached)

Allow $T_a = 19.6^{k}$ for $E_d = 8.4"$ & $S_{dc} = 19.8$ c/c bolts
$V_a = 10.2^{k}$ $m_t = 4.3$ = Edge dist. for tension

Due to overlapping cones. Since $S_d = 8" < 19.8"$ (Arbitrary)
Increase embedment to 18" & Reduce cone area to 80%

$\frac{V}{V_a} + \frac{T}{T_a} = \frac{1.04}{10.2\times.8} + \frac{17.62}{19.8\times.8} = 1.23 \approx 1.2$ (20% increase for seismic or wind loads OK)

USE 24" x 24" x $1\frac{1}{2}$" Base pl. w/ 8 - $1\frac{1}{4}"\phi$ x 18" A.B.'s or

$f_p = \frac{22.6}{24\times24} + \frac{70.46\times12}{\frac{1}{6}\times24\times24^2} = .406^{ksi}$ $t_{min.} = 2\times7.25\sqrt{\frac{.406}{36}} = 1.54"$

$1\frac{1}{2}"$ Tk pl. OK

TABLE 3 ALLOWABLE LOADS - WORKING STRESS DESIGN

Steel Type	D(in.) =>	1/2	5/8	3/4	7/8	1	1-1/8	1-1/4	1-3/8	1-1/2	1-3/4	2	2-1/4	2-1/2	2-3/4	3
A36	Ta (kips)	2.9	4.6	6.6	9.4	12.3	15.5	19.6	23.5	28.6	38.5	50.6	65.6	81.0	99.6	120.9
	Va (kips)	1.5	2.4	3.5	4.9	6.4	8.0	10.2	12.2	14.8	20.0	26.3	34.2	42.1	51.9	62.6
A307	Ta (kips)	2.6	4.1	6.0	8.3	10.9	13.7	17.4	20.9	25.4	34.2	45.0	58.5	72.0	88.7	107.5
	Va (kips)	1.3	2.1	3.1	4.3	5.7	7.1	9.1	10.8	13.2	17.8	23.4	30.4	37.4	46.1	55.8
A449	Ta (kips)	7.3	11.7	17.3	23.9	31.4	34.8	44.2	52.9	64.2	62.0	81.6	106.0	130.5	160.8	194.8
	Va (kips)	3.8	6.1	9.0	12.4	16.3	18.1	22.9	27.5	33.4	32.2	42.4	55.1	67.8	83.5	101.2
A325	Ta (kips)	7.3	11.7	17.3	23.9	31.4	34.8	44.2	52.9	64.2	-	-	-	-	-	-
	Va (kips)	3.8	6.1	9.0	12.4	16.3	18.1	22.9	27.5	33.4	-	-	-	-	-	-
A354 Gr. BC	Ta (kips)	8.7	13.9	20.5	28.3	37.2	46.8	59.4	71.1	86.5	116.5	153.3	199.3	245.3	274.5	322.4
	Va (kips)	4.5	7.2	10.6	14.7	19.3	24.3	30.9	36.9	44.9	60.5	79.6	103.5	127.4	142.6	172.7
A354 Gr. BD	Ta (kips)	10.4	16.5	24.4	33.6	44.3	55.8	70.9	84.8	103.1	138.9	182.8	237.7	292.5	316.9	386.2
	Va (kips)	5.0	7.9	11.7	16.2	21.2	26.8	34.0	40.7	49.4	66.6	87.7	114.0	140.3	165.7	200.6
A490	Ta (kips)	10.4	16.5	24.4	33.6	44.3	55.8	70.9	84.8	103.1	-	-	-	-	-	-
	Va (kips)	5.0	7.9	11.7	16.2	21.2	26.8	34.0	40.7	49.4	-	-	-	-	-	-
A540	Ta (kips)	-	-	-	-	-	-	-	-	-	-	-	182.8	225.0	277.3	335.8
fut=115 psi	Va (kips)	-	-	-	-	-	-	-	-	-	-	-	65.0	116.9	144.0	174.4
A540	Ta (kips)	8.4	13.3	19.7	27.3	35.8	45.1	57.2	68.5	83.3	112.2	147.7	192.0	236.3	291.2	352.6
fut=120 psi	Va (kips)	4.4	6.9	10.2	14.2	18.6	23.4	29.7	35.6	43.3	58.3	76.7	99.7	122.7	151.3	183.2
A540	Ta (kips)	9.6	15.3	22.5	31.2	40.9	51.5	65.4	78.3	95.2	128.3	168.8	219.4	270.0	332.8	403.0
fut=135 psi	Va (kips)	5.0	7.9	11.7	16.2	21.2	26.8	34.0	40.7	49.4	66.6	87.7	114.0	140.3	172.9	209.3
A540	Ta (kips)	10.3	16.4	24.2	33.5	43.9	55.3	70.3	84.1	102.2	137.8	181.3	235.6	290.0	357.4	432.8
fut=145 psi	Va (kips)	5.0	7.9	11.7	16.2	21.2	26.8	34.0	40.7	49.4	66.6	87.7	114.0	140.3	172.9	209.3
A540	Ta (kips)	11.0	17.5	25.9	35.8	47.0	59.1	75.1	89.9	109.3	147.3	193.8	251.9	310.0	382.1	462.7
fut=155 psi	Va (kips)	5.0	7.9	11.7	16.2	21.2	26.8	34.0	40.7	49.4	66.6	87.7	114.0	140.3	172.9	209.3
A540	Ta (kips)	11.7	18.6	27.6	38.1	50.0	62.9	79.9	95.7	116.3	156.8	206.3	268.1	330.0	406.7	492.5
fut=165 psi	Va (kips)	5.0	7.9	11.7	16.2	21.2	26.8	34.0	40.7	49.4	66.6	87.7	114.0	140.3	172.9	209.3

TABLE 5. MINIMUM REQUIREMENTS FOR EMBEDMENT AND SPACING FOR DUCTILE DESIGN
(c) f'c = 5,000 PSI

Steel Type	D (in.) =>	1/2	5/8	3/4	7/8	1	1-1/8	1-1/4	1-3/8	1-1/2	1-3/4	2	2-1/4	2-1/2	2-3/4	3
A36	Ed (in.)	3.4	4.3	5.2	6.2	7.0	7.9	8.9	9.8	10.8	12.4	14.3	16.3	18.1	20.1	22.2
	Sde (in.)	7.6	9.6	11.6	13.7	15.7	17.8	19.8	21.7	23.9	27.6	31.9	36.3	40.3	44.7	49.2
A307	Ed (in.)	3.5	4.4	5.3	6.3	7.2	8.1	9.1	10.0	11.0	12.8	14.8	16.7	18.5	20.6	22.7
	Sde (in.)	7.7	9.7	11.8	13.9	15.9	17.9	20.2	22.1	24.3	28.2	32.4	36.9	41.0	45.5	50.0
A449 or A325	Ed (in.)	5.0	6.4	7.8	9.1	10.5	10.9	12.3	13.5	14.9	15.9	18.2	20.6	23.1	25.6	28.2
	Sde (in.)	10.9	13.7	16.7	19.6	22.5	23.6	26.6	29.1	32.1	34.5	39.6	45.1	50.1	55.6	61.2
A354 Gr.BC	Ed (in.)	5.2	6.5	7.9	9.3	10.7	12.0	13.5	14.8	16.3	19.0	21.7	24.8	27.5	29.2	32.2
	Sde (in.)	11.1	14.0	17.0	20.0	23.0	25.8	29.0	31.8	35.0	40.8	46.6	53.2	59.0	62.8	69.1
A354 Gr.BD or A490	Ed (in.)	5.7	7.2	8.7	10.3	11.8	13.2	14.9	16.3	18.0	20.9	24.0	27.3	30.3	32.5	35.8
	Sde (in.)	12.2	15.4	18.7	21.9	25.1	28.2	31.8	34.8	38.3	44.5	51.1	58.2	64.6	69.3	76.2
A540 fut=115 psi	Ed (in.)	-	-	-	-	-	-	-	-	-	-	-	23.7	26.3	29.2	32.1
	Sde (in.)	-	-	-	-	-	-	-	-	-	-	-	51.0	56.6	62.8	69.1
A540 fut=120 psi	Ed (in.)	5.0	6.4	7.8	9.1	10.5	11.7	13.2	14.5	16.0	18.5	21.2	24.2	26.9	29.9	32.9
	Sde (in.)	10.9	13.7	16.7	19.6	22.5	25.2	28.4	31.1	34.3	39.8	45.7	52.1	57.8	64.2	70.6
A540 fut=135 psi	Ed (in.)	5.4	6.8	8.3	9.7	11.1	12.5	14.1	15.4	17.0	19.7	22.6	25.8	28.6	31.8	35.0
	Sde (in.)	11.5	14.6	17.7	20.8	23.9	26.8	30.2	33.0	36.4	42.2	48.5	55.2	61.3	68.0	74.9
A540 fut=145 psi	Ed (in.)	5.8	7.1	8.6	10.1	11.6	13.0	14.6	16.0	17.7	20.4	23.5	26.8	29.7	33.0	36.4
	Sde (in.)	12.0	15.1	18.4	21.6	24.7	27.7	31.3	34.2	37.7	43.8	50.2	57.2	63.5	70.5	77.6
A540 fut=155 psi	Ed (in.)	5.8	7.3	8.9	10.5	12.0	13.5	15.2	16.6	18.3	21.2	24.3	27.7	30.8	34.2	37.7
	Sde (in.)	12.4	15.6	19.0	22.3	25.6	28.7	32.3	35.4	39.0	45.3	51.9	59.2	65.7	72.9	80.2
A540 fut=165 psi	Ed (in.)	6.0	7.6	9.2	10.8	12.4	13.9	15.7	17.2	18.9	21.9	25.1	28.7	31.8	35.4	39.0
	Sde (in.)	12.8	16.1	19.6	23.0	26.4	29.6	33.3	36.5	40.2	46.7	53.6	61.1	67.7	75.2	82.7

NOTES:

TABLE 6. MINIMUM EDGE DISTANCES FOR TENSION AND SHEAR WITHOUT ADDITIONAL REINFORCEMENT FOR AN INDIVIDUAL BOLT
(c) f'c = 5,000 PSI

Steel type	(in.) =>	1/2	5/8	3/4	7/8	1	1-1/8	1-1/4	1-3/8	1-1/2	1-3/4	2	2-1/4	2-1/2	2-3/4	3
A36	m_c (in.)	1.7	2.1	2.5	3.0	3.4	3.8	4.3	4.7	5.2	6.0	6.9	7.9	8.8	9.7	10.7
	m_v (in.)	4.4	5.6	6.8	8.0	9.2	10.3	11.5	12.7	14.0	16.2	18.6	21.2	23.5	26.1	28.7
A307	m_c (in.)	1.7	2.1	2.6	3.0	3.5	3.9	4.4	4.8	5.3	6.1	7.0	8.0	8.9	9.9	10.9
	m_v (in.)	4.5	5.7	6.9	8.1	9.3	10.4	11.6	12.9	14.2	16.5	18.9	21.6	23.9	26.6	29.2
A449 or A325	m_c (in.)	2.4	3.0	3.6	4.3	4.9	5.1	5.8	6.3	7.0	7.5	8.6	9.8	10.9	12.1	13.3
	m_v (in.)	6.4	8.0	9.6	11.5	13.2	13.8	15.6	17.0	18.8	20.2	23.2	26.6	29.3	32.5	35.8
A354 Gr.BC	m_c (in.)	2.4	3.1	3.7	4.4	5.0	5.6	6.3	6.9	7.6	8.9	10.2	11.6	12.9	13.7	15.1
	m_v (in.)	6.5	8.2	10.0	11.7	13.4	15.1	17.0	18.9	20.5	23.8	27.3	31.1	34.5	36.6	40.4
A354 Gr.BD or A490	m_c (in.)	2.7	3.3	4.1	4.8	5.5	6.2	6.9	7.6	8.4	9.7	11.1	12.7	14.1	15.1	16.8
	m_v (in.)	7.1	9.0	10.9	12.9	14.7	16.5	18.6	20.4	22.5	26.1	29.9	34.1	37.8	40.6	44.6
A540 fut=115 psi	m_c (in.)	-	-	-	-	-	-	-	-	-	-	-	11.1	12.3	13.7	15.1
	m_v (in.)	-	-	-	-	-	-	-	-	-	-	-	29.8	33.1	36.8	40.4
A540 fut=120 psi	m_c (in.)	2.4	3.0	3.6	4.3	4.9	5.5	6.2	6.8	7.5	8.7	10.0	11.4	12.6	14.0	15.4
	m_v (in.)	6.4	8.0	9.6	11.5	13.2	14.8	16.6	18.2	20.1	23.3	26.7	30.5	33.8	37.5	41.3
A540 fut=135 psi	m_c (in.)	2.5	3.2	3.9	4.5	5.2	5.8	6.6	7.2	7.9	9.2	10.6	12.1	13.4	14.8	16.3
	m_v (in.)	6.8	8.5	10.4	12.2	14.0	15.7	17.7	19.3	21.3	24.7	28.4	32.3	35.9	39.8	43.8
A540 fut=145 psi	m_c (in.)	2.6	3.3	4.0	4.7	5.4	6.1	6.8	7.5	8.2	9.5	11.0	12.5	13.9	15.4	16.9
	m_v (in.)	7.0	8.8	10.7	12.6	14.5	16.2	18.3	20.0	22.1	25.6	29.4	33.5	37.2	41.3	45.4
A540 fut=155 psi	m_c (in.)	2.7	3.4	4.1	4.9	5.6	6.3	7.1	7.7	8.5	9.9	11.3	12.9	14.3	15.9	17.5
	m_v (in.)	7.2	9.1	11.1	13.1	15.0	16.8	18.9	20.7	22.8	26.5	30.4	34.6	38.4	42.7	47.0
A540 fut=165 psi	m_c (in.)	2.8	3.5	4.3	5.0	5.8	6.5	7.3	8.0	8.8	10.2	11.7	13.3	14.8	16.4	18.1
	m_v (in.)	7.5	9.4	11.5	13.5	15.4	17.3	19.5	21.4	23.5	27.3	31.4	35.7	39.7	44.0	48.5

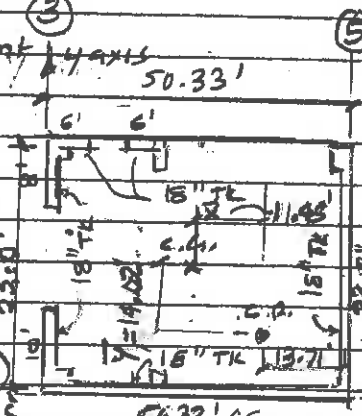
E2 Consulting Engineers, Inc. 1900 Powell Street, Suite 250 Emeryville, CA 94608	Designed By: K.D.	Date: 7/31/12
	Checked By:	Date:
	Revised By:	Date:
Project No. WW-PEG-2124-043062		Sheet No. 18

Project Description Lateral Analysis, Topock W.C. plant, Shear Walls

Lateral Analysis (Lower Building)

Assume portion bet'n ③ & ④ is built now - Referred to as current Bldg

N-S Dir. Distribute Shears



Diaph. @ 2nd Flr. is rigid diaph.

Assume C.G. at Floor in the center of floor in both directions

See charts for values of Δ_F

See attachments

Compute V_d and V_t (Torsional Shears)

R_x & R_y are stiffness in X & Y dir.'s

Wall line	Ht.	d (Length)	h/d	Δ_F	R	ΣR
3	14'	8	1.75	1.061	.943	
3	14'	10	1.40	0.694	1.44	
5	14'	34.5	.405	.128	7.81	
4	12.75	—	—	1.86	.54	10.733 (ΣR_y)
A	14	6	2.33	1.964	.509	
A	14	6	2.33	1.964	.509	
B	14	53.5	.262	.08	12.5	
						13.518 (ΣR_x)

Locate C.R. of Floor W.r.t. front wall & Left wall (line ③)

$$\bar{X} = \frac{7.81 \times 50.33}{10.733} = 36.62' \text{ (From Y axis)} \qquad e_x = 36.62 - \frac{50.34}{2} = 11.45'$$

$$\bar{Y} = \frac{2 \times .509 \times 33.0}{13.518} = 2.485' \text{ (From X axis)} \qquad e_y = \frac{33.0}{2} - 2.48 = 14.02'$$

Torsional Moments

$T_{NS} = V_3 \times e_x = 190 \times 11.45 = 2176^{IK}$ (pg. 13) $\qquad \frac{T_{NS}}{J} = \frac{2176}{5811} = .374$

$T_{EW} = 190 \times 14.02 = 2664^{IK}$ $\qquad \frac{T_{EW}}{J} = \frac{2664}{5811} = .453$

Torsional Shears

$$J = X_R^2 Y_R + Y_R^2 X_R = .509(30.5)^2 \times 2 + 12.5 \times (2.48)^2 + .942(36.62)^2 + 1.44(36.62)^2 + 7.81(13.71)^2 + .54(15.12)^2 = 5811$$

Wall ③ $V_{T3B} = .374 \times .942 \times 36.62 = 12.90^K$ $\quad V_{T3D} = .374 \times 1.44 \times 38.51 = 20.77^K$

Wall ⑤ $V_{T5} = .374 \times 7.81 \times 13.71 = 40.05^K$ $\quad V_{T4} = .374 \times .54 \times 15.12 = 3.05^K$

Wall Ⓐ $V_{TA} = .453 \times .509 \times 30.52 = 7.04^K$ $\quad V_{TB} = .453 \times 12.5 \times 2.48 = 14.07^K$

For Shears: N-S Dir $V_T = \frac{T_{NS}}{J} \times R_y \times X_R$ $\quad$ E-W Dir $V_T = \frac{T_{EW}}{J} \times R_x \times Y_R$ $\quad$ X_R & Y_R are distances from wall to C.R.

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Project Description Lateral Analysis, Shear Walls Topock W.C. plant

Lateral Analysis Shear Walls

For ΣR_x & ΣR_y & V_t see pg. 17

Wall direct Shears + Torsional Shear = V

Wall Line	Wall R_x OR R_y	$\frac{R_x}{\Sigma R_x}$ OR $\frac{R_y}{\Sigma R_y}$	V_d Direct Shear	V_t Tor. Shear From Pg. 17	$V = Q_E$	$V' = \frac{2.5 Q_E}{\ell}$	v ksi
(3)	.943	.0879	16.70	12.90	29.60	9.25	.071
	1.44	.134	25.46	20.77	46.23	11.56	.089
(5)	7.81	.728	138.32	40.05	178.37	12.93	.10
(4)	.54	.05	9.50	3.05	12.55	31.38	—
(A)	.509	.0376	7.15	7.04	14.19	5.90	.046
(B)	12.50	.925	175.25	14.07	189.82	9.42	.073

for shear & torsion $\Phi = .75$ ACI 9.3.2.3

$\lambda = 1.0$

ACI 11.9.5 Allow. shear $V_{all} = 2\lambda\sqrt{f_c'}\,hd$ $h_{wl} = .8\ell_w$

$= 2\times1\sqrt{5000}\times.8\ell$ $d = 18 - 2.5 = 15.5''$

$v = \frac{V_u}{\Phi} = \frac{2.5V/\ell}{.8\times.75\times12\times18} = 0.00772\,V'$ where V → kips, ℓ → ft

Allow. $v_c = 2\sqrt{5000} = 141.42^{psi} > v$ (Table above) OK

11.9.9.1 No shear reinforcement req'd.

R11.9.9 $\frac{h_w}{l_w} = \frac{14}{53} = .26 < .5$ provide vert. Reinf. equal to horiz. reinf.

Min. vert. reinf. $= .0025\times12\times18 = .54^{in^2}$

#6 @ 18" ea. face $A_{sa} = .44\times12\times2 = .587^{in^2/ft}$

Min horiz. reinf. $= .0025\times12\times18 = .54$

#6 @ 18" ea. face $A_{sa} = .587 > .54^{in^2}$ OK

Provide Reinf. based on overturning for short walls

DL on walls + Seismic as per Combination 5 & 7 page 13

Line (4) $M_o = 2.5\times12.9\times14 = 451.4^{k'}$ $M_R = .819(.225\times14\times\frac{6^2}{2}) = 56.7^{k'}$

$M_p - M_R = 451.4 - 56.7 = 394.8$ $P_c = \frac{451.4}{.8\times6} + 1.28(.225\times14\times6) = 106^{k}$

$P_{uplift} = (394.8)/.8\times6 = 82.25^{k}$

Line (3) $M_o = 2.5\times29.60\times14 = 1151.5^{k'}$ $M_R = .819(.225\times14\times\frac{8^2}{2}) = 82.6^{k'}$

$P_u = (1151.5 - 82.6)/8\times8 = 167.0^{k}$ $P_c = 196.1^{k}$

Double P_u & P_c for future loads

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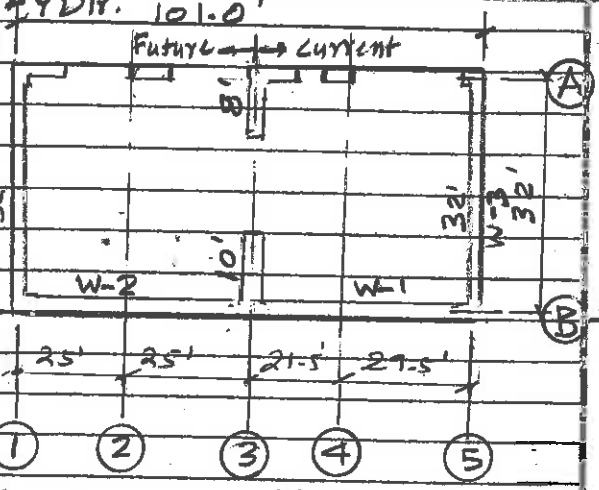
Project Description

Lateral Analysis (Lower Bldg. Assuming future part is Build new)

Assume 2nd flr. Diaph. is Rigid

Col. lines ② & ④ Are concrete Mom. frame for which stiffness obtained from Computer output (load comb. 2)

For simplicity (Due to symmetry) Assume torsional shears to be only 5% of direct shears



Calculations of Direct Shears + Torsional Shears

Total V = 2 x 190^k = 380^k

WALL	h/d	Δ_F	R_x OR R_y	ΣR	$\frac{R_x R_y}{\Sigma R_x \Sigma R_y}$	V_d Direct Sh	V_t Tor. Sh.	Total Shear
1	.424	.133	7.5		.406	154.28	7.72	162.0
2	.	1.86	.54		.0293	11.13	.56	11.69
3	1.75	1.061	.943		.052	19.76	.99	20.75
3	1.40	.694	1.44		.078	29.64	1.48	31.12
4	.	1.86	.54		.0293	11.13	.56	11.69
5	.424	.133	7.5	18.46	.406	154.28	7.72	162.0
A	2.33	1.964	.509		.02	7.6	.40	8.0
A	2.33	1.964	.509		.02	7.6	.40	8.0
A	2.33	1.964	.509		.02	7.6	.40	8.0
A	2.33	1.964	.509		.02	7.6	.40	8.0
B	.138	0.041	23.6	25.636	.92	349.6	17.48	367.10

Shears above as calculated are less than shown on page 18 (Assuming half of the building done in future)

All shear & reinforcement calc's on pages 19 & 20 remain conservative - Hence OK

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Project Description Lateral Analysis, Shear Wall Columns Topock W.C. plant

Line (A) Pilasters

Try pilaster 18 x 24" GS conc. wall

Line (A) See pg. 18 for forces

$\phi P_n = .55\phi f'_c A_g \left[1 - \left(\frac{k\ell_c}{32h}\right)^2\right]$ $\ell_c = 14'$ $K = 2$

$= .55 \times .7 \times 5 \times 18 \times 24 \left[1 - \left(\frac{2 \times 14 \times 12}{32 \times 18}\right)^2\right]$ $h = 18"$ $A_g = 18" \times 24"$

$= .55 \times .7 \times 5 \times 18 \times 24 \left[1 - .34\right]$

$= 548.62^k > 71.06^k$

USE 2-#6 @ 12" vert. in the wall

6-#6 Ten. cap. $= .90 \times 6 \times .44 \times 60 = 142.6^k > 82.25^k$

Line (3) See pg 18 USE 18" x 24" Pilaster w/ 6-#6 for all 6'-0" sections of wall

Try 18" x 36" Pilaster

$\phi P_n = .55 \times .7 \times 5 \times 18 \times 36 \left[1 - \left(\frac{2 \times 14 \times 12}{32 \times 18}\right)^2\right]$

$= 1247.40 \left[1 - .34\right]$

$= 823.3^k > 196.1^k$

6-#9 bars 3-#3 @ 12" o/c

Ten. Cap. $= .9 \times .6 \times 10.0 \times 60 = 324^k > 167^k$

USE 18" x 36" pilaster w/ 6-#9 Bars

Long Walls

Line (5) See pg 11

$M_o = 2.5 \times 178.37 \times 14 = 6243^{lk}$ $M_{r2} = .819\left(.225 \times 14 \times \frac{17^2}{2}\right) = 372.8^{lk}$

$P_u = \frac{6243 - 342.8}{.8 \times 34.5 \text{ (1.25 D) for pilaster (18 x 48)}} = 213.8^k$

$P_c = 226.2 + 16.30 = 242.5^k$

provide 18" x 48" pilasters @ ends w/ 2-#7 @ 12" o/c

Ten. Cap. $= .9 \times 2 \times .60 \times 60 = 259.2 > 213.8^k$ ok

$\phi P_n = .55 \times .7 \times 5 \times 18 \times 48 \left[1 - \frac{2 \times 14 \times 12}{32 \times 18}\right] = 1098^k > 242.5^k$

(See pg. 11) Other Reinf.

2-#6 @ 12" vert reinf. 2-#6 @ 15" horiz. bars

(@ 18 x 36" pilasters) 2 #6 @ 15" vert. bars

Line (B) See page 10 for Basement wall calc's

(See pg. 10) 6 #9 Bars in pilaster 18" x 36" Vert. Reinf. - Ret #9 @ 12" (E.F.)

7 # @ 15" Horiz Reinf ea. face (E.F.) #9 @ 18" (E.F.)

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Project Description: Topock Concrete Mom. frame line 4

Lateral Analysis Cont'd

Mom. Frame Line-4 (Also See pg. 16)

Determine Stiffness (Assume Support pinned)

P = 100^k 50^k @ N2 & 50^k N3

Max Defl @ Top of the frame = 1.86" = Δ

Stiffness R = 1/Δ = 1/1.86 = .54

See pgs 18 & 19 for direct & torsion shears

Line (4) Apply Total Load = $V_j + V_7$ = 9.5 + 3.05 = 12.55 Say 12.6^k

Also Apply load from Steel mom. frame above (Load comb. 6) Stl. frame

~~See Load combination 1 (Conc frame for values)~~

Total Deflection of Conc. frame Comb. 3 = .833" (DL + Total Less)

δe = 2.4 x δ = 2.4 x 0.833 = 2.0" < .015 x 12.75 x 12 = 2.295"

Design Reinf. in Frame members.

From Computer output — USE 8-#10 Top & Bot

Conc Bm. 6-#10 @ Top 6-#10 @ Bot

w/ 32-#4 @ 3" S1 = 3" @ from ea. suppt.

16-#4 @ 6" S2 = 6" Rest middle portion.

Max tot. Bm. Deflection = (1.586") (1.6) = 1.18" = ℓ/326 < ℓ/240 OK

(Stiff. Less factor)

Mom. frame Col. line (4)

See computer output (pg. 5)

Beam Size 30"x30" : Reinf. Top 6-#10 Reinf. bot 6-#10 Comment: USE 8-#10 @ T. & B

Shear Reinf.: #4 Rebar S1 = 3" S2 = 11"

Col. Size 30"x30" Vert Reinf. 12-#10 Ties: S1 = #5 @ 6" S2 = #5 @ 12"

Wall	Vert. Reinf.	Horiz. Reinf.	Size	PILASTER REINF	Comment
A	2-#6 @ 12"	2-#6 @ 12"	18"x24"	6-#6	18" TK Walls
B	#9 @ 12" Soil Side ~~#7 @ 18" Inside~~	2-#7 @ 15"	18"x36"	6-#9	18" TK. Retaining Wall
3	2-#7 @ 12"	2-#6 @ 12"	18"x36"	6-#9	
1 & 5	2-#7 @ 12"	2-#6 @ 12"	18"x48"	8-#7	

Mom. Frame Reinf.	Line	Beam			Beam Shear		COLUMN		COL TIES	
	(2) & (4)	Size	Reinf. @ Top	Reinf. @ BOT	S1	S2	Size	Vert. Reinf	S1	S2
		30"x30"	8-#10	8-#10	#4@3"	#4@11"	30"x30"	12-#10	#5@6"	#5@12"

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Project Description Topock W.C. plant, Foundation Design

Footings (Concrete Frame columns)

Max P_u = 243.5^k Say 250^k $P = \frac{250}{1.6} = 156.2^k$

Allow. Soil press = 4 KSF $A_f = \frac{156.2}{4} = 39.06\ ft^2$

Size Reqd = $\sqrt{39.06} = 6.25$ ft.

Try 6'-6" SQ. Ftg. Conc. Col. Size - 2.5 SQ.

WT. OF FTG. = 6.5 x 6.5 x 2 x .15 = 12.7^k

$P = \frac{(156.3+12.7)}{6.5 \times 6.5} = 4^{KSF}$ OK

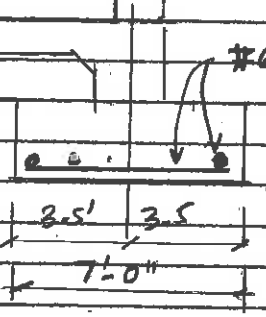
7'-0" SQ. FTG. Preferred.

$M_u = \frac{4 \times 1.6 \times 1.75^2}{2} = 9.8^{IK}$

Try #6 @ 12" o/c $d = 24 - 3.5 = 21.5"$

$\phi M_n = .9 \times .44 \times 60 \left(21.5 - \frac{.44 \times 60}{5 \times 12 \times 2}\right)$

$= 42^{IK} > 9.8^{IK}$ OK



Check Shear

$v = \frac{4 \times 1.6 \times 1.75 \times 10^3}{12 \times 21.5 \times .85} = 51^{PSI} < 2\sqrt{5000} = 141.4^{PSI}$

Punching Shear @ dist. d/2 $= \frac{250000}{4 \times 21.5 \times 21.5 \times .85} = 159.1^{PSI} < 4 \times \sqrt{5000}$ OK

USE 7'-0" SQ. FTG. W/ #6 @ 12" Ea Way

Footings (Shear Walls Lines ①, ⑤) COL. LINE A (Current)

Max Comp'n @ pilasters = 242.5^k (pg. 19) 18"x48" pilaster

Try 5' Wide x 8' Long FTG.

$P = \frac{(242.5)/1.4}{5 \times 8} = 4.33^{KSF} < 4 \times 1.33 = 5.32$

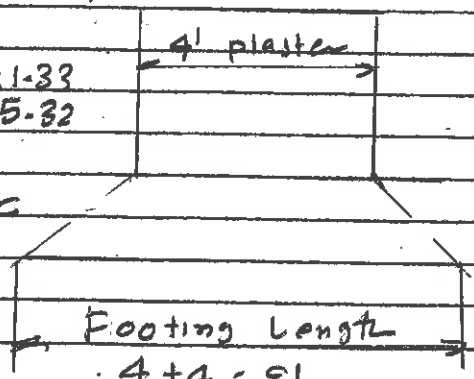
$M_u = 4.33 \times 1.4 \times \left(\frac{5 - 1.5}{2}\right)^2 \times \frac{1}{2}$

$= 18.56^{IK}$ #6 @ 12" o/c

$\phi M_n = 42^{IK} > 18.56^{IK}$ OK

(See Ftg. Calc.'s above

USE 5' W Continuous Ftg W/ #6 @ 12" Ea. Way



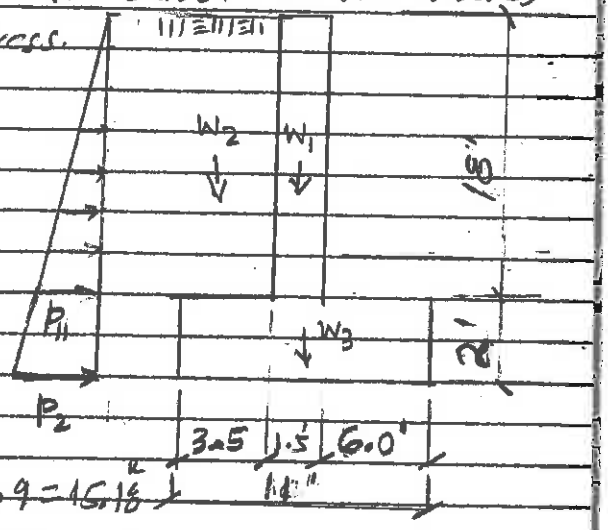
Line ③ USE Same Ftg as Line ① & ⑤ OK

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Project Description Topock W-C- plant Fdn. Design

Footings (Shear Wall line A)
Assume Cantilever Ret. wall for future building
Max. P_c @ pilaster = 106^k (18"x24" pilaster)
Try 3'-6" wide x 6'-0" long FTG.
$p = \frac{(106)/1.4}{3.5 \times 6.0} = 3.6^{KSF} < 4.0^{KSF}$
#6@12" Ea. Way @ bottom of F'tg.

Footing (Col. line A) Retaining Wall OTM Design
Level Backfill
NO Surcharge (No Trucks)
Design for 60 pcf. lateral press.
Conc. $f_c' = 5^{KSI}$ $f_y = 60^{KSI}$
$p_1 = 60 \times 18 = 1080^{PSF}$
$p_2' = 60 \times 20 = 1200^{PSF}$
For stem Design see pg.



Stability
$W_1 = 18 \times 1.5 \times .15 = 4.05^k$
$W_2 = 18 \times 3.5 \times .11 = 6.93$
$W_3 = 11 \times 2.0 \times .15 = 3.3$
$\Sigma W = 14.28^k + .9 = 15.18^k$

$M_O = 1.08 \times \frac{18}{2}\left(\frac{18}{3}+2\right) = 77.76^{IK}$

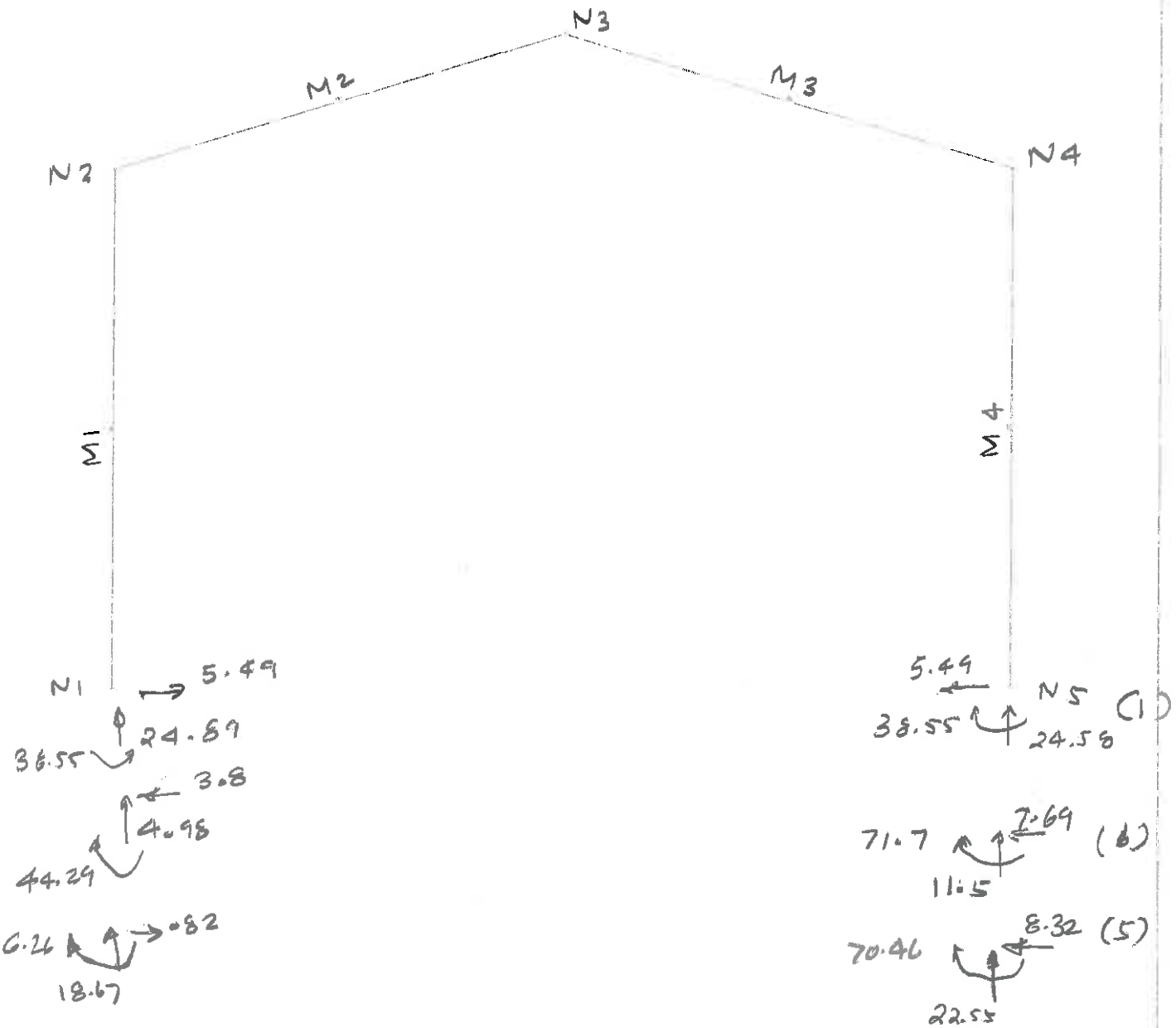
$M_R = W_1\left(\frac{1.5}{2}+6\right) + W_2\left(11 - \frac{3.5}{2}\right) + W_3\left(\frac{11}{2}\right) + .15 \times 6 \times 3$ (Ftg slab)
$= 4.05 \times 6.75 + 6.93 \times 9.25 + 3.3 \times 5.5 + .15 \times 18 = 116.3^{IK}$

$F.S = M_R / M_O = \frac{116.3}{77.76} = 1.5$ ok

Soil press
$\bar{X} = \frac{RM - OTM}{\Sigma W} = \frac{116.3 - 77.76}{15.18} = 2.54'$ $3\bar{X} = 7.616'$
$p = \frac{2 \times \Sigma W}{3 \times \bar{X} \times b} = \frac{2 \times 15.18}{7.616 \times 1} = 3.99^{KSF} < 4 \times 1.33 = 5.33^{KSF}$

USE 18" Tk Wall with 4' Tk x 10'-0" L FTG. for future wall
USE 18" Tk Wall with 2' Tk x 9'-0" L FTG for current wall
All rebars #6 @ 12" @ T & B of FTG.

For load comb. See pg. 2 of this Output



e-2	Steel	SK - 1
kd	topock water conditioning structure mom.frame	July 27, 2012 at 9:23 AM
ww-peg-2174-043062		topockgwr.momfr.r2d

Company : e-2
Designer : kd
Job Number : ww-peg-2174-043062 topock water conditioning structure mom.frame

July 30, 2012
8:35 AM
Checked By:_____

Joint Loads and Enforced Displacements (BLC 3 : gl-seismic)

	Joint Label	L,D,M	Direction	Magnitude[(k,k-ft), (in,rad), (k*s^...
1	N2	L	X	2.5
2	N4	L	X	2.5

Joint Loads and Enforced Displacements (BLC 4 : P wind)

	Joint Label	L,D,M	Direction	Magnitude[(k,k-ft), (in,rad), (k*s^...
1	N2	L	X	5
2	N4	L	X	5

Joint Loads and Enforced Displacements (BLC 5 : P crane)

	Joint Label	L,D,M	Direction	Magnitude[(k,k-ft), (in,rad), (k*s^...
1	N2	L	X	.5
2	N4	L	X	.5

Joint Loads and Enforced Displacements (BLC 6 : M crane)

	Joint Label	L,D,M	Direction	Magnitude[(k,k-ft), (in,rad), (k*s^...
1	N2	L	M	-6.75

Basic Load Cases

	BLC Description	Category	X Gravity	Y Gravity	Joint	Point	Distributed
1	d	None					2
2	l	None					2
3	gl-seismic	None			2		
4	P wind	None			2		
5	P crane	None			2		
6	M crane	None			1		

Member Primary Data

	Label	I Joint	J Joint	Rotate(deg)	Section/Shape	Type	Design List	Material	Design Rules
1	M1	N1	N2		W10X45	Column	Wide Flange	A572 Gr.50	Typical
2	M2	N2	N3		W18X60	Beam	Wide Flange	A572 Gr.50	Typical
3	M3	N3	N4		W18X60	Beam	Wide Flange	A572 Gr.50	Typical
4	M4	N4	N5		W10X45	Column	Wide Flange	A572 Gr.50	Typical

Joint Boundary Conditions

	Joint Label	X [k/in]	Y [k/in]	Rotation[k-ft/rad]	Footing
1	N1	Reaction	Reaction	Reaction	
2	N5	Reaction	Reaction	Reaction	

Hot Rolled Steel Section Sets

	Label	Shape	Type	Design List	Material	Design Rules	A [in2]	I (90,270) [i...	I (0,180) [in4]
1	HR1A	W10X45	Column	Wide Flange	A572 Gr.50	Typical	13.3	53.4	248
2	HR2	W18X60	Beam	Wide Flange	A572 Gr.50	Typical	17.6	50.1	984

Member AISC 13th(360-05): ASD Steel Code Checks

	LC	Member	Shape	UC Max	Loc[ft]	Shear UC	Loc[ft]	Pnc/om [k]	Pnt/om [k]	Mn/om [...	Cb	Eqn
1	1	M1	W10X45	.543	18.5	.078	0	162.302	398.204	136.976	2.194	H1-1b
2	1	M2	W18X60	.379	15.312	.148	0	187.409	526.946	301.27	1.484	H1-1b
3	1	M3	W18X60	.379	1.392	.146	16.53	187.409	526.946	301.318	1.484	H1-1b

Member AISC 13th(360-05): ASD Steel Code Checks (Continued)

	LC	Member	Shape	UC Max	Loc[ft]	Shear UC	Loc[ft]	Pnc/om [k]	Pnt/om [k]	Mn/om [...	Cb	Eqn
4	1	M4	W10X45	.542	0	.078	0	162.302	398.204	136.976	2.194	H1-1b
5	2	M1	W10X45	.304	0	.048	0	162.302	398.204	136.976	2.191	H1-1b
6	2	M2	W18X60	.234	9.918	.034	0	187.409	526.946	215.148	1.059	H1-1b
7	2	M3	W18X60	.236	16.704	.069	16.53	187.409	526.946	306.886	2.501	H1-1b
8	2	M4	W10X45	.533	0	.103	0	162.302	398.204	136.976	2.267	H1-1b
9	3	M1	W10X45	.337	0	.061	0	162.302	398.204	136.976	2.221	H1-1b
10	3	M2	W18X60	.175	4.872	.020	16.53	187.409	526.946	215.852	1.063	H1-1b
11	3	M3	W18X60	.193	16.704	.044	16.53	187.409	526.946	306.886	2.408	H1-1b
12	3	M4	W10X45	.456	18.5	.089	0	162.302	398.204	136.976	2.264	H1-1b
13	4	M1	W10X45	.201	0	.028	0	162.302	398.204	136.976	2.166	H1-1b
14	4	M2	W18X60	.196	11.31	.036	0	187.409	526.946	223.128	1.099	H1-1b
15	4	M3	W18X60	.188	16.704	.061	16.53	187.409	526.946	306.886	2.237	H1-1b
16	4	M4	W10X45	.424	0	.080	0	162.302	398.204	136.976	2.26	H1-1b
17	5	M1	W10X45	.204	18.5	.011	0	162.302	398.204	136.976	1.38	H1-1b
18	5	M2	W18X60	.385	13.746	.110	0	187.409	526.946	255.808	1.26	H1-1b
19	5	M3	W18X60	.311	16.704	.135	16.53	187.409	526.946	306.886	1.696	H1-1b
20	5	M4	W10X45	.700	0	.120	0	162.302	398.204	136.976	2.235	H1-1b
21	6	M1	W10X45	.339	0	.054	0	162.302	398.204	136.976	2.194	H1-1b
22	6	M2	W18X60	.253	8.7	.028	0	187.409	526.946	211.352	1.041	H1-1b
23	6	M3	W18X60	.250	16.704	.069	16.53	187.409	526.946	306.886	2.592	H1-1b
24	6	M4	W10X45	.565	0	.110	0	162.302	398.204	136.976	2.27	H1-1b

Joint Coordinates and Temperatures

	Label	X [ft]	Y [ft]	Temp [F]
1	N1	0	0	0
2	N2	0	18.5	0
3	N3	16	23.3	0
4	N4	32	18.5	0
5	N5	32	0	0

Hot Rolled Steel Properties

	Label	E [ksi]	G [ksi]	Nu	Therm (\1E5 F)	Density[k/ft^3]	Yield[ksi]
1	A36 Gr.36	29000	11154	.3	.65	.49	36
2	A572 Gr.50	29000	11154	.3	.65	.49	50
3	A992	29000	11154	.3	.65	.49	50
4	A500 Gr.42	29000	11154	.3	.65	.49	42
5	A500 Gr.46	29000	11154	.3	.65	.49	46

Load Combinations

	Description	Solve	PDe	SR	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor
1	d+l	Yes	Y		1	1	2	1												
2	d+ql	Yes	Y		1	1.057	3	2.1												
3	d1+ql	Yes	Y		1	.543	3	2.1												
4	d+Pw	Yes	Y		1	1	4	.75												
5	d+.75l+.75Pw	Yes	Y		1	1	2	.75	4	.75										
6	d+Pc+ql	Yes	Y		1	1	3	2.1	5	1	6	1								

Joint Reactions (By Combination)

	LC	Joint Label	X [k]	Y [k]	MZ [k-ft]
1	1	N1	5.493	24.894	-38.549
2	1	N5	-5.493	24.576	38.542
3	1	Totals:	0	49.47	

Company : e-2
Designer : kd
Job Number : ww-peg-2174-043062 topock water conditioning structure mom.frame

July 30, 2012
8:35 AM
Checked By:____

Joint Reactions (By Combination) (Continued)

	LC	Joint Label	X [k]	Y [k]	MZ [k-ft]
4	1	COG (ft)	X: 15.897	Y: 20.9	
5	2	N1	-3.33	5.921	39.204
6	2	N5	-7.17	11.509	66.308
7	2	Totals:	-10.5	17.43	
8	2	COG (ft)	X: 15.897	Y: 20.9	
9	3	N1	-4.272	1.673	45.461
10	3	N5	-6.228	7.281	59.387
11	3	Totals:	-10.5	8.954	
12	3	COG (ft)	X: 15.897	Y: 20.9	
13	4	N1	-1.925	6.264	24.844
14	4	N5	-5.575	10.226	50.469
15	4	Totals:	-7.5	16.49	
16	4	COG (ft)	X: 15.897	Y: 20.9	
17	5	N1	.82	18.674	6.261
18	5	N5	-8.32	22.551	70.464
19	5	Totals:	-7.5	41.225	
20	5	COG (ft)	X: 15.897	Y: 20.9	
21	6	N1	-3.808	4.983	44.291
22	6	N5	-7.692	11.507	71.697
23	6	Totals:	-11.5	16.49	
24	6	COG (ft)	X: 15.897	Y: 20.9	

Load Combination Design

	Description	ASIF	CD	ABIF	Service	Hot Rolled	Cold Form...	Wood	Concrete	Masonry	Footings	Aluminum
1	d+l					Yes	Yes	Yes	Yes	Yes	Yes	Yes
2	d+ql					Yes	Yes	Yes	Yes	Yes	Yes	Yes
3	d1+ql					Yes	Yes	Yes	Yes	Yes	Yes	Yes
4	d+Pw					Yes	Yes	Yes	Yes	Yes	Yes	Yes
5	d+.75l+.75Pw					Yes	Yes	Yes	Yes	Yes	Yes	Yes
6	d+Pc+ql					Yes	Yes	Yes	Yes	Yes	Yes	Yes

Joint Deflections (By Combination)

	LC	Joint Label	X [in]	Y [in]	Rotation [rad]
1	1	N1	0	0	0
2	1	N2	-.261	-.018	-5.875e-3
3	1	N3	0	-.899	2.512e-7
4	1	N4	.261	-.018	5.876e-3
5	1	N5	0	0	0
6	2	N1	0	0	0
7	2	N2	.968	-.004	-3.715e-3
8	2	N3	1.061	-.316	7.555e-4
9	2	N4	1.151	-.008	4.172e-4
10	2	N5	0	0	0
11	3	N1	0	0	0
12	3	N2	1.006	-.001	-2.7e-3
13	3	N3	1.054	-.162	7.507e-4
14	3	N4	1.1	-.005	-5.769e-4
15	3	N5	0	0	0
16	4	N1	0	0	0
17	4	N2	.67	-.005	-3.13e-3
18	4	N3	.757	-.299	5.393e-4
19	4	N4	.843	-.007	7.766e-4
20	4	N5	0	0	0
21	5	N1	0	0	0
22	5	N2	.553	-.013	-6.092e-3

Joint Deflections (By Combination) (Continued)

	LC	Joint Label	X [in]	Y [in]	Rotation [rad]
23	5	N3	.771	-.749	5.495e-4
24	5	N4	988	-.016	3.695e-3
25	5	N5	0	0	0
26	6	N1	0	0	0
27	6	N2	1.082	-.004	-4.031e-3
28	6	N3	1.174	-.313	8.788e-4
29	6	N4	1.263	-.008	1.955e-4
30	6	N5	0	0	0

Member Section Forces

	LC	Member Label	Sec	Axial[k]	Shear[k]	Moment[k-ft]
1	1	M1	1	24.894	-5.539	-38.549
2			2	24.894	-5.539	-12.93
3			3	24.894	-5.539	12.69
4			4	24.894	-5.539	38.309
5			5	24.894	-5.539	63.928
6	1	M2	1	12.414	22.33	63.928
7			2	10.614	16.33	-16.798
8			3	8.814	10.33	-72.468
9			4	7.014	4.33	-103.08
10			5	5.306	-1.361	-108.67
11	1	M3	1	5.215	1.666	-108.67
12			2	7.015	-4.334	-103.098
13			3	8.815	-10.334	-72.47
14			4	10.615	-16.334	-16.785
15			5	12.323	-22.026	63.924
16	1	M4	1	24.576	5.539	63.924
17			2	24.576	5.539	38.308
18			3	24.576	5.539	12.691
19			4	24.576	5.539	-12.925
20			5	24.576	5.539	-38.542
21	2	M1	1	5.921	3.371	39.204
22			2	5.921	3.371	23.614
23			3	5.921	3.371	8.023
24			4	5.921	3.371	-7.568
25			5	5.921	3.371	-23.159
26	2	M2	1	3.541	5.125	-23.159
27			2	2.906	3.011	-40.148
28			3	2.272	.897	-48.31
29			4	1.638	-1.217	-47.643
30			5	1.036	-3.222	-38.159
31	2	M3	1	2.642	-2.134	-38.159
32			2	3.276	-4.248	-24.832
33			3	3.911	-6.362	-2.676
34			4	4.545	-8.476	28.309
35			5	5.146	-10.482	68.11
36	2	M4	1	11.509	7.266	68.11
37			2	11.509	7.266	34.506
38			3	11.509	7.266	.901
39			4	11.509	7.266	-32.703
40			5	11.509	7.266	-66.308
41	3	M1	1	1.673	4.284	45.461
42			2	1.673	4.284	25.646
43			3	1.673	4.284	5.831
44			4	1.673	4.284	-13.984
45			5	1.673	4.284	-33.799

Member Section Forces (Continued)

	LC	Member Label	Sec	Axial[k]	Shear[k]	Moment[k-ft]
46	3	M2	1	1.417	1.322	-33.799
47			2	1.091	.236	-37.053
48			3	.766	-.85	-35.771
49			4	.44	-1.936	-29.955
50			5	.131	-2.966	-19.609
51	3	M3	1	1.742	-2.408	-19.609
52			2	2.068	-3.494	-7.284
53			3	2.394	-4.58	9.576
54			4	2.72	-5.666	30.971
55			5	3.029	-6.696	56.895
56	3	M4	1	7.281	6.286	56.895
57			2	7.281	6.286	27.825
58			3	7.281	6.286	-1.246
59			4	7.281	6.286	-30.317
60			5	7.281	6.286	-59.387
61	4	M1	1	6.264	1.955	24.844
62			2	6.264	1.955	15.802
63			3	6.264	1.955	6.761
64			4	6.264	1.955	-2.281
65			5	6.264	1.955	-11.322
66	4	M2	1	3.548	5.481	-11.322
67			2	2.948	3.481	-30.034
68			3	2.348	1.481	-40.394
69			4	1.748	-.519	-42.401
70			5	1.179	-2.417	-36.067
71	4	M3	1	2.318	-1.382	-36.067
72			2	2.918	-3.382	-26.12
73			3	3.518	-5.382	-7.821
74			4	4.118	-7.382	18.831
75			5	4.687	-9.279	53.824
76	4	M4	1	10.226	5.637	53.824
77			2	10.226	5.637	27.75
78			3	10.226	5.637	1.677
79			4	10.226	5.637	-24.396
80			5	10.226	5.637	-50.469
81	5	M1	1	18.674	-.746	6.261
82			2	18.674	-.746	9.709
83			3	18.674	-.746	13.158
84			4	18.674	-.746	16.607
85			5	18.674	-.746	20.056
86	5	M2	1	9.743	16.615	20.056
87			2	8.243	11.615	-38.89
88			3	6.743	6.615	-76.956
89			4	5.243	1.615	-94.141
90			5	3.82	-3.128	-90.472
91	5	M3	1	4.934	-.591	-90.472
92			2	6.434	-5.591	-77.562
93			3	7.934	-10.591	-43.771
94			4	9.434	-15.591	10.9
95			5	10.857	-20.335	86.425
96	5	M4	1	22.551	8.48	86.425
97			2	22.551	8.48	47.202
98			3	22.551	8.48	7.98
99			4	22.551	8.48	-31.242
100			5	22.551	8.48	-70.464
101	6	M1	1	4.983	3.847	44.291
102			2	4.983	3.847	26.499

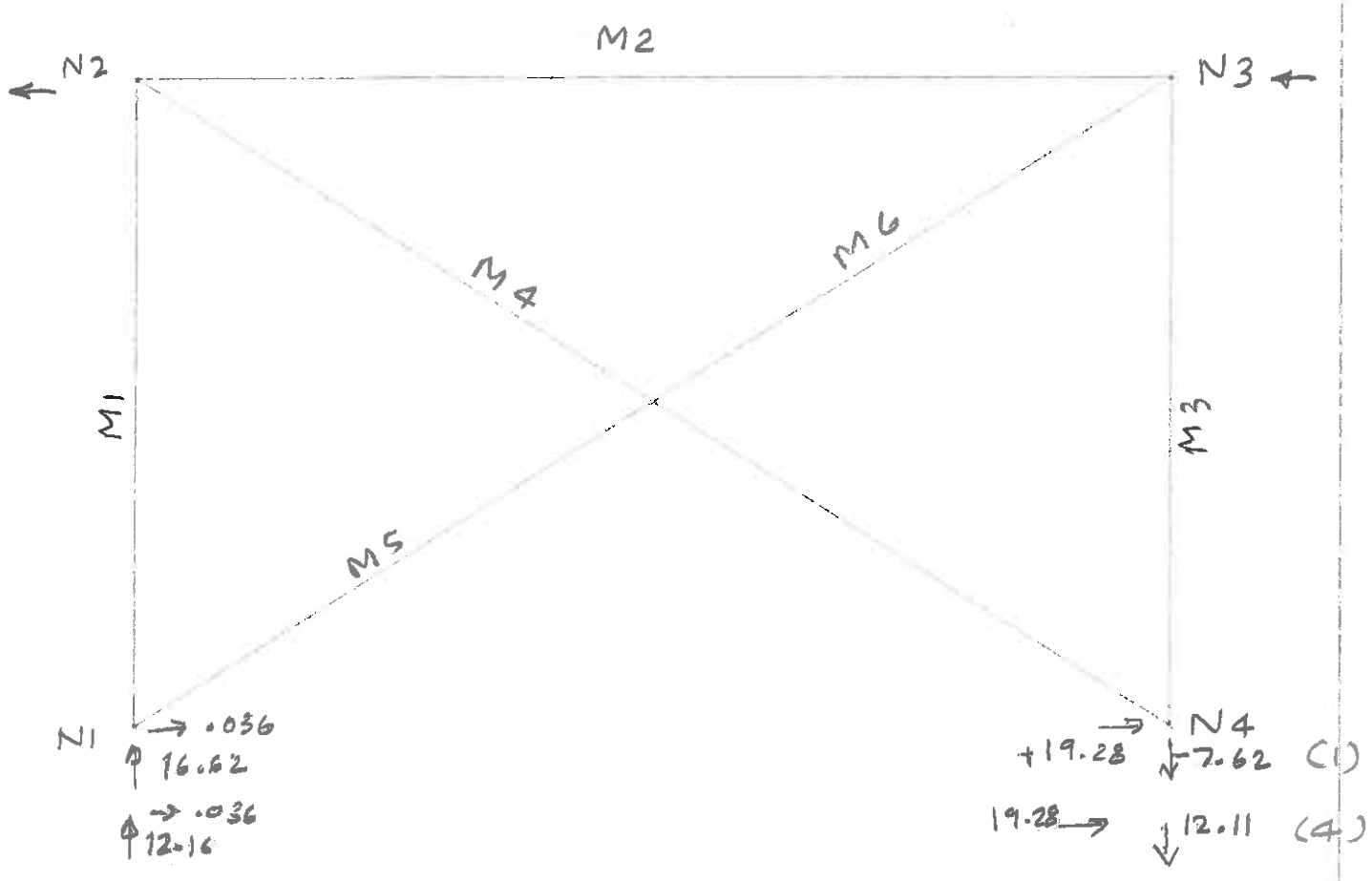
Member Section Forces (Continued)

	LC	Member Label	Sec	Axial[k]	Shear[k]	Moment[k-ft]
103			3	4.983	3.847	8.707
104			4	4.983	3.847	-9.085
105			5	4.983	3.847	-26.877
106	6	M2	1	3.292	4.22	-33.627
107			2	2.692	2.22	-47.074
108			3	2.092	22	-52.168
109			4	1.492	-1.78	-48.91
110			5	.923	-3.677	-37.311
111	6	M3	1	2.797	-2.577	-37.311
112			2	3.397	-4.577	-22.374
113			3	3.997	-6.577	.916
114			4	4.597	-8.577	32.558
115			5	5.167	-10.474	72.542
116	6	M4	1	11.507	7.797	72.542
117			2	11.507	7.797	36.482
118			3	11.507	7.797	.422
119			4	11.507	7.797	-35.637
120			5	11.507	7.797	-71.697

Material Takeoff

	Material	Size	Pieces	Length[ft]	Weight[K]
1	Hot Rolled Steel				
2	A572 Gr.50	W10X45	2	37	1.7
3	A572 Gr.50	W18X60	2	33.4	2
4	Total HR Steel		4	70.4	3.7

Col line (B) - Braced Frame



E2	Frame B Frame A topock wcs braced frame	SK - 1
kd		July 27, 2012 at 9:14 AM
ww-peg-2174-043062		topockwcp. braced frame A.r2d

Joint Coordinates and Temperatures

	Label	X [ft]	Y [ft]	Temp [F]
1	N1	0	0	0
2	N2	0	18.5	0
3	N3	29.5	18.5	0
4	N4	29.5	0	0
5	N5	14.75	9.25	0

Member Primary Data

	Label	I Joint	J Joint	Rotate(deg)	Section/Shape	Type	Design List	Material	Design Rules
1	M1	N1	N2		W10X45	Column	Wide Flange	A572 Gr.50	Default
2	M2	N2	N3		w12x40	Beam	Wide Flange	A572 Gr.50	Default
3	M3	N3	N4		W10X45	Column	Wide Flange	A572 Gr.50	Default
4	M4	N4	N2		w6x15	VBrace	Wide Flange	A572 Gr.50	Default
5	M5	N1	N5		w6x15	VBrace	Wide Flange	A572 Gr.50	Default
6	M6	N5	N3		w6x15	VBrace	Wide Flange	A572 Gr.50	Default

Joint Loads and Enforced Displacements (BLC 1 : d)

	Joint Label	L,D,M	Direction	Magnitude[(k,k-ft), (in,rad), (k*s^...
1	N2	L	Y	-5
2	N3	L	Y	-8

Joint Loads and Enforced Displacements (BLC 2 : Pcr)

	Joint Label	L,D,M	Direction	Magnitude[(k,k-ft), (in,rad), (k*s^...
1	N2	L	Y	-5
2	N3	L	Y	-5

Joint Loads and Enforced Displacements (BLC 3 : gl)

	Joint Label	L,D,M	Direction	Magnitude[(k,k-ft), (in,rad), (k*s^...
1	N2	L	X	-3.5
2	N3	L	X	-3.5

Joint Loads and Enforced Displacements (BLC 4 : Pw)

	Joint Label	L,D,M	Direction	Magnitude[(k,k-ft), (in,rad), (k*s^...
1	N2	L	X	-4
2	N3	L	X	-4

Hot Rolled Steel Section Sets

	Label	Shape	Type	Design List	Material	Design Rules	A [in2]	I (90,270) [i...	I (0,180) [in4]
1	HR1A	w12x40	Beam	Wide Flange	A572 Gr.50	Default	11.7	44.1	307
2	HR2	W10X45	Column	Wide Flange	A572 Gr.50	Default	13.3	53.4	248
3	HR3	w6x15	VBrace	Wide Flange	A572 Gr.50	Default	4.43	9.32	29.1

Basic Load Cases

	BLC Description	Category	X Gravity	Y Gravity	Joint	Point	Distributed
1	d	None			2		
2	Pcr	None			2		
3	gl	None			2		
4	Pw	None			2		

Load Combinations

	Description	Solve	PDe...	SR...	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor
1	d+Pcr+gl	Yes	Y		DL	1.057	2	.9	3	2.1												
2	d+Pcr+gl	Yes	Y		DL	.543	2	.9	3	2.1												
3	d+PwPcr	Yes	Y		DL	1	2	.9	4	.75												
4	d+gl	Yes	Y		DL	.543	3	2.1														
5	d+Pw	Yes	Y		DL	1	4	.75														

Joint Boundary Conditions

	Joint Label	X [k/in]	Y [k/in]	Rotation[k-ft/rad]	Footing
1	N1	Reaction	Reaction		
2	N4	Reaction	Reaction		

Hot Rolled Steel Properties

	Label	E [ksi]	G [ksi]	Nu	Therm (\1E5 F)	Density[k/ft^3]	Yield[ksi]
1	A36 Gr.36	29000	11154	.3	.65	.49	36
2	A572 Gr.50	29000	11154	.3	.65	.49	50
3	A992	29000	11154	.3	.65	.49	50
4	A500 Gr.42	29000	11154	.3	.65	.49	42
5	A500 Gr.46	29000	11154	.3	.65	.49	46

Load Combination Design

	Description	ASIF	CD	ABIF	Service	Hot Rolled	Cold Form	Wood	Concrete	Masonry	Footings	Aluminum
1	d+Pcr+gl					Yes	Yes	Yes	Yes	Yes	Yes	Yes
2	d+Pcr+gl					Yes	Yes	Yes	Yes	Yes	Yes	Yes
3	d+PwPcr					Yes	Yes	Yes	Yes	Yes	Yes	Yes
4	d+gl					Yes	Yes	Yes	Yes	Yes	Yes	Yes
5	d+Pw					Yes	Yes	Yes	Yes	Yes	Yes	Yes

Member AISC 13th(360-05): ASD Steel Code Checks (By Combination)

	LC	Member	Shape	UC Max	Loc[ft]	Shear UC	Loc[ft]	Pnc/om [k]	Pnt/om [k]	Mn/om [...	Cb	Eqn
1	1	M1	W10X45	.042	0	.000	0	162.302	398.204	107.502	1	H1-1b
2	1	M2	w12x40	.070	0	.000	0	52.895	350.299	58.061	1	H1-1b
3	1	M3	W10X45	.014	0	.000	0	162.302	398.204	107.502	1	H1-1b
4	1	M4	w6x15	.089	17.41	.000	0	8.023	132.635	9.084	1.316	H1-1b
5	1	M5	w6x15	.001	0	.000	0	32.093	132.635	15.745	1	H1-1b
6	1	M6	w6x15	.000	0	.000	0	32.093	132.635	15.745	1	H1-1a
7	2	M1	W10X45	.042	0	.000	0	162.302	398.204	107.502	1	H1-1b
8	2	M2	w12x40	.070	0	.000	0	52.895	350.299	58.061	1	H1-1b
9	2	M3	W10X45	.014	0	.000	0	162.302	398.204	107.502	1	H1-1b
10	2	M4	w6x15	.089	17.41	.000	0	8.023	132.635	9.084	1.316	H1-1b
11	2	M5	w6x15	.001	0	.000	0	32.093	132.635	15.745	1	H1-1b
12	2	M6	w6x15	.000	0	.000	0	32.093	132.635	15.745	1	H1-1a
13	3	M1	W10X45	.025	0	.000	0	162.302	398.204	107.502	1	H1-1b
14	3	M2	w12x40	.028	0	.000	0	52.895	350.299	58.061	1	H1-1b
15	3	M3	W10X45	.014	0	.000	0	162.302	398.204	107.502	1	H1-1b
16	3	M4	w6x15	.037	17.41	.000	0	8.023	132.635	9.084	1.316	H1-1b
17	3	M5	w6x15	.000	0	.000	0	32.093	132.635	15.745	1	H1-1b
18	3	M6	w6x15	.000	0	.000	0	32.093	132.635	15.745	1	H1-1a
19	4	M1	W10X45	.028	0	.000	0	162.302	398.204	107.502	1	H1-1b
20	4	M2	w12x40	.069	0	.000	0	52.895	350.299	58.061	1	H1-1b
21	4	M3	W10X45	.000	0	.000	0	162.302	398.204	107.502	1	H1-1b
22	4	M4	w6x15	.088	17.41	.000	0	8.023	132.635	9.084	1.316	H1-1b

Member AISC 13th(360-05): ASD Steel Code Checks (By Combination) (Continued)

	LC	Member	Shape	UC Max	Loc[ft]	Shear UC	Loc[ft]	Pnc/om [k]	Pnt/om [k]	Mn/om [...	Cb	Eqn
23	4	M5	w6x15	.001	0	.000	0	32.093	132.635	15.745	1	H1-1b
24	4	M6	w6x15	.000	0	.000	0	32.093	132.635	15.745	1	H1-1a
25	5	M1	W10X45	.012	0	.000	0	162.302	398.204	107.502	1	H1-1b
26	5	M2	w12x40	.028	0	.000	0	52.395	350.299	58.061	1	H1-1b
27	5	M3	W10X45	.000	0	.000	0	162.302	398.204	107.502	1	H1-1b
28	5	M4	w6x15	.036	17.41	.000	0	8.023	132.635	9.084	1.316	H1-1b
29	5	M5	w6x15	.000	0	.000	0	32.093	132.635	15.745	1	H1-1b
30	5	M6	w6x15	.000	0	.000	0	32.093	132.635	15.745	1	H1-1a

Joint Deflections

	LC	Joint Label	X [in]	Y [in]	Rotation [rad]
1	1	N1	0	0	0
2	1	N2	-.089	-.01	0
3	1	N3	-.097	-.003	0
4	1	N4	0	0	0
5	1	N5	-.021	.033	1.337e-4
6	2	N1	0	0	0
7	2	N2	-.089	-.01	0
8	2	N3	-.097	-.003	0
9	2	N4	0	0	0
10	2	N5	-.021	.033	1.337e-4
11	3	N1	0	0	0
12	3	N2	-.038	-.006	0
13	3	N3	-.041	-.003	0
14	3	N4	0	0	0
15	3	N5	-.009	.014	5.997e-5
16	4	N1	0	0	0
17	4	N2	-.087	-.007	0
18	4	N3	-.095	0	0
19	4	N4	0	0	0
20	4	N5	-.021	.033	1.245e-4
21	5	N1	0	0	0
22	5	N2	-.036	-.003	0
23	5	N3	-.039	0	0
24	5	N4	0	0	0
25	5	N5	-.009	.014	5.081e-5

Joint Reactions

	LC	Joint Label	X [k]	Y [k]	MZ [k-ft]
1	1	N1	.026	13.722	0
2	1	N4	14.674	-4.722	0
3	1	Totals:	14.7	9	
4	1	COG (ft):	X: 14.75	Y: 18.5	
5	2	N1	.026	13.722	0
6	2	N4	14.674	-4.722	0
7	2	Totals:	14.7	9	
8	2	COG (ft):	X: 14.75	Y: 18.5	
9	3	N1	.01	8.264	0
10	3	N4	5.99	.736	0
11	3	Totals:	6	9	
12	3	COG (ft):	X: 14.75	Y: 18.5	
13	4	N1	.027	9.218	0
14	4	N4	14.673	-9.218	0
15	4	Totals:	14.7	0	
16	4	COG (ft):	NC	NC	

Joint Reactions (Continued)

	LC	Joint Label	X [k]	Y [k]	MZ [k-ft]
17	5	N1	.01	3.763	0
18	5	N4	5.99	-3.763	0
19	5	Totals:	6	0	
20	5	COG (ft):	NC	NC	

Member Section Forces (By Combination)

	LC	Member Label	Sec	Axial[k]	Shear[k]	Moment[k-ft]
1	1	M1	1	13.7	0	0
2			2	13.7	0	0
3			3	13.7	0	0
4			4	13.7	0	0
5			5	13.7	0	0
6	1	M2	1	7.353	0	0
7			2	7.353	0	0
8			3	7.353	0	0
9			4	7.353	0	0
10			5	7.353	0	0
11	1	M3	1	4.5	0	0
12			2	4.5	0	0
13			3	4.5	0	0
14			4	4.5	0	0
15			5	4.5	0	0
16	1	M4	1	-17.334	.012	0
17			2	-17.334	.012	-.108
18			3	-17.352	.012	-.216
19			4	-17.352	-.012	-.108
20			5	-17.352	-.012	0
21	1	M5	1	.041	0	0
22			2	.041	0	0
23			3	.041	0	0
24			4	.041	0	0
25			5	.041	0	0
26	1	M6	1	0	0	0
27			2	0	0	0
28			3	0	0	0
29			4	0	0	0
30			5	0	0	0
31	2	M1	1	13.7	0	0
32			2	13.7	0	0
33			3	13.7	0	0
34			4	13.7	0	0
35			5	13.7	0	0
36	2	M2	1	7.353	0	0
37			2	7.353	0	0
38			3	7.353	0	0
39			4	7.353	0	0
40			5	7.353	0	0
41	2	M3	1	4.5	0	0
42			2	4.5	0	0
43			3	4.5	0	0
44			4	4.5	0	0
45			5	4.5	0	0
46	2	M4	1	-17.334	.012	0
47			2	-17.334	.012	-.108
48			3	-17.352	.012	-.216
49			4	-17.352	-.012	-.108

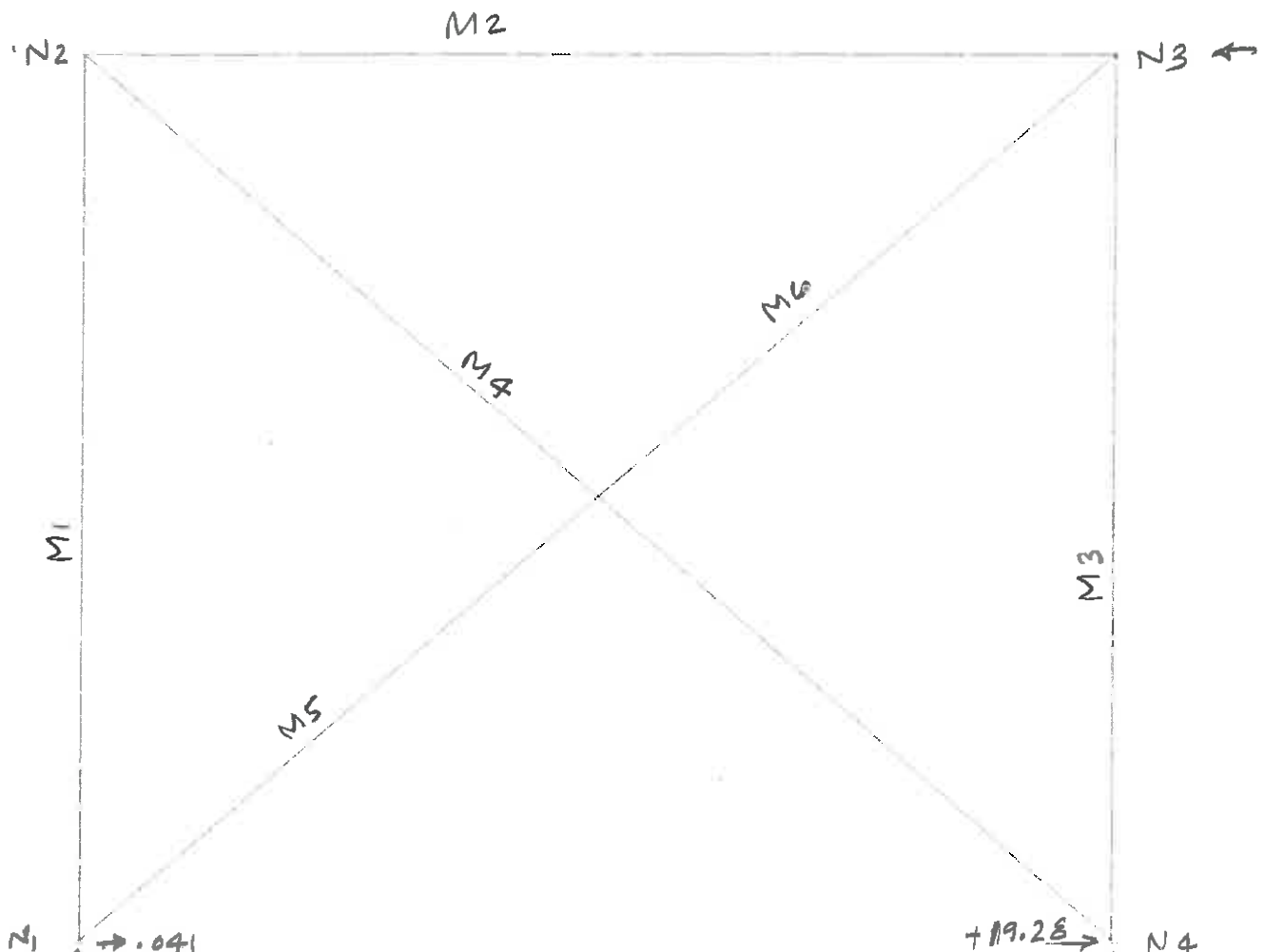
Member Section Forces (By Combination) (Continued)

	LC	Member Label	Sec	Axial[k]	Shear[k]	Moment[k-ft]
50			5	-17.352	-.012	0
51	2	M5	1	.041	0	0
52			2	.041	0	0
53			3	.041	0	0
54			4	.041	0	0
55			5	.041	0	0
56	2	M6	1	0	0	0
57			2	0	0	0
58			3	0	0	0
59			4	0	0	0
60			5	0	0	0
61	3	M1	1	8.257	0	0
62			2	8.257	0	0
63			3	8.257	0	0
64			4	8.257	0	0
65			5	8.257	0	0
66	3	M2	1	3.001	0	0
67			2	3.001	0	0
68			3	3.001	0	0
69			4	3.001	0	0
70			5	3.001	0	0
71	3	M3	1	4.5	0	0
72			2	4.5	0	0
73			3	4.5	0	0
74			4	4.5	0	0
75			5	4.5	0	0
76	3	M4	1	-7.076	.005	0
77			2	-7.076	.005	-.047
78			3	-7.082	.005	-.094
79			4	-7.082	-.005	-.047
80			5	-7.082	-.005	0
81	3	M5	1	.014	0	0
82			2	.014	0	0
83			3	.014	0	0
84			4	.014	0	0
85			5	.014	0	0
86	3	M6	1	0	0	0
87			2	0	0	0
88			3	0	0	0
89			4	0	0	0
90			5	0	0	0
91	4	M1	1	9.198	0	0
92			2	9.198	0	0
93			3	9.198	0	0
94			4	9.198	0	0
95			5	9.198	0	0
96	4	M2	1	7.35	0	0
97			2	7.35	0	0
98			3	7.35	0	0
99			4	7.35	0	0
100			5	7.35	0	0
101	4	M3	1	0	0	0
102			2	0	0	0
103			3	0	0	0
104			4	0	0	0
105			5	0	0	0
106	4	M4	1	-17.328	.012	0

Member Section Forces (By Combination) (Continued)

	LC	Member Label	Sec	Axial[k]	Shear[k]	Moment[k-ft]
107			2	-17.328	.012	-.103
108			3	-17.345	.012	-.207
109			4	-17.345	-.012	-.103
110			5	-17.345	-.012	0
111	4	M5	1	.039	0	0
112			2	.039	0	0
113			3	.039	0	0
114			4	.039	0	0
115			5	.039	0	0
116	4	M6	1	0	0	0
117			2	0	0	0
118			3	0	0	0
119			4	0	0	0
120			5	0	0	0
121	5	M1	1	3.756	0	0
122			2	3.756	0	0
123			3	3.756	0	0
124			4	3.756	0	0
125			5	3.756	0	0
126	5	M2	1	3	0	0
127			2	3	0	0
128			3	3	0	0
129			4	3	0	0
130			5	3	0	0
131	5	M3	1	0	0	0
132			2	0	0	0
133			3	0	0	0
134			4	0	0	0
135			5	0	0	0
136	5	M4	1	-7.074	.005	0
137			2	-7.074	.005	-.042
138			3	-7.079	.005	-.084
139			4	-7.079	-.005	-.042
140			5	-7.079	-.005	0
141	5	M5	1	.013	0	0
142			2	.013	0	0
143			3	.013	0	0
144			4	.013	0	0
145			5	.013	0	0
146	5	M6	1	0	0	0
147			2	0	0	0
148			3	0	0	0
149			4	0	0	0
150			5	0	0	0

Col. line - (A) Braced frame



$d + P_L + 9_H$

E2	LINE A	SK - 1
kd	topock wcs braced frame	July 27, 2012 at 8:59 AM
ww-peg-2174-043062		topockwcp. braced frame.r2d

Joint Coordinates and Temperatures

	Label	X [ft]	Y [ft]	Temp [F]
1	N1	0	0	0
2	N2	0	18.5	0
3	N3	21.5	18.5	0
4	N4	21.5	0	0
5	N5	10.75	9.25	0

Member Primary Data

	Label	I Joint	J Joint	Rotate(deg)	Section/Shape	Type	Design List	Material	Design Rules
1	M1	N1	N2		W10X45	Column	Wide Flange	A572 Gr.50	Default
2	M2	N2	N3		W12X40	Beam	Wide Flange	A572 Gr.50	Default
3	M3	N3	N4		W10X45	Column	Wide Flange	A572 Gr.50	Default
4	M4	N4	N2		W6X15	VBrace	Wide Flange	A572 Gr.50	Default
5	M5	N1	N5		W6X15	VBrace	Wide Flange	A572 Gr.50	Default
6	M6	N5	N3		W6X15	VBrace	Wide Flange	A572 Gr.50	Default

Basic Load Cases

	BLC Description	Category	X Gravity	Y Gravity	Joint	Point	Distributed
1	d	None			2		
2	Pcr	None			2		
3	gl	None			2		
4	Pw	None			2		

Joint Boundary Conditions

	Joint Label	X [k/in]	Y [k/in]	Rotation[k-ft/rad]	Footing
1	N1	Reaction	Reaction		
2	N4	Reaction	Reaction		

Load Combination Design

	Description	ASIF	CD	ABIF	Service	Hot Rolled	Cold Form	Wood	Concrete	Masonry	Footings	Aluminum
1	d+Pcr+gl					Yes	Yes	Yes	Yes	Yes	Yes	Yes
2	d+Pcr+gl					Yes	Yes	Yes	Yes	Yes	Yes	Yes
3	d+PwPcr					Yes	Yes	Yes	Yes	Yes	Yes	Yes
4	d+gl					Yes	Yes	Yes	Yes	Yes	Yes	Yes
5	d+Pw					Yes	Yes	Yes	Yes	Yes	Yes	Yes

Hot Rolled Steel Design Parameters

	Label	Shape	Length[...	Lb-out[ft]	Lb-in[ft]	Lcomp top	Lcomp bot	K-out	K-in	Cm	Cb	Out s...	In sway	Functi...
1	M1	W10X45	18.5											Lateral
2	M2	W12X40	21.5											Lateral
3	M3	W10X45	18.5											Lateral
4	M4	W6X15	28.364											Lateral
5	M5	W6X15	14.182											Lateral
6	M6	W6X15	14.182											Lateral

Joint Loads and Enforced Displacements (BLC 1 : d)

	Joint Label	L,D,M	Direction	Magnitude[(k,k-ft), (in,rad), (k*s^...
1	N2	L	Y	-5
2	N3	L	Y	-8

Joint Loads and Enforced Displacements (BLC 2 : Pcr)

	Joint Label	L,D,M	Direction	Magnitude[(k,k-ft), (in,rad), (k*s^...
1	N2	L	Y	-5
2	N3	L	Y	-5

Joint Loads and Enforced Displacements (BLC 3 : ql)

	Joint Label	L,D,M	Direction	Magnitude[(k,k-ft), (in,rad), (k*s^...
1	N2	L	X	-3.5
2	N3	L	X	-3.5

Joint Loads and Enforced Displacements (BLC 4 : Pw)

	Joint Label	L,D,M	Direction	Magnitude[(k,k-ft), (in,rad), (k*s^...
1	N2	L	X	-4
2	N3	L	X	-4

Hot Rolled Steel Properties

	Label	E [ksi]	G [ksi]	Nu	Therm (\1E5 F)	Density[k/ft^3]	Yield[ksi]
1	A36 Gr.36	29000	11154	.3	.65	.49	36
2	A572 Gr.50	29000	11154	.3	.65	.49	50
3	A992	29000	11154	.3	.65	.49	50
4	A500 Gr.42	29000	11154	.3	.65	.49	42
5	A500 Gr.46	29000	11154	.3	.65	.49	46

Load Combinations

	Description	Solve	PDe	SR...	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor
1	d+Pcr+ql	Yes	Y		DL	1.057	2	.9	3	2.1										
2	d+Pcr+ql	Yes	Y		DL	.543	2	.9	3	2.1										
3	d+PwPcr	Yes	Y		DL	1	2	.9	4	.75										
4	d+ql	Yes	Y		DL	.543	3	2.1												
5	d+Pw	Yes	Y		DL	1	4	.75												

Joint Reactions (By Combination)

	LC	Joint Label	X [k]	Y [k]	MZ [k-ft]
1	1	N1	.031	17.154	0
2	1	N4	14.669	-8.154	0
3	1	Totals:	14.7	9	
4	1	COG (ft):	X: 10.75	Y: 18.5	
5	2	N1	.031	17.154	0
6	2	N4	14.669	-8.154	0
7	2	Totals:	14.7	9	
8	2	COG (ft):	X: 10.75	Y: 18.5	
9	3	N1	.013	9.665	0
10	3	N4	5.987	-.665	0
11	3	Totals:	6	9	
12	3	COG (ft):	X: 10.75	Y: 18.5	
13	4	N1	.032	12.648	0
14	4	N4	14.668	-12.648	0
15	4	Totals:	14.7	0	
16	4	COG (ft):	NC	NC	
17	5	N1	.013	5.163	0
18	5	N4	5.987	-5.163	0
19	5	Totals:	6	0	
20	5	COG (ft):	NC	NC	

Joint Deflections

	LC	Joint Label	X [in]	Y [in]	Rotation [rad]
1	1	N1	0	0	0
2	1	N2	-.095	-.012	0
3	1	N3	-.101	-.003	0
4	1	N4	0	0	0
5	1	N5	-.021	.025	2.1e-4
6	2	N1	0	0	0
7	2	N2	-.095	-.012	0
8	2	N3	-.101	-.003	0
9	2	N4	0	0	0
10	2	N5	-.021	.025	2.1e-4
11	3	N1	0	0	0
12	3	N2	-.041	-.007	0
13	3	N3	-.043	-.003	0
14	3	N4	0	0	0
15	3	N5	-.009	.01	9.313e-5
16	4	N1	0	0	0
17	4	N2	-.092	-.009	0
18	4	N3	-.098	0	0
19	4	N4	0	0	0
20	4	N5	-.021	.025	1.974e-4
21	5	N1	0	0	0
22	5	N2	-.038	-.004	0
23	5	N3	-.04	0	0
24	5	N4	0	0	0
25	5	N5	-.009	.01	8.056e-5

Member AISC 13th(360-05): ASD Steel Code Checks (By Combination)

	LC	Member	Shape	UC Max	Loc[ft]	Shear UC	Loc[ft]	Pnc/om [k]	Pnt/om [k]	Mn/om [...	Cb	Eqn
1	1	M1	W10X45	.053	0	.000	0	162.302	398.204	107.502	1	H1-1b
2	1	M2	W12X40	.037	0	.000	0	99.582	350.299	87.847	1	H1-1b
3	1	M3	W10X45	.014	0	.000	0	162.302	398.204	107.502	1	H1-1b
4	1	M4	W6X15	.099	14.182	.001	14.182	12.092	132.635	11.431	1.316	H1-1b
5	1	M5	W6X15	.001	0	.000	0	48.369	132.635	18.975	1	H1-1b
6	1	M6	W6X15	.000	0	.000	0	48.369	132.635	18.975	1	H1-1a
7	2	M1	W10X45	.053	0	.000	0	162.302	398.204	107.502	1	H1-1b
8	2	M2	W12X40	.037	0	.000	0	99.582	350.299	87.847	1	H1-1b
9	2	M3	W10X45	.014	0	.000	0	162.302	398.204	107.502	1	H1-1b
10	2	M4	W6X15	.099	14.182	.001	14.182	12.092	132.635	11.431	1.316	H1-1b
11	2	M5	W6X15	.001	0	.000	0	48.369	132.635	18.975	1	H1-1b
12	2	M6	W6X15	.000	0	.000	0	48.369	132.635	18.975	1	H1-1a
13	3	M1	W10X45	.030	0	.000	0	162.302	398.204	107.502	1	H1-1b
14	3	M2	W12X40	.015	0	.000	0	99.582	350.299	87.847	1	H1-1b
15	3	M3	W10X45	.014	0	.000	0	162.302	398.204	107.502	1	H1-1b
16	3	M4	W6X15	.041	14.182	.000	0	12.092	132.635	11.431	1.316	H1-1b
17	3	M5	W6X15	.000	0	.000	0	48.369	132.635	18.975	1	H1-1b
18	3	M6	W6X15	.000	0	.000	0	48.369	132.635	18.975	1	H1-1a
19	4	M1	W10X45	.039	0	.000	0	162.302	398.204	107.502	1	H1-1b
20	4	M2	W12X40	.037	0	.000	0	99.582	350.299	87.847	1	H1-1b
21	4	M3	W10X45	.000	0	.000	0	162.302	398.204	107.502	1	H1-1b
22	4	M4	W6X15	.097	14.182	.001	0	12.092	132.635	11.431	1.316	H1-1b
23	4	M5	W6X15	.001	0	.000	0	48.369	132.635	18.975	1	H1-1b
24	4	M6	W6X15	.000	0	.000	0	48.369	132.635	18.975	1	H1-1a
25	5	M1	W10X45	.016	0	.000	0	162.302	398.204	107.502	1	H1-1b
26	5	M2	W12X40	.015	0	.000	0	99.582	350.299	87.847	1	H1-1b
27	5	M3	W10X45	.000	0	.000	0	162.302	398.204	107.502	1	H1-1b

Member AISC 13th(360-05): ASD Steel Code Checks (By Combination) (Continued)

	LC	Member	Shape	UC Max	Loc[ft]	Shear UC	Loc[ft]	Pnc/om [k]	Pnt/om [k]	Mn/om [...	Cb	Eqn
28	5	M4	W6X15	.040	14.182	000	14.182	12.092	132.635	11.431	1.316	H1-1b
29	5	M5	W6X15	.000	0	.000	0	48.369	132.635	18.975	1	H1-1b
30	5	M6	W6X15	.000	0	000	0	48.369	132.635	18.975	1	H1-1a

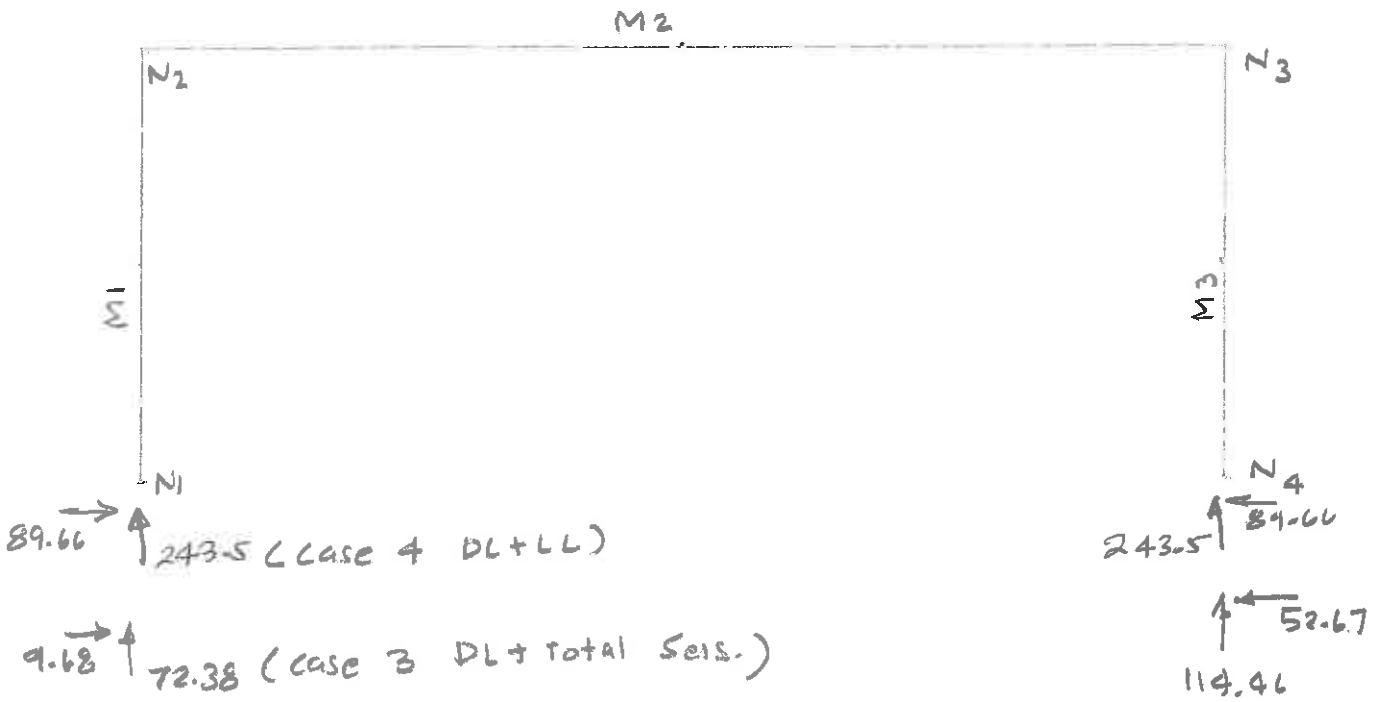
Member Section Forces (By Combination)

	LC	Member Label	Sec	Axial[k]	Shear[k]	Moment[k-ft]
1	1	M1	1	17.117	0	0
2			2	17.117	0	0
3			3	17.117	0	0
4			4	17.117	0	0
5			5	17.117	0	0
6	1	M2	1	7.353	0	0
7			2	7.353	0	0
8			3	7.353	0	0
9			4	7.353	0	0
10			5	7.353	0	0
11	1	M3	1	4.5	0	0
12			2	4.5	0	0
13			3	4.5	0	0
14			4	4.5	0	0
15			5	4.5	0	0
16	1	M4	1	-19.375	.021	0
17			2	-19.375	.021	-.146
18			3	-19.383	-.021	-.293
19			4	-19.383	-.021	-.146
20			5	-19.383	-.021	0
21	1	M5	1	.057	0	0
22			2	.057	0	0
23			3	.057	0	0
24			4	.057	0	0
25			5	.057	0	0
26	1	M6	1	0	0	0
27			2	0	0	0
28			3	0	0	0
29			4	0	0	0
30			5	0	0	0
31	2	M1	1	17.117	0	0
32			2	17.117	0	0
33			3	17.117	0	0
34			4	17.117	0	0
35			5	17.117	0	0
36	2	M2	1	7.353	0	0
37			2	7.353	0	0
38			3	7.353	0	0
39			4	7.353	0	0
40			5	7.353	0	0
41	2	M3	1	4.5	0	0
42			2	4.5	0	0
43			3	4.5	0	0
44			4	4.5	0	0
45			5	4.5	0	0
46	2	M4	1	-19.375	.021	0
47			2	-19.375	.021	-.146
48			3	-19.383	-.021	-.293
49			4	-19.383	-.021	-.146
50			5	-19.383	-.021	0

Member Section Forces (By Combination) (Continued)

	LC	Member Label	Sec	Axial[k]	Shear[k]	Moment[k-ft]
51	2	M5	1	.057	0	0
52			2	.057	0	0
53			3	.057	0	0
54			4	057	0	0
55			5	.057	0	0
56	2	M6	1	0	0	0
57			2	0	0	0
58			3	0	0	0
59			4	0	0	0
60			5	0	0	0
61	3	M1	1	9.651	0	0
62			2	9.651	0	0
63			3	9.651	0	0
64			4	9.651	0	0
65			5	9.651	0	0
66	3	M2	1	3.001	0	0
67			2	3.001	0	0
68			3	3.001	0	0
69			4	3.001	0	0
70			5	3.001	0	0
71	3	M3	1	4.5	0	0
72			2	4.5	0	0
73			3	4.5	0	0
74			4	4.5	0	0
75			5	4.5	0	0
76	3	M4	1	-7.908	.009	0
77			2	-7.908	.009	-.064
78			3	-7.911	.009	-.129
79			4	-7.911	-.009	-.064
80			5	-7.911	-.009	0
81	3	M5	1	.021	0	0
82			2	021	0	0
83			3	.021	0	0
84			4	.021	0	0
85			5	.021	0	0
86	3	M6	1	0	0	0
87			2	0	0	0
88			3	0	0	0
89			4	0	0	0
90			5	0	0	0
91	4	M1	1	12.613	0	0
92			2	12.613	0	0
93			3	12.613	0	0
94			4	12.613	0	0
95			5	12.613	0	0
96	4	M2	1	7.35	0	0
97			2	7.35	0	0
98			3	7.35	0	0
99			4	7.35	0	0
100			5	7.35	0	0
101	4	M3	1	0	0	0
102			2	0	0	0
103			3	0	0	0
104			4	0	0	0
105			5	0	0	0
106	4	M4	1	-19.368	.02	0
107			2	-19.368	.02	-.139

Concrete Moment Frame line (2) & (4)



e2	topock concrete moment frame	SK - 1
kd		Aug 3, 2012 at 9:41 AM
ww-peg-2174-043062		topockconc.momfr.r2d

Joint Loads and Enforced Displacements (BLC 1 : seismic)

	Joint Label	L,D,M	Direction	Magnitude[(k,k-ft), (in,rad), (k*s^...
1	N2	L	X	6.3
2	N3	L	X	6.3

Joint Loads and Enforced Displacements (BLC 3 : seismic steel frame)

	Joint Label	L,D,M	Direction	Magnitude[(k,k-ft), (in,rad), (k*s^...
1	N2	L	X	3.8
2	N3	L	X	7.7
3	N2	M	M	44.29
4	N3	M	M	71.7
5	N2	L	Y	-4.98
6	N3	L	Y	-11.51

Member Distributed Loads (BLC 2 : Dead load D)

	Member Label	Direction	Start Magnitude[k/ft,d...	End Magnitude[k/ft,d	Start Location[ft,%]	End Location[ft,%]
1	M2	y	-6.5	-6.5	0	32

Member Distributed Loads (BLC 4 : live load)

	Member Label	Direction	Start Magnitude[k/ft,d...	End Magnitude[k/ft,d...	Start Location[ft,%]	End Location[ft,%]
1	M2	Y	-3.6	-3.6	0	32

Basic Load Cases

	BLC Description	Category	X Gravity	Y Gravity	Joint	Point	Distributed
1	seismic	None			2		
2	Dead load D	None					1
3	seismic steel frame	None			6		
4	live load	None					1

Concrete Beam Design Parameters

	Label	Shape	Length[ft]	B-eff Left[in]	B-eff Right[in]	Slab Thic...	Slab Thic...	Icr Factor	Flexural L...	Shear Lay...
1	M2	CRECT30X30	32						Default	Default

Member Primary Data

	Label	I Joint	J Joint	Rotate(deg)	Section/Shape	Type	Design List	Material	Design Rules
1	M1	N1	N2		CRECT30X30	Column	Rectangular	Conc5000L...	Typical
2	M2	N2	N3		CRECT30X30	Beam	Rectangular	Conc5000L...	Typical
3	M3	N3	N4		CRECT30X30	Column	Rectangular	Conc5000L...	Typical

Concrete Column Design Parameters

	Label	Shape	Length[ft]	Lu-out[ft]	Lu-in[ft]	Cm-out	Cm-in	K-out	K-in	Out sw...	In sway	Icr Fac...	Flexur...	Shear
1	M1	CRECT3...	12.75										Default	Default
2	M3	CRECT3...	12.75										Default	Default

Concrete Properties

	Label	E [ksi]	G [ksi]	Nu	Therm (\1E...	Density[k/ft...	f'c[ksi]	Lambda	Flex Steel[...	Shear Stee...
1	Conc3000NW	3156	1372	.15	.6	.145	3	1	60	60
2	Conc3500NW	3409	1482	.15	.6	.145	3.5	1	60	60
3	Conc4000NW	3644	1584	.15	.6	.145	4	1	60	60

Concrete Properties (Continued)

	Label	E [ksi]	G [ksi]	Nu	Therm (\1E..	Density[k/ft..	f'c[ksi]	Lambda	Flex Steel[..	Shear Stee..
4	Conc3000LW	2085	907	.15	.6	.11	3	75	60	60
5	Conc3500LW	2252	979	.15	.6	.11	3.5	.75	60	60
6	Conc5000LW	2408	1047	.15	.6	.11	4	75	60	60

Joint Boundary Conditions

	Joint Label	X [k/in]	Y [k/in]	Rotation[k-ft/rad]	Footing
1	N1	Reaction	Reaction		
2	N4	Reaction	Reaction		

Joint Coordinates and Temperatures

	Label	X [ft]	Y [ft]	Temp [F]
1	N1	0	0	0
2	N2	0	12.75	0
3	N3	32	12.75	0
4	N4	32	0	0

Load Combinations

	Description	Solve	PDe..	SR..	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor
1	Total Seismic	Yes	Y		1	2.5	3	1												
2	Stiffness	Yes	Y		1	7.936														
3	D+Total seis..	Yes	Y		1	2.5	3	1	2	.819										
4	D+L	Yes	Y		2	1.4	4	1.7												

Load Combination Design

	Description	ASIF	CD	ABIF	Service	Hot Rolled	Cold Form..	Wood	Concrete	Masonry	Footings	Aluminum
1	Total Seismic					Yes	Yes	Yes	Yes	Yes	Yes	Yes
2	Stiffness					Yes	Yes	Yes	Yes	Yes	Yes	Yes
3	D+Total seis..					Yes	Yes	Yes	Yes	Yes	Yes	Yes
4	D+L					Yes	Yes	Yes	Yes	Yes	Yes	Yes

Joint Deflections (By Combination)

	LC	Joint Label	X [in]	Y [in]	Rotation [rad]
1	1	N1	0	0	-5.959e-3
2	1	N2	.803	0	-3.741e-3
3	1	N3	.803	-.002	-3.743e-3
4	1	N4	0	0	-5.962e-3
5	2	N1	0	0	-1.381e-2
6	2	N2	1.861	.003	-8.67e-3
7	2	N3	1.861	-.003	-8.671e-3
8	2	N4	0	0	-1.381e-2
9	3	N1	0	0	-5.146e-3
10	3	N2	.833	-.005	-6.077e-3
11	3	N3	.828	-.008	-1.663e-3
12	3	N4	0	0	-7.184e-3
13	4	N1	0	0	2.909e-3
14	4	N2	.008	-.017	-6.312e-3
15	4	N3	-.008	-.017	6.312e-3
16	4	N4	0	0	-2.909e-3

Member Section Forces

	LC	Member Label	Sec	Axial[k]	Shear[k]	Moment[k-ft]
1	1	M1	1	-12.208	21.567	0
2			2	-12.208	21.567	-68.745
3			3	-12.208	21.567	-137.489
4			4	-12.208	21.567	-206.234
5			5	-12.208	21.567	-274.979
6	1	M2	1	-2.119	-17.188	-274.979
7			2	-2.119	-17.188	-137.476
8			3	-2.119	-17.188	027
9			4	-2.119	-17.188	137.529
10			5	-2.119	-17.188	275.032
11	1	M3	1	28.698	21.571	275.032
12			2	28.698	21.571	206.274
13			3	28.698	21.571	137.516
14			4	28.698	21.571	68.758
15			5	28.698	21.571	0
16	2	M1	1	-39.841	49.996	0
17			2	-39.841	49.996	-159.362
18			3	-39.841	49.996	-318.725
19			4	-39.841	49.996	-478.087
20			5	-39.841	49.996	-637.449
21	2	M2	1	-.775	-39.841	-637.449
22			2	-.775	-39.841	-318.72
23			3	-.775	-39.841	.01
24			4	-.775	-39.841	318.739
25			5	-.775	-39.841	637.469
26	2	M3	1	39.841	49.998	637.469
27			2	39.841	49.998	478.102
28			3	39.841	49.998	318.734
29			4	39.841	49.998	159.367
30			5	39.841	49.998	0
31	3	M1	1	72.378	-9.046	0
32			2	72.378	-9.046	28.833
33			3	72.378	-9.046	57.666
34			4	72.378	-9.046	86.5
35			5	72.378	-9.046	115.333
36	3	M2	1	29.226	67.398	115.333
37			2	29.226	24.81	-253.498
38			3	29.226	-17.778	-281.625
39			4	29.226	-60.366	30.952
40			5	29.226	-102.954	684.233
41	3	M3	1	114.464	53.665	684.233
42			2	114.464	53.665	513.174
43			3	114.464	53.665	342.116
44			4	114.464	53.665	171.058
45			5	114.464	53.665	0
46	4	M1	1	243.52	-89.64	0
47			2	243.52	-89.64	285.728
48			3	243.52	-89.64	571.455
49			4	243.52	-89.64	857.183
50			5	243.52	-89.64	1142.911
51	4	M2	1	89.66	243.52	1142.911
52			2	89.66	121.76	-318.209
53			3	89.66	0	-805.249
54			4	89.66	-121.76	-318.209
55			5	89.66	-243.52	1142.911
56	4	M3	1	243.52	89.64	1142.911

Member Section Forces (Continued)

	LC	Member Label	Sec	Axial[k]	Shear[k]	Moment[k-ft]
57			2	243.52	89.64	857.183
58			3	243.52	89.64	571.455
59			4	243.52	89.64	285.728
60			5	243.52	89.64	0

Joint Reactions (By Combination)

	LC	Joint Label	X [k]	Y [k]	MZ [k-ft]
1	1	N1	-21.669	-12.208	0
2	1	N4	-21.331	28.698	0
3	1	Totals:	-43	16.49	
4	1	COG (ft):	X: 22.336	Y: 12.75	
5	2	N1	-50.771	-39.841	0
6	2	N4	-49.222	39.841	0
7	2	Totals:	-99.994	0	
8	2	COG (ft):	NC	NC	
9	3	N1	9.676	72.378	0
10	3	N4	-52.676	114.464	0
11	3	Totals:	-43	186.842	
12	3	COG (ft):	X: 16.559	Y: 12.75	
13	4	N1	89.66	243.52	0
14	4	N4	-89.66	243.52	0
15	4	Totals:	0	487.04	
16	4	COG (ft):	X: 16	Y: 12.75	

Member Section Deflections (By Combination)

	LC	Member Label	Sec	x [in]	y [in]	(n) L/y Ratio
1	1	M1	1	0	0	NC
2			2	0	-.227	5769.346
3			3	0	-.444	3605.841
4			4	0	-.639	4120.961
5			5	0	-.803	NC
6	1	M2	1	.803	0	NC
7			2	.803	-.133	2859.345
8			3	.803	0	NC
9			4	.803	.132	2918.726
10			5	.803	-.002	NC
11	1	M3	1	.002	.803	NC
12			2	.002	.639	4120.162
13			3	.001	.444	3605.141
14			4	0	.227	5768.226
15			5	0	0	NC
16	2	M1	1	0	0	NC
17			2	0	-.527	2488.742
18			3	.001	-1.029	1555.464
19			4	.002	-1.482	1777.673
20			5	.003	-1.861	NC
21	2	M2	1	1.861	.003	NC
22			2	1.861	-.308	1239.605
23			3	1.861	0	NC
24			4	1.861	.308	1239.377
25			5	1.861	-.003	NC
26	2	M3	1	.003	1.861	NC
27			2	.002	1.482	1777.618
28			3	.001	1.029	1555.416
29			4	0	.527	2488.666

Member Section Deflections (By Combination) (Continued)

	LC	Member Label	Sec	x [in]	y [in]	(n) L/y Ratio
30			5	0	0	NC
31	3	M1	1	0	0	NC
32			2	-.001	-.197	776.028
33			3	-.003	-.399	383.685
34			4	-.004	-.609	251.12
35			5	-.005	-.833	183.646
36	3	M2	1	.833	-.005	NC
37			2	.832	-.551	703.934
38			3	.831	-.66	587.69
39			4	.829	-.276	1427.4
40			5	.828	-.008	NC
41	3	M3	1	.008	.828	NC
42			2	.006	.713	1656.128
43			3	.004	.52	1449.112
44			4	.002	.273	2318.579
45			5	0	0	NC
46	4	M1	1	0	0	NC
47			2	-.004	.108	1388.076
48			3	-.009	.172	867.548
49			4	-.013	.148	991.483
50			5	-.017	-.008	NC
51	4	M2	1	.008	-.017	NC
52			2	.004	-1.182	329.728
53			3	0	-1.886	205.524
54			4	-.004	-1.182	329.728
55			5	-.008	-.017	NC
56	4	M3	1	.017	-.008	NC
57			2	.013	.148	991.483
58			3	.009	.172	867.548
59			4	.004	.108	1388.076
60			5	0	0	NC

Concrete Beam Bending Reinforcement (By Combination)

	Member	Shape	Span	Left Top	Left Bot	Mid Top	Mid Bot	Right Top	Right Bot
1	M2	CRECT30X30	1	6 #10	4 #10		6 #10	6 #10	

Concrete Beam Shear Reinforcement

	Member	Span	Region 1	Region 2	Region 3	Region 4
1	M2	1	32 #4 @3in	15 #4 @11in	3 #4 @7in	25 #4 @3in

Concrete Column Bending Reinforcement

	Column	Shape	Span	Perim Bars
1	M1	CRECT30X30	1	12 #10
2	M3	CRECT30X30	1	12 #10

Concrete Column Shear Reinforcement

	Column	Span	Region 1	Region 2	Region 3	Region 4
1	M1	1	28 #4 @5in			
2	M3	1	11 #4 @13in			

Concrete Column Design Results (By Combination)

	Column	Shape	UC Max	Loc[ft]	UC LC	Shear ...	Loc[ft]	Dir	Phi used	Pn[k]	Mn[k-ft]	Vn[k]
1	M1	CRECT30...	.997	11.555	2	.927	0	y	.9	-44.418	644.046	128.955
2	M3	CRECT30	.972	1.195	2	.938	1.195	y	.9	45.541	660.361	127.48

Concrete Beam Design Results

	Member	Shape	UC Max ...	Loc[ft]	UC Max	Loc[ft]	Shear UC	Loc[ft]	Phi*Mn Top[...	Phi*Mn Bot[...	Phi*Vn[k]
1	M2	CRECT30X...	.968	30.667	.99	1.333	.955	24	859.499	589.99	127.494

ATTN: VINOD / E2

NO. OF PAGES - 11

APPENDIX A - CALCULATION COVER SHEET

CALCULATION ID NUMBER	
REVISION NUMBER	
JOB NUMBER	WW-PEB-2174-043062

TITLE	Topock Groundwater Remediation Project, Water Tank

Page No.	CONTENT
1	References And Data
2 TO 5	Impulsive And Convective Forces
6	Sloshing Height, Wind loads
7	Annular Ring & Anchor Bolts
8, 9	Foundation
10	Attachments

		initial	date
PREPARED			
TITLE			
REVIEWED			
TITLE			

REVISION NOTES	

E2 Consulting Engineers, Inc. 1900 Powell Street, Suite 250 Eneryville, CA 94608	Designed By: KD	Date: 3/29/12
	Checked By:	Date:
	Revised By:	Date:
Project No. WW-PSA-2174-435062 - 01.02.02		Sheet No. 1

Project Description Topock Groundwater Remediation Project Ref.'s & Data

Design References

1. AWWA Standard D-100-11 (Rev. of ANSI/AWAA D100.05)
2. IBC 2009 / CBC 2010
3. ACI 318-11
4. Nuclear Reactors & Earthquakes (TID 7024) chap.-6

Design Data

Concrete $f_c' = 4.0^{ksi}$ $f_y = 60^{ksi}$

Anchor Bolts - A-307

Tank Data

Total Height = 16' Height of water = H = 12.5'

Dia. of Tank = 25' = D

Min t for shell = $\frac{2.6\, h_p D G}{s_t} = \frac{2.6 \times 12.5 \times 25 \times 1}{15000 \times .66} = .05''$ use .25" (Table 15)

Seismic Data (See attachment-1)

Site Class - D (Assumed w/o any Soil Info.)

Seismic coefficients based on general area in needles, CA.

$S_s = .434$ $S_1 = .135$ $F_a = 1.4$ $F_v = 2.3$

$S_{MS} = F_a \times S_s = 1.4 \times .434 = .608$

$S_{M1} = F_v \times S_1 = 2.3 \times .135 = .311$

$S_{DS} = .667 \times .608 = .406$ $S_{D1} = .667 \times .311 = .207$

Soil Data (NO Soil Report)

Allow. Soil press. = $1 \times 1.2 = 1200^{PSF}$

Wind Data - Code AWWA D100-11

Assume G = Gust factor = 1.0 V = wind vel. = $100^{M/hr.}$

$P_W = q_z G C_f$ | $q_z = .00256 K_z I V^2$

$= 32 \times 1.0 \times .6$ | $= .00256 \times 1.09 \times 1.15 \times 100^2 = 32^{PSF}$

$= 19.2^{PSF} > 30^{PSF}$

However use $25^{PSF} = P_W$

Total wind $P_W = 25 \times 25 \times 16 = 10000^{\#} = 10^{K}$

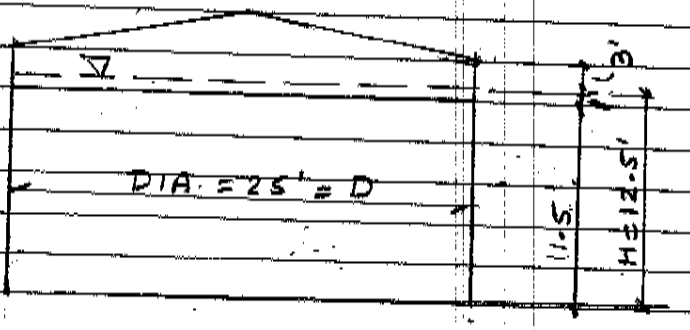
$V_{max} = 10^{K}$ $M_{max} = 10 \times 8 = 80^{IK}$ (overturning)

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Designed By: LKD	Date: 3/30/12		
Checked By:	Date:		
Revised By:	Date:		
Project No. WW-PEG-2174-43052	Sheet No. 2		

Project Description Topock Groundwater Remediation Proj.

Design of 25' Dia Water Tank (Ref. #1 pg. 1)



Impulsive Components

$A_i = \frac{S_{ai} I_E}{1.4 R_I}$ (Table 24 (Group II)) $I_E = 1.25$ $R_I = 3.0$ (Table-28) (Impulsive) $R_I = 1.5$ (convective)

$= \frac{.406 \times 1.25}{1.40 \times 3.0}$ $S_{ai} = S_{DS}$ (For $T_i \le T_s$)

$= .121\ g$ $T_i = C_t h_n^{x} = .02 \times 16^{.75} = .16$ sec. $< .51$ sec.

Min. $A_i = \frac{.36 S_1 \times I_E}{R_i} = \frac{.36 \times .311 \times 1.25}{3.0}$ $T_L = 12$ sec. $T_s = \frac{S_{D1}}{S_{DS}} = \frac{.207}{.406} = .51$ sec.

$= .047$ USE $A_i = .121\ g$

Eq. 13-20 $V_i = A_i (W_s + W_r + W_f + W_i)$

$M_i = A_i (W_s x_s + W_r \times H_t + W_i x_i)$

Weights

W_T = wt. of contents $= .49 HD^2 = .49 \times 12.5 \times 25^2 \times 10^{-3} = 382.8^k$

$\frac{D}{H} = \frac{25}{12.5} = 2 < 3.33$ $\frac{W_1}{W_T} = .55$ $\frac{x_1}{H} = .35$

$\frac{W_2}{W_T} = .43$ $\frac{x_2}{H} = .62$

$x_1 = .35 H = .35 \times 12.5 = 4.38'$

$W_1 = .55 \times W_T = .55 \times 382.8 = 210.5^k$ (Effective Weight)

$x_2 = .62 H = .62 \times 12.5 = 7.75'$

$W_2 = .43 W_T = .43 \times 382.8 = 164.6^k$

$W_r = \frac{\pi}{4} (25)^2 \times .01 = 4.91^k$ = Wt. of Roof

$W_s = \frac{\pi}{4} (25.042^2 - 25^2) \times 16 \times .49 = 12.84$ = Wt. of shell

Total Wt. $W = W_1 + W_r + W_s = 210.5 + 4.91 + 12.84 = 228.25^k$ Say 229^k

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Designed By: KD	Date: 3/30/12		
Checked By:	Date:		
Revised By:	Date:		
Project No. WWW-PEA-2174-43052	Sheet No. 3		

Project Description Topock Groundwater Remediation Press.

(25' Dia. Water Tank Contd.)

Total W = 229^k

Note: Floor Weight not included since it is at ground level.

Shear V_i (due to impulsive forces)

Eq. 13-20 $= A_i (W_i + W_y + W_s) = .121 \times 229 = 27.7^k$

Moment M_i (due to impulsive forces

partial Eq. 13-23 $= A_i (W_s \times X_s + W_r \times H_t + W_i \times X_i)$

$= .121 (12.84 \times 8 + 4.91 \times 16 + 210.5 \times 4.38)$

$= .121 (102.72 + 78.56 + 922) = 133.5^{ik}$

Adjust & Calculate effective impulsive weight to include varying hor. press. if supported on pile fdn. (Sect. A-13.5.3)

Eq. 13-29 $X_i = .375 H = .375 \times 12.5 = 4.69'$

$$X_{imf} = .375 \left[1 + 1.333 \left\{ \frac{.866 \frac{D}{H}}{\tanh(1.866 \times \frac{D}{H})} - 1 \right\} \right] H$$

$$= .375 \left[1 + 1.333 \left\{ \frac{.866 \times 2}{\tanh(1.732)} - 1 \right\} \right] 12.5$$

$.939$

$= .375 [26.572] = 9.96'$

Eq. 13-32 Moment $M_{imf} = .121 (102.72 + 78.56 + 210.5 \times 9.96)$

$= 264.77^{ik}$

? To be used if supported on pile fdn. or MAT FDN See sect. A-13.5.3

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Checked By: | Date:
Revised By: | Date:
Project No. WW-PEG-2174-435062 | Sheet No. 4
Project Description Tapock Groundwater Remediation Proj.-

(25' DIA. TANK CONTD.)

Convective Forces (Sloshing Effect)

$A_c = \frac{S_{ac} I_E}{1.4 R_I}$ $I_E = 1.25$ $R_I = 1.5$

$S_{ac} = \frac{K S_{D1}}{T_c} \leq S_{DS}$ (Eq. 13-12) $T_c \leq T_L$

First mode of sloshing effect given by

$$T_c = 2\pi \sqrt{\frac{D}{3.68 g \tanh\left(\frac{3.68H}{D}\right)}}$$

$\tanh\left(\frac{3.68 \times 12.5}{25}\right) = \tanh(1.84) = .9508$

$T_c = 2\pi \sqrt{\frac{25}{3.68 \times 32.2 \times .9508}} = 2.96$ sec. < 12 sec.

Eq. 13-12 $S_{ac} = \frac{1.5 \times .207}{2.96} = .1049$

$A_c = \frac{.1049 \times 1.25}{1.4 \times 1.5} = .0625$

Eq. 13-30 $$x_c = \left[1 - \frac{\cosh\left[\frac{3.67H}{D}\right] - 1}{\frac{3.67H}{D} \sinh\left[\frac{3.67H}{D}\right]}\right] H$$

Substitute $H = 12.5$, $D = 25$

$$= \left[1 - \frac{\cosh(1.835) - 1}{1.835 \sinh(1.835)}\right] 12.5$$

$$= \left[1 - \frac{3.2129 - 1}{1.835 \times 3.0528}\right] \times 12.5 = 7.5634'$$

$$W_c = .230 \frac{D}{H} \tanh\left[\frac{3.67 \times H}{D}\right] W_T$$

$H = 12.5$ $D = 25$

$W_T = 49 \gamma H D^2 = 382.8^k$

$= .230 \times 2 \tanh\left[1.835\right] \times 382.8$

$= .230 \times 2 \times .9503 \times 382.8 = 167.34^k$

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Project No. WW-PEB-2174-935062 | Sheet No. 5
Project Description Topock Groundwater Remediation Project

Eq. 13-35 Height from bot. of shell to the c.G. of effective convective weight W_c adjusted for varying hot. press.

$$X_{cmf} = \left[1 - \frac{\cosh\left[\frac{3.67H}{D}\right] - 1.937}{\frac{3.67H}{D}\sinh\left[\frac{3.67H}{D}\right]}\right] H \qquad H = 12.5 \quad D = 25$$

$$= \left[1 - \frac{\cosh(1.835) - 1.937}{1.835 \sinh(1.835)}\right] 12.5$$

$$= \left[1 - \frac{3.2124 - 1.937}{1.835 \times 3.0525}\right] \times 12.5 = 9.654'$$

Eq. 13-32 $$M_{cmf} = \sqrt{A_i\left(W_s X_s + W_r H_r + W_i X_{imf}\right)^2 + \left[A_c W_c X_{cmf}\right]^2}$$

Moment due to convective (sloshing)

$$= A_c W_c X_{cmf}$$
$$= .0625 \times 167.34 \times 9.654$$
$$= 100.97$$

$A_c = .0625$ (Pg. 4)
$X_{cmf} = 9.654'$
$W_c = 167.34$ (Pg. 4)

$$M_{cmf} = \sqrt{(264.77)^2 + (100.97)^2}$$
$$= 283.37^{1k}$$

↳ Moment to be used if supported on pile or Mat Fdn. (Sect. 13.5.3.2.2)

Eq. 13-23 $$M_s = \sqrt{\left[A_i\left(W_s X_s + W_r H_r + W_i X_i\right)\right]^2 + \left[A_c W_c X_c\right]^2}$$

$$= \sqrt{(133.5)^2 + (.0625 \times 167.34 \times 7.563)^2}$$
$$= \sqrt{17822.25 + 6257.4} = 155.18^{1k}$$

USE 160^{1k}

M_s is Design overturning moment @ bot. of shell (w/o bot varying press effect) for Ring Fdn.

Eq. 13-31 V_f = Design shear @ top of Ring Fdn

$$= \sqrt{\left[A_i(W_s + W_r + W_i + W_i)\right]^2 + (A_c W_c)^2}$$
$$= \sqrt{[.121(229)]^2 + [.0625 \times 167.34]^2} = 29.62^k$$ USE 30^k

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	Revised By:	Date:
Project No. WW-PEB-2174-435062		Sheet No. 6

Project Description Topock Groundwater Remediation Project

Uplift Check

Eq 13-36 J = overturning Ratio (Sect. 13.5.4.3)

$A_v = 1.4 S_{DS} = 1.4 \times .406 = .057$

$= \dfrac{M_s}{D^2 [W_t (1 - .4 A_v) + W_L]}$ $M_s = 160^{1K}$ $D = 25'$

Eq 13-41 $W_t = \dfrac{W_s}{\pi D} + W_{rs}$ $W_t = 12.84$

$W_{rs} = \dfrac{5}{\pi D} = .064^{K/'} = 64\ \#/'$ say $100\ \#/'$

$= \dfrac{12840}{\pi D} + 100$

$= 163.5 + 100 = 263.5\ \#/'$

Eq 13-39 $W_L = 7.9 t_b \sqrt{F_y H G} \leq 1.28 H D G$

$1.28 H D G = 1.28 \times 12.5 \times 25 \times 1 = 400\ \#/'$

Eq 13.38 Required Annulus Width $= L = .216 t_b \sqrt{\dfrac{F_y}{HG}} \leq .035 D$ $.035 \times 25 = .875'$

$= .216 \times 25 \sqrt{\dfrac{36000}{12.5 \times 1}}$

$= 2.9'$ say $3'$

$J = \dfrac{160 \times 10^3}{25^2 [2635 (1 - .40 \times .057) + 400]}$ $= .389 < .785$

Sloshing Wave Height

Eq 13-52 $d = .5 D A_f$

A_f when $T_c < 4 = \dfrac{K S_{D1} I_E}{T_c}$ $T_c = 2.96$ sec (pg 4)

$S_{D1} = .207$ $I_E = 1.25$ $K = 1.5$

$A_f = \dfrac{1.5 \times .207 \times 1.25}{2.96} = .1311$

$d = .5 \times 25 \times .1311 = 1.64' < 3'$ ok

Wind loads (See pg. 1)

Max $M_w = P_w \times 16 \times .5 = 10 \times 8 = 80^{1K} < 160^{1K}$ (Seismic)

Seismic Loads govern the design of the Tank

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Project No.	WW-PEB-2174-435062		Sheet No. 7

Project Description Topock Groundwater Remediation Project

Annular Ring

Eq 13-37 $W_L = 7.9 t_b \sqrt{F_y H_G} \leq 1.25$ HDG

$W_L = 7.9 \times .25 \sqrt{36000 \times 12.5 \times 1} = 1325$ #/"

1.25 HDG $= 1.25 \times 1.5 \times 160 = 400$ #/"

30" | 6"

Eq 13-38 Require t (Annulus width)

$= .216 \times .25 \sqrt{\frac{36000}{12.5 \times 1}} = 2.9" > .035 \times 25 = .875"$

USE 3'-0"

For $I \leq .785$

Eq. 13-39 $f_c = \left[W_t (1 + .4 A_v) + \frac{1.273 M_s}{D^2} \right] \frac{1}{12 t_s}$

$= \left[263.5 (1 + .4 \times .057) + \frac{1.273 \times 160 \times 10^3}{(25)^2} \right] \times \frac{1}{12 \times .25}$

$= \left[595.4 \right] \times \frac{1}{12 \times .25} = 198.5$ PSI Small ok

Anchor Bolts

AWWA-D-100-11 $V_{max} = V_c = 30^k$ (pg. 5)

$M_{max} = M_s = 160'^k$

$V_A = \tan 30 (W_s + W_r + W_l)(1 - .4 A_v)$

$= .577 (229)(1 - .4 \times .057) = .577 \times 229 \times .977$

$= 129.1^k \gg 30^k$

Min. Anchor Bolts to be provided

Min. SPA. = 6'

TD $= \pi \times 25 = 78.5'$

No of Anchor Bolts $= \frac{78.5}{6} = 13$ USE 14 - 1 3/4" x 18" A-307 A-B.'s

Eq. 3-42 $p_s = \frac{4 M_s}{N D_{ac}} - \frac{W'}{N} = \left[\frac{4 \times 160}{25} - \frac{.057 \times 18 \times 9}{W_r + W_s} \right] \times \frac{1}{14}$

(Design uplift) ten.

$= 1.76^k$ ok

Sect. 3.3.3.2 Cap. of 1" x 1'-6" (Emb.) A.B. $= .5 \times 58 \times .606 = 17.57^k$

Cap. of Cone. $= 12.1^k$ for Emb. $= 18"$ Root Tensile Area

Sect. 3.8.5 Min. Dia. $= 1"$ Allowance .25" for Corrosion USE Root Area for 3/4" $\phi = .334$

Ten. Cap. $= .5 \times 58 \times .334 = 9.7^k > 1.76^k$ ok

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Project Description Topock Groundwater Remediation Proj.

Ring Wall Foundation

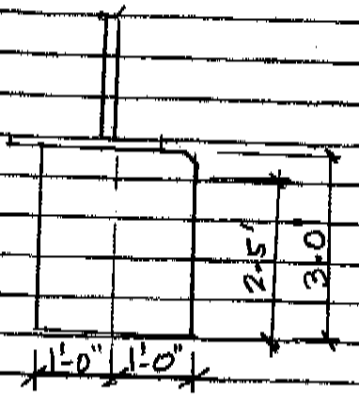
Try 2'-0" wide x 3'-0" deep foundation

Ring wall outside dia = $d = 2(25+1) = 27'$

Ring wall Inside dia. = $d_1 = 2(12.5-1) = 23'$

Width = 2.0'

Depth = 3.0'



$$A = \frac{\pi}{4}\left[27^2 - 23^2\right]$$

$$= 157.08 \text{ ft}^2$$

$$S = \frac{\pi}{32}\left[\frac{27^4 - 23^4}{27}\right]$$

$$= 914.84 \text{ ft}^4$$

Calculate W

$W_1' = W_Y + W_S = 5 + 13 = 18^k$

$W_2' = W_L \times \pi \times D = .4 \times \pi \times 25 = 31.42^k$

W_3' = Weight of Ftg

$$= .15\left\{\frac{\pi}{4}\left[27^2 - 23^2\right]\right\}3.0 = 70.7^k$$

$\Sigma W = 18 + 31.42 + 70.7 = 120.11^k$ use 125^k

Assume wt. of water is supported by slab or ground

$$q_1 = \frac{125}{157.08} = .796 \text{ KSF}$$

$M_{OTM} = 160^{ik}$ $M_d = 160 + 30 \times 3.0 = 250^{ik}$

$$q_2 = \frac{250}{914.84} = .273 \text{ KSF}$$

DL+Seis. $q_1 + q_2 = .796 + .274 = 1.07^{KSF} < 1.2^{KSF} \times 1.33$ OK

Assume LL = $.016 \times \frac{\pi}{4} \times 25^2 = 7.85^k$ $q_3 = \frac{7.85}{157.08} = .05^{KSF}$

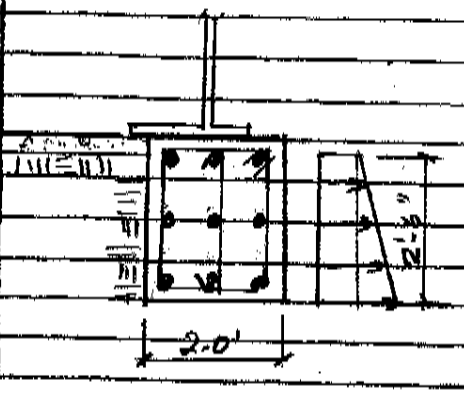
DL+LL $q_1 + q_3 = .796 + .05 = .846^{KSF} < 1.2^{KSF}$ OK

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Project No.	WW-PEB-2174-43062	Revised By:	Date:
			Sheet No. 9

Project Description Topock Groundwater Remediation Proj.

Ring Wall Foundation (cont'd.)

Hoop Tension



Soil Active Press

$= P_a = K_a w h'$ $h' = 2.5'$

$= .5 \times 120 \times 2.5$ $K_a = .50$

$= 150$ #/' $w = 120$ PSF/'

Surcharge

$P_s = w_H \times H \times .5$ $w_H = 62.4$ PSF/'

$= 62.4 \times 12.5 \times .5$ $H = 12.5$

$= 390$ #/'

Hoop Ten. $T_H = w_p h' R$

$w_p = \left[\frac{P_a}{2} + P_s \right] = \frac{150}{2} + 390 = 465$ #/'

Av.

$T_H = 465 \times 2.5 \times \frac{25}{2} = 14531\ \# = 14.53^k$

$T_{H_U} = 1.7 \times 14.53 = 24.7^k$

$A_{s_r} = \frac{24.7}{.9 \times 60} = .46\ in^2$

Min. $A_s = .002 \times 36 \times 24 = 1.73\ in^2$

USE 9 - #5 Bars $A_{s_a} = 9 \times .31 = 2.79\ in^2 > 1.73\ in^2$

USE 2'-0" W x 3'-0" Tk Ftg. w/ 9 - #5 Bars

w/ #4 Stirrups @ 18" o/c or #5 stirrups @ 24" o/c

Shear Reinf.

$A_v = \frac{50 b_w s}{f_y} = \frac{50 \times (36) \times 18}{60000} = .54\ in^2 < .2 \times 3 = .6\ in^2$

Alternate #5 Stirrups @ 24" o/c

$A_v = \frac{50 \times 36 \times 24}{60000} = .72\ in^2 < .31 \times 3 = .93\ in^2$

Attachment - 1

USGS.gov
NSHMP HazardApp.Jar

Conterminous 48 States
2003 NEHRP Seismic Design Provisions
Zip Code = 92363 (Needles, CA)
Spectral Response Accelerations Ss and S1
Ss and S1 = Mapped Spectral Acceleration Values
Data are based on a 0.05 deg grid spacing

Period (sec)	Centroid Sa (g)	
0.2	0.225	(Ss)
1.0	0.135	(S1)

Period (sec)	Maximum Sa (g)	
0.2	0.434	(Ss)
1.0	0.205	(S1)

Period (sec)	Minimum Sa (g)	
0.2	0.204	(Ss)
1.0	0.131	(S1)

Conterminous 48 States
2003 NEHRP Seismic Design Provisions
Zip Code = 86436 (Topock, AZ)
Spectral Response Accelerations Ss and S1
Ss and S1 = Mapped Spectral Acceleration Values
Data are based on a 0.05 deg grid spacing

Period (sec)	Centroid Sa (g)	
0.2	0.221	(Ss)
1.0	0.131	(S1)

Period (sec)	Maximum Sa (g)	
0.2	0.230	(Ss)
1.0	0.134	(S1)

Period (sec)	Minimum Sa (g)	
.2	.204	(Ss)
1.0	.131	(S1)

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Project No. ww-PE&-2174-043062		Sheet No. 25

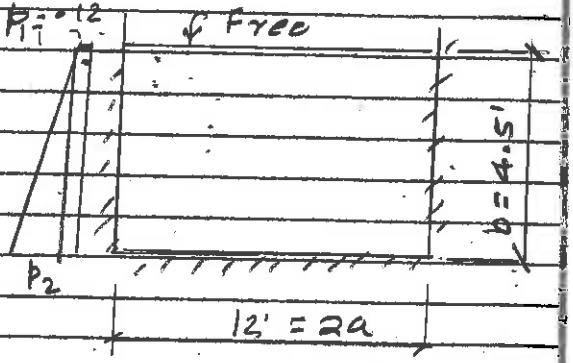
Project Description Topock Groundwater Remediation Proj.

Meter Valve Vaults

(A) 6'x8' Vault (B) 10'x12' Vault

P_{20} loading = 16 K

Design Vault (B)



Assume 3 sides fixed free @ Top

$P_1 = wh = .06 \times 2 = .12$ KSF

(Surcharge Truck Loading)

$P_2 = .06 \times 4.5 = .27$ KSF

$\frac{a}{b} = \frac{6}{4.5} = 1.33$

$M_x = .3304 \times .12 \times 4.5^2 + .0857 \times .27 \times 4.5^2$

$= .503 + .469 = 1.272$ IK

$M_y = .3508 \times .12 \times 4.5^2 + .1262 \times .27 \times 4.5^2$

$= .877 + .69 = 1.567$ IK

$R_x = 1.6267 \times .12 \times 4.5 + .3127 \times .27 \times 4.5 = 1.258$

$R_y = 1.0123 \times .12 \times 4.5 + .5047 \times .27 \times 4.5 = 1.166$

$d_{wall} = 12 - 2 - .25 = 9.75"$ $b = 12"$ $F = \frac{9.75^2}{1000} = .095$

$M_{umax} = 1.567 \times 1.7 \times 1.3 = 3.46$ IK $B_{umax} = 1.258 \times 2.21 = 2.78$ K

$v_u = \frac{2780}{.85 \times 12 \times 9.75} = .028$ KSI $= 28$ PSI $< 2\sqrt{5000}$ OK

#5 @ 12".

$\phi M_n = .9 \times .31 \times 60 \left(9.75 - \frac{.31 \times 60}{5 \times 12 \times 2}\right) = 13.38$ IK > 3.46 IK

USE #5 @ 12" Ea. Face Vert & Horiz. Reinf.

$f_c = 5$ KSI, $f_y = 60$ KSI

Footings

Wt. of walls + slab $= 2(12+10) \times 4.5 \times 1 \times .15 + 10 \times 8 \times 1 \times .15 = 42$ K (30) (12K)

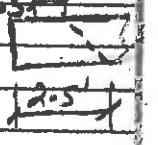
Wt. of Lid + platform + Truck $= 1 + 1 + 16 = 18$ K

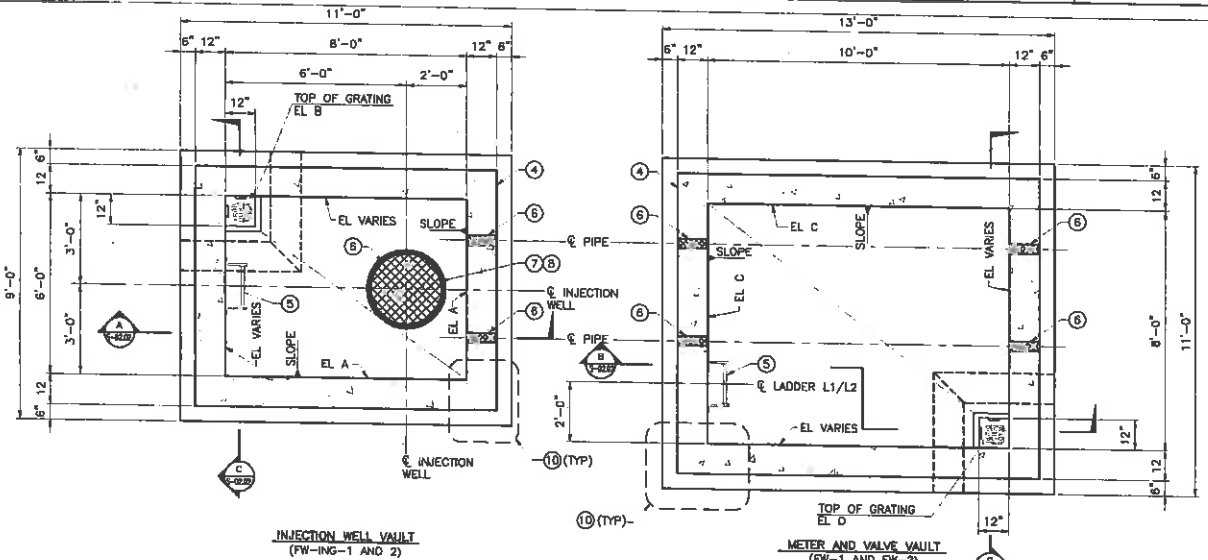
$P_{@wall} = \frac{(30+18)}{2} = 33^K$ $P = \frac{33}{10} = 3.3$ KSF

$P_{Ftg} = \frac{3.3}{2} + \frac{.15 \times 1}{1} = 1.80$ OK

#5 @ 12" Eq. Way OK by insp.

USE 11'x13'x1' Tk Ftg. w/ #5 @ 12" Ea. Way @ bot

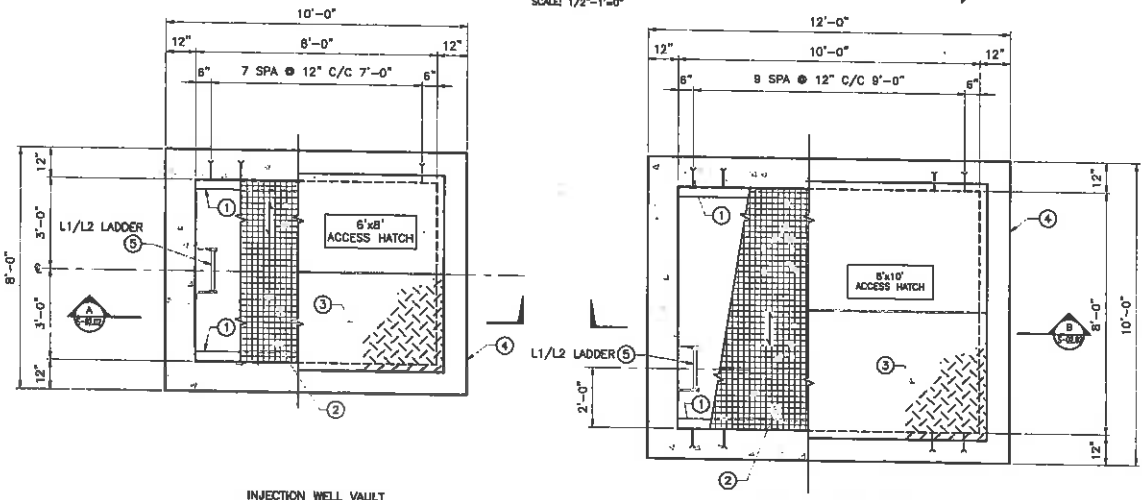




INJECTION WELL VAULT (FW-ING-1 AND 2)

METER AND VALVE VAULT (FW-1 AND FW-2)

BOTTOM PLAN
SCALE: 1/2"=1'-0"



INJECTION WELL VAULT (FW-ING-1 AND 2)

METER AND VALVE VAULT (FW-1 AND FW-2)

TOP PLAN
SCALE: 1/2"=1'-0"

KEY NOTE:

1. GRATING SUPPORT L4x4x3/8, PROVIDE 3/4"ø SS 316 AB @ 12 C/C MAX. MINIMUM EMBEDMENT = 8".
2. REMOVABLE FRP GRATING - 3" DEEP (HI 4730)x24"W FIBERGRATE OR APPROVED SECTIONS. (DESIGN LL = 300 PSF)
3. GALVANIZED STEEL ACCESS HATCH DESIGN LL= H20 LANDING
4. PRECAST CONCRETE WALL OPTION WILL BE ACCEPTABLE AS APPROVED BY ENGINEER.
5. ACCESS LADDER L-1 WITH EXTENSION LADDER L-2. SEE DETAIL 6/S-00.01
6. INDICATES WALL OR FLOOR PENETRATION. LOCATION PER MECHANICAL DRAWINGS. PROVIDE ADDITIONAL REINFORCING PER DETAIL 4/S-00.01
7. PROVIDE 1/2"x1/2" JOINT SEALANT AROUND WELL AT TOP.
8. ROUGHEN SURFACE OF NEAT GROUT POURED AROUND WALL AND APPLY BONDING AGENT PRIOR TO POURING BOTTOM SLAB.
10. PROVIDE CORNER REINFORCING PER DETAIL 5/S-00.01

CH2MHILL.

REVISIONS

NO.	DATE	DESCRIPTION	GM/SPEC	DRN	CHKD	SUPV	APVD BY

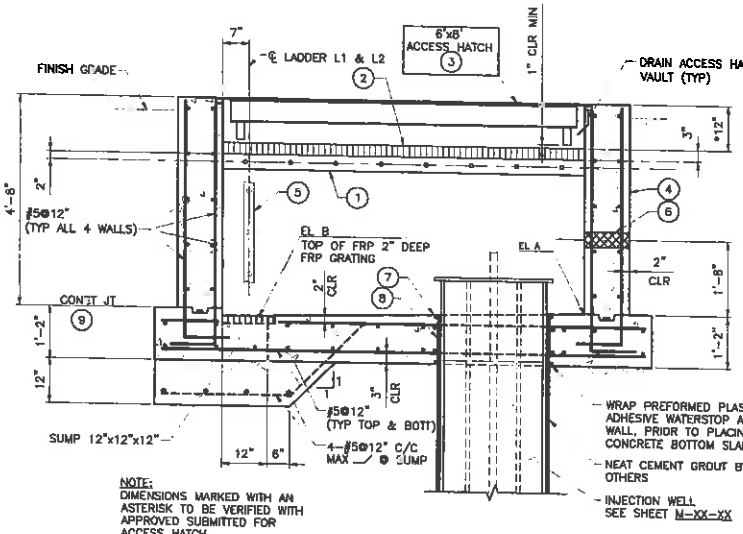
APPROVED BY: GD, SUPV, DSGN K. DOSHI, DRN M. DAVIS, CHKD V. BADAMI, QA, DATE, SCALES 1/2"=1'-0"

TOPOCK GROUNDWATER REMEDIATION PROJECT
INJECTION WELL AND METER-VALVE VAULTS TOP AND BOTTOM PLANS
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM, BILL OF MATL, ENG LIST, SUPERS, SUPED BY, SHEET NO. 01, SHEETS, 8-02.01, REV

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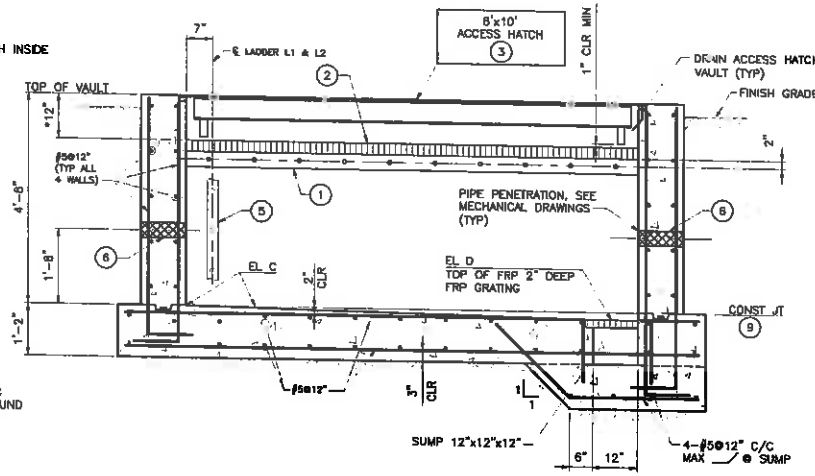
25B



NOTE:
DIMENSIONS MARKED WITH AN ASTERISK TO BE VERIFIED WITH APPROVED SUBMITTED FOR ACCESS HATCH

INJECTION WELL VAULT
(FW-INJ - 1 AND 2)

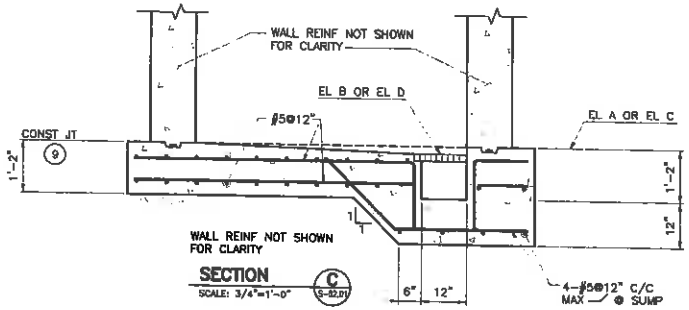
SECTION A
SCALE: 3/4"=1'-0"



METER AND VALVE VAULT
(FW-1 AND FW-2)

SECTION B
SCALE: 3/4"=1'-0"

FOR ELEVATIONS, SEE SHEET S-02.01



SECTION C
SCALE: 3/4"=1'-0"

KEY NOTE:

1. GRATING SUPPORT L4x4x3/8, PROVIDE 3/4"ø SS 316 AB @ 12 C/C MAX. MINIMUM EMBEDMENT = 6".
2. REMOVABLE FRP GRATING - 3" DEEP (HI 4730)x24"W FIBERGRATE OR APPROVED SECTIONS. (DESIGN LL = 300 PSF)
3. GALVANIZED STEEL ACCESS HATCH DESIGN LL= H20 LANDING
4. PRECAST CONCRETE WALL OPTION WILL BE ACCEPTABLE AS APPROVED BY ENGINEER.
5. ACCESS LADDER L-1 WITH EXTENSION LADDER L-2. SEE DETAIL 6 S-00.03
6. [redacted] INDICATES WALL OR FLOOR PENETRATION. LOCATION PER MECHANICAL DRAWINGS, PROVIDE ADDITIONAL REINFORCING PER DETAIL 4 S-00.02
7. PROVIDE 1/2"x1/2" JOINT SEALANT AROUND WELL AT TOP.
8. ROUGHEN SURFACE OF NEAT GROUT POURED AROUND WALL AND APPLY BONDING AGENT PRIOR TO POURING BOTTOM SLAB.
9. WALL HORIZONTAL CONSTRUCTION JOINT W/PREFORMED PLASTIC ADHESIVE WATERSTOP, SEE DETAIL 1 S-00.02

CH2MHILL.

REVISIONS

NO.	DATE	DESCRIPTION	BY/CHKD	DSN	CHKD	SUPV	APVD BY

APPROVED BY
SUPV
DSGN K. OOSHI
DRW M. DAVIS
CHKD V. BADANI
QC
DATE
SCALES 1/2"=1'-0"

TOPOCK GROUNDWATER REMEDIATION PROJECT
INJECTION WELL AND METER-VALVE VAULTS SECTIONS
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. of SHEETS
S-02.02
REV

PLOT DATE: 8/PLOTDATE PLOT TIME: 8/PLOTTIME
FILENAME: S2-X-XXXXS01.AD

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		kd
		e2

topock 200' pipe bridge

200pb.topock.r2d

July 25, 2012 at 8:01 AM

SK-1

Attn: Vinod From: Kirti

Max. Defl. for DL+LL = 8.83" = $\frac{l}{280} \approx \frac{l}{300}$

Max. Defl. for DL = 5.55" = $\frac{l}{432}$

Max. Defl for DL + ALT. LL = 6.95" = $\frac{l}{345}$

Max. horiz. defl. @ Roller = 1.59"

Max horiz. defl. @ Roller = 1.393"

PAGE 02/02
DPK CONSULTANTS INC
10/20/2009 01:22 5107921652

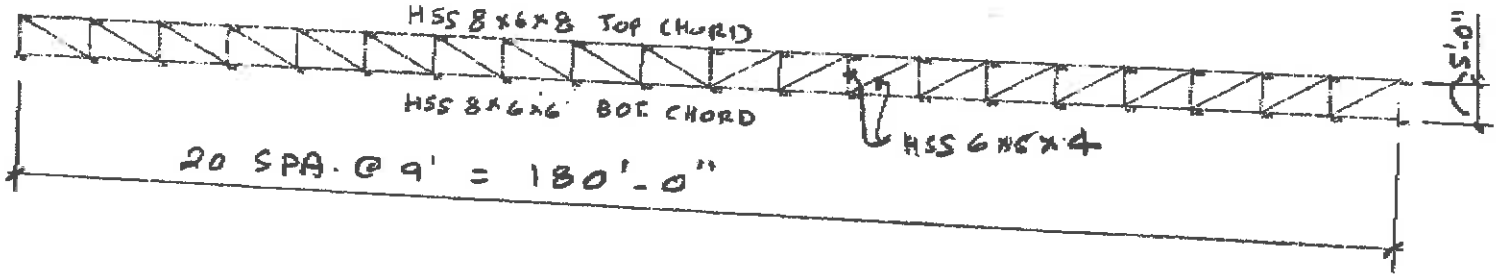
Attn: Vinod From: Kirti

Load Case

1 Max Defl. for DL+LL = 7.36 / 7.15" = $\frac{\ell}{302}$

2 Max Defl. for DL = 9.73 / 4.59"

3 Max. Defl. for DL+ALL. LL = 5.88" / 6.05 = $\frac{\ell}{367}$



e2	topock 180' pipe bridge	SK - 1
kd		July 24, 2012 at 3:45 PM
ww-peg-2174-043062		180pb.topock.r2d

Freshwater Injection/ Remedy-Produced Water Collection/ Conditioned Remedy Water Distribution and Disposal Hydraulic Network Modeling Calculations from EPANET Software

Topock Remediation Design

Hydraulic analysis of Freshwater Injection System

The piping for the freshwater injection system on the Topock Remediation project was sized from simulations of a hydraulic network model of the system. The hydraulic network model of the freshwater injection system proposed for Topock remediation was constructed using EPANET. EPANET is software that models water distribution piping systems. EPANET tracks the flow of water at each pipe, the pressure at each node, pumping heads and levels of water in tanks and reservoirs. Chemical species can be tracked, although that was not needed for the freshwater system at Topock.

Pipe junctions, reservoirs and tanks are represented as nodes. A listing of nodes is contained on the following pages. Pipes, pumps and valves are represented as links. A listing of links is contained on the pages following the node listing. A map showing the location of all nodes and links is shown on the sheet following the links listing.

The piping routes and corridors have been approved by the client, Pacific Gas & Electric; however, they are subject to change pending stakeholder and regulatory review. The following summary describes the development of the hydraulic model:

Junction nodes, tanks and wells (modeled as pumps attached to an underground reservoir) have been located on the plan and profile sheets for the 60% submittal. Some liberties were taken with underground reservoir (well) locations to make the node and link map more legible, however, this did not affect the accuracy of the analysis as exact coordinates were used in model simulations. A summary of the model development is as follows:

Ground elevations for pipe junctions, reservoirs, wells and tanks are taken from the 60% plan and profile sheets, which were based on the Toponex aerial survey.

Pipe lengths have been taken off from plan and profile drawings.

Probable maximum flows are used for demands. The following demands are used:

- Freshwater Injection Well no. 1 (FW-1, node 73) = 200 gpm
- Freshwater Injection Well no. 2 (FW-2, node 20) = 100 gpm
- Inner Recirculation Loop Well no. 1 (IRL-1, node 50) = 0 gpm during the maximum condition
- Inner Recirculation Loop Well no. 2 (IRL-2, node 56) =200 gpm during the maximum condition
- Inner Recirculation Loop Well no. 3 (IRL-3, node 62) = 200 gpm during the maximum condition
- Inner Recirculation Loop Well no. 4 (IRL-4, node 68) = 200 gpm during the maximum condition
- Topock Compressor Station (node 11) = 110 gpm
- Transwestern bench service (node 29) = 0 gpm – flows are too trivial and sporadic to consider as part of the maximum case

- MW-20 bench service (node 35) = 0 gpm – flows are too trivial and sporadic to consider as part of the maximum case
- TCS Loop Injection Well no. 1 (TCS-1, node 24) = 20 gpm
- TCS Loop Injection Well no. 2 (TCS-2, node 26) = 20 gpm
- Topock residential customers (node 103) = 5 gpm

Inner Loop injection wells no 3 and 4 and TCS loop injection wells no. 1 and 2 are normally fed with carbon amended water from the floodplain extracted wells, but will be designed to accept freshwater as a backup measure.

Injection wells will be fed from a pressure reducing valve (PRV). Minimum pressure upstream of the PRV is to be 5 psi.

There are three sources of supply. All are existing wells located in Arizona (where water quality is more suitable for freshwater injection). Two of the wells currently discharge to PG & E's water system.

- Havasu National Wildlife Refuge well (node HNWR and pump 201) currently supplies a revegetation project in Topock marsh. A new 14 inch diameter transmission main is proposed to connect this well to the existing PG & E potable water tanks. A manufacturer's pump curve was used to model this pump. The pumping well level has been observed to be about 410 feet (above sea level) and this was used for the analysis.
- Topock 2 and 3 currently supply PG & E's Topock Compressor Station with a 6 inch diameter pipe to the existing potable water tanks. A manufacturer's pump curve was used to model this pump. The pumping well levels are not known for these wells. A level of 400 feet was assumed based on observations from similar wells.

There are two existing fresh water tanks located above TCS at a base elevation of 672 feet (above sea level). Each tank is 30 feet high and contains 210,000 gallons. A minimum tank level of 2 feet and maximum tank level of 28 feet was assumed for this analysis.

Hazen-Williams C value of 130 was assumed for all existing pipes. New steel pipes were assumed to have a C value of 130 and new HDPE and PVC pipes were assumed to have a C value of 150.

Pipe sizing is an iterative process. After the initial simulation, pipe diameters for various segments of pipes are increased or decreased for subsequent simulations until an optimum size is selected for each segment. The criterion used for determining optimum size was based on unit head loss. In general, unit head losses of between 1 to 10 feet per 1,000 foot of pipe length yield the optimal combination of pipe capital cost and pumping energy costs. This was the criteria used to size most of the pipes. The only exceptions to this were for 1) short segments of pipes, such as pumping manifolds and 2) dead end pipes connected to injection wells. In the latter case, there was excess pressure which would have been dissipated in the pressure reducing valve. A larger pipe size does not serve any purpose in this case.

The freshwater system was modeled with a parallel pipe along National Trails Highway and for the IM-3 access road up to IRL-3. Low water levels (in the existing potable water storage tanks) and high water

levels were simulated for this configuration. The results from these simulations are contained in the following sections.

The combined pumping capacity of the existing well pumps at HNWR-1, Topock 2 and 3 are sufficient to meet probable maximum system demands.

Freshwater Injection System - Junction, Reservoir and Tank Data

Network Table - Nodes

Node ID	Elevation ft	Base Demand GPM
Junc 1	382	0
Junc 2	466	0
Junc 3	467	0
Junc 4	467	0
Junc 5	504	0
Junc 6	467	0
Junc 7	507	0
Junc 8	511	0
Junc 9	551	0
Junc 10	628	0
Junc 11	632	110
Junc 12	637	0
Junc 13	633	0
Junc 14	610	0
Junc 15	605	0
Junc 16	605	0
Junc 17	595	0

Freshwater Injection System - Junction, Reservoir and Tank Data

Node ID	Elevation ft	Base Demand GPM
Junc 18	562	0
Junc 19	542	0
Junc 20	542	100
Junc 21	625	0
Junc 22	622	0
Junc 23	620	0
Junc 24	620	20
Junc 25	584	0
Junc 26	584	20
Junc 27	517	0
Junc 28	532	0
Junc 29	535	0
Junc 30	505	0
Junc 31	482	0
Junc 32	457	0
Junc 33	459	0
Junc 34	468	0
Junc 35	494	0

Freshwater Injection System - Junction, Reservoir and Tank Data

Node ID	Elevation ft	Base Demand GPM
Junc 36	494	0
Junc 37	493	0
Junc 38	492	0
Junc 39	476	0
Junc 40	476	0
Junc 41	476	0
Junc 42	527	0
Junc 43	478	0
Junc 44	476	0
Junc 45	496	0
Junc 46	497	0
Junc 47	497	0
Junc 48	497	0
Junc 49	497	0
Junc 50	384	0
Junc 51	548	0
Junc 52	552	0
Junc 53	552	0

Freshwater Injection System - Junction, Reservoir and Tank Data

Node ID	Elevation ft	Base Demand GPM
Junc 54	552	0
Junc 55	552	0
Junc 56	395	200
Junc 57	552	0
Junc 58	546	0
Junc 59	546	0
Junc 60	546	0
Junc 61	546	0
Junc 62	389	200
Junc 63	554	0
Junc 64	567	0
Junc 65	567	0
Junc 66	557	0
Junc 67	557	0
Junc 68	557	200
Junc 69	559	0
Junc 70	559	0
Junc 71	559	0

Freshwater Injection System - Junction, Reservoir and Tank Data

Node ID	Elevation ft	Base Demand GPM
Junc 72	559	0
Junc 73	391	200
Junc 101	520	0
Junc 102	506	0
Junc 103	502	5
Junc 104	502	0
Junc 105	502	0
Junc 106	507	0
Junc 15A	605	0
Junc 23A	620	0
Junc 25A	584	0
Junc 52A	552	0
Junc 58A	546	0
Junc 64A	567	0
Junc 69A	559	0
Junc 46A	497	0
Junc 100A	672	0
Resvr HNWR	400	#N/A

Freshwater Injection System - Junction, Reservoir and Tank Data

Node ID	Elevation ft	Base Demand GPM
Resvr Topock2&3	410	#N/A
Tank 100B	672	#N/A
Tank 100C	672	#N/A

Freshwater Injection System - Pipe, Pump and Valve Data

Network Table - Links

Link ID	Length ft	Diameter in	Roughness
Pipe 1	101	12	130
Pipe 2	228	14	130
Pipe 3	43	12	130
Pipe 4	3475	12	130
Pipe 5	742	14	150
Pipe 6	82	14	130
Pipe 7	1511	14	130
Pipe 8	437	14	150
Pipe 9	1524	14	150
Pipe 10	79	14	130
Pipe 11	151	6	130
Pipe 12	154	6	150
Pipe 13	262	6	150
Pipe 14	70	4	150
Pipe 15	137	4	150
Pipe 16	97	4	150
Pipe 17	227	4	130

Freshwater Injection System - Pipe, Pump and Valve Data

Link ID	Length ft	Diameter in	Roughness
Pipe 18	224	4	150
Pipe 19	206	6	150
Pipe 20	139	4	150
Pipe 21	688	4	150
Pipe 22	205	4	150
Pipe 23	56	4	150
Pipe 24	145	2	150
Pipe 25	34	2	150
Pipe 26A	655	8	150
Pipe 26B	655	8	150
Pipe 27	124	3	150
Pipe 28	124	3	150
Pipe 29A	267	8	150
Pipe 29B	267	8	150
Pipe 30A	306	8	150
Pipe 30B	306	8	150
Pipe 31A	1009	8	150
Pipe 31B	1009	8	150

Freshwater Injection System - Pipe, Pump and Valve Data

Link ID	Length ft	Diameter in	Roughness
Pipe 32A	278	8	150
Pipe 32B	278	8	150
Pipe 33A	462	8	150
Pipe 33B	462	8	150
Pipe 34A	242	8	150
Pipe 34B	242	8	150
Pipe 35A	67	8	150
Pipe 35B	67	8	150
Pipe 36A	43	8	150
Pipe 36B	43	8	150
Pipe 37A	140	8	150
Pipe 37B	140	8	150
Pipe 38A	211	8	150
Pipe 38B	211	8	150
Pipe 39A	95	8	150
Pipe 39B	95	8	150
Pipe 40A	65	8	150
Pipe 40B	65	8	150

Freshwater Injection System - Pipe, Pump and Valve Data

Link ID	Length ft	Diameter in	Roughness
Pipe 41A	118	8	150
Pipe 41B	118	8	150
Pipe 42A	2096	6	150
Pipe 42B	2096	6	150
Pipe 43A	283	6	150
Pipe 43B	283	6	150
Pipe 44A	316	6	150
Pipe 44B	316	6	150
Pipe 45	52	6	150
Pipe 46	49	6	150
Pipe 47	5	6	150
Pipe 48	25	6	150
Pipe 49	113	6	150
Pipe 50A	544	6	150
Pipe 50B	544	6	150
Pipe 51	86	6	150
Pipe 52	49	6	150
Pipe 53	5	6	150

Freshwater Injection System - Pipe, Pump and Valve Data

Link ID	Length ft	Diameter in	Roughness
Pipe 54	25	6	150
Pipe 55	157	6	150
Pipe 56A	143	6	150
Pipe 56B	143	6	150
Pipe 57	58	6	150
Pipe 58	49	6	150
Pipe 59	5	6	150
Pipe 60	25	6	150
Pipe 61	158	6	150
Pipe 62	42	6	150
Pipe 63	124	6	150
Pipe 64	49	6	150
Pipe 65	443	6	150
Pipe 66	25	6	150
Pipe 67	156	6	150
Pipe 68	953	6	150
Pipe 69	140	6	150
Pipe 70	5	6	150

Freshwater Injection System - Pipe, Pump and Valve Data

Link ID	Length ft	Diameter in	Roughness
Pipe 71	37	6	150
Pipe 72	136	6	150
Pipe 101	2842	6	130
Pipe 102	17	8	130
Pipe 103	229	8	130
Pipe 104	284	4	130
Pipe 105	180	6	130
Pipe 106	50	6	130
Pipe 107	109	6	130
Pipe 108	52	6	130
Pipe 109	52	6	130
Pump 201	#N/A	#N/A	#N/A
Pump 202	#N/A	#N/A	#N/A
Pump 203	#N/A	#N/A	#N/A
Valve 301	#N/A	4	#N/A
Valve 302	#N/A	4	#N/A
Valve 303	#N/A	2	#N/A
Valve 304	#N/A	4	#N/A

Freshwater Injection System - Pipe, Pump and Valve Data

Link ID	Length ft	Diameter in	Roughness
Valve 305	#N/A	4	#N/A
Valve 306	#N/A	4	#N/A
Valve 307	#N/A	4	#N/A
Valve 308	#N/A	4	#N/A

Freshwater Injection System
Link Tabulation

Link	Type	Mtl	Start Node	End Node
1	Pipe	Stl	1	2
2	Pipe	Stl	2	3
3	Pipe	Stl	3	4
4	Pipe	HDPE	4	5
5	Pipe	HDPE	5	6
6	Pipe	Stl	6	7
7	Pipe	Stl	7	8
8	Pipe	HDPE	8	9
9	Pipe	HDPE	9	10
10	Pipe	Stl	10	11
11	Pipe	Stl	11	12
12	Pipe	HDPE	12	13
13	Pipe	HDPE	13	14
14	Pipe	HDPE	14	15
301	Valve	PVC	15	15A
15	Pipe	PVC	15A	16
16	Pipe	HDPE	16	17
17	Pipe	Stl	17	18
18	Pipe	HDPE	18	19
19	Pipe	Stl	19	20
20	Pipe	HDPE	13	21
21	Pipe	HDPE	21	22
22	Pipe	HDPE	22	23
302	Valve	PVC	23	23A
23	Pipe	PVC	23A	24
24	Pipe	HDPE	22	25
303	Valve	PVC	25	25A
25	Pipe	PVC	25A	26
26A	Pipe	HDPE	9	27
26B	Pipe	HDPE	9	27
27	Pipe	HDPE	27	28
28	Pipe	HDPE	28	29
29A	Pipe	HDPE	27	30

Freshwater Injection System
Link Tabulation

Link	Type	Mtl	Start Node	End Node
29B	Pipe	HDPE	27	30
30A	Pipe	HDPE	30	31
30B	Pipe	HDPE	30	31
31A	Pipe	HDPE	31	32
31B	Pipe	HDPE	31	32
32A	Pipe	HDPE	32	33
32B	Pipe	HDPE	32	33
33A	Pipe	HDPE	33	34
33B	Pipe	HDPE	33	34
34A	Pipe	HDPE	34	35
34B	Pipe	HDPE	34	35
35A	Pipe	HDPE	35	36
35B	Pipe	HDPE	35	36
36A	Pipe	HDPE	36	37
36B	Pipe	HDPE	36	37
37A	Pipe	HDPE	37	38
37B	Pipe	HDPE	37	38
38A	Pipe	HDPE	38	39
38B	Pipe	HDPE	38	39
39A	Pipe	HDPE	39	40
39B	Pipe	HDPE	39	40
40A	Pipe	HDPE	40	41
40B	Pipe	HDPE	40	41
41A	Pipe	HDPE	41	42
41B	Pipe	HDPE	41	42
42A	Pipe	HDPE	42	43
42B	Pipe	HDPE	42	43
43A	Pipe	HDPE	43	44
43B	Pipe	HDPE	43	44
44A	Pipe	HDPE	44	45
44B	Pipe	HDPE	44	45
45	Pipe	HDPE	45	46
304	Valve	PVC	46	46A

Freshwater Injection System
Link Tabulation

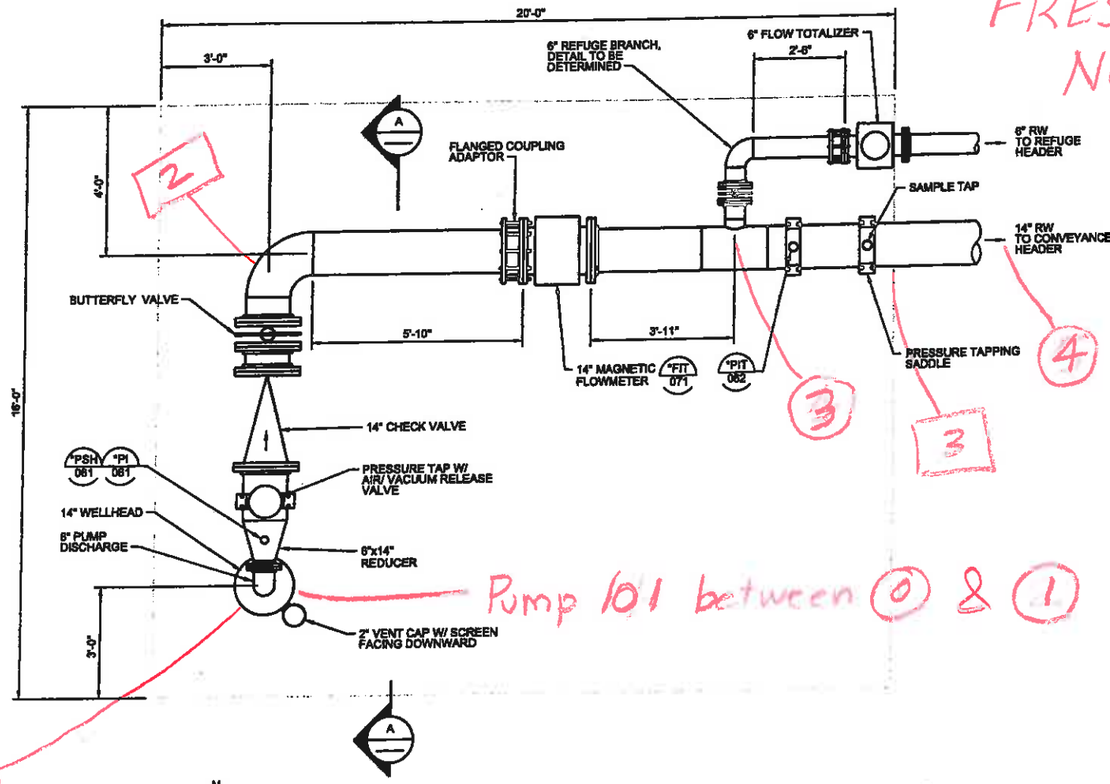
Link	Type	Mtl	Start Node	End Node
46	Pipe	PVC	46A	47
47	Pipe	PVC	47	48
48	Pipe	PVC	48	49
49	Pipe	Stl	49	50
50A	Pipe	HDPE	45	51
50B	Pipe	HDPE	45	51
51	Pipe	HDPE	51	52
305	Valve	PVC	52	52A
52	Pipe	PVC	52A	53
53	Pipe	PVC	53	54
54	Pipe	PVC	54	55
55	Pipe	Stl	55	56
56A	Pipe	HDPE	51	57
56B	Pipe	HDPE	51	57
57	Pipe	HDPE	57	58
306	Valve	PVC	58	58A
58	Pipe	PVC	58A	59
59	Pipe	PVC	59	60
60	Pipe	PVC	60	61
61	Pipe	Stl	61	62
62	Pipe	HDPE	57	63
63	Pipe	HDPE	63	64
307	Valve	PVC	64	64A
64	Pipe	PVC	64A	65
65	Pipe	HDPE	65	66
66	Pipe	PVC	66	67
67	Pipe	Stl	67	68
68	Pipe	HDPE	63	69
308	Valve	PVC	69	69A
69	Pipe	PVC	69A	70
70	Pipe	PVC	70	71
71	Pipe	PVC	71	72
72	Pipe	Stl	72	73

Freshwater Injection System
Link Tabulation

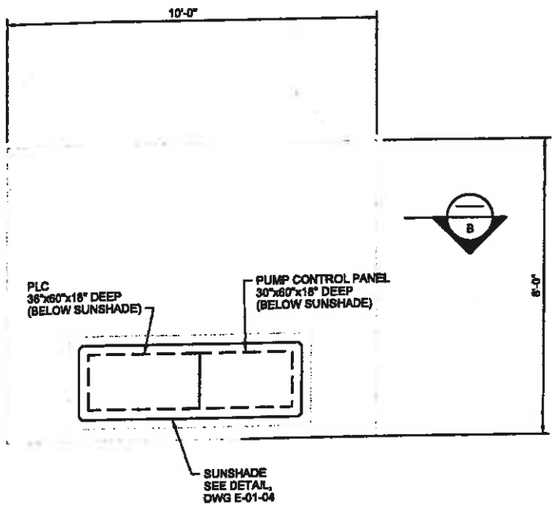
Link	Type	Mtl	Start Node	End Node
101	Pipe	Stl	101	102
102	Pipe	HDPE	102	103
103	Pipe	HDPE	103	104
104	Pipe	HDPE	104	105
105	Pipe	Stl	105	106
106	Pipe	Stl	106	7
107	Pipe	Stl	11	100A
108	Pipe	Stl	100A	100B
109	Pipe	Stl	100A	100C
201	Pump		HNWR	1
202	Pump		Topock 2 & 3	101
203	Pump		Topock 2 & 3	101

FRESHWATER SYSTEM NODE AND LINK MAP

1/41



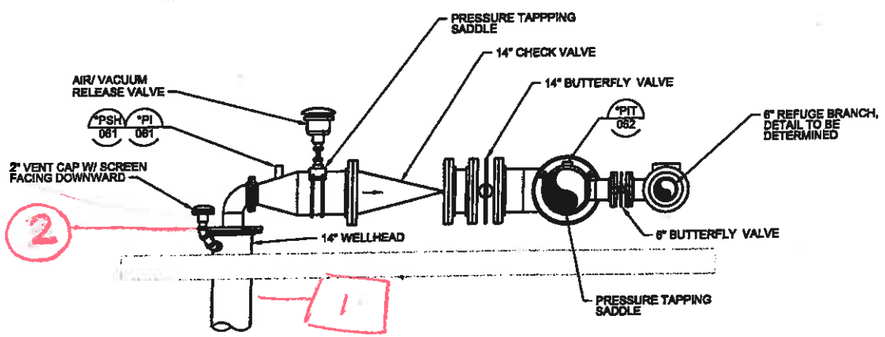
N **WELL HEAD PIPING PAD PLAN**
1/2"=1'-0"



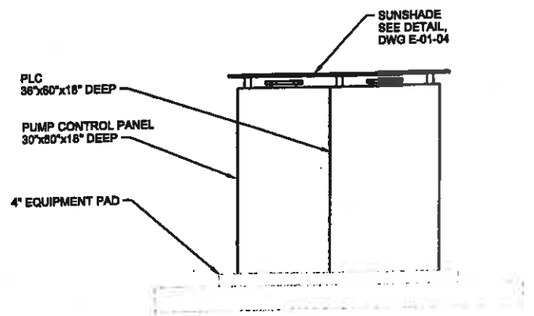
N **ELECTRICAL PAD PLAN**
1/2"=1'-0"

○ = Node, Res or Tank

□ = Pipe, Pump or Valve



A **SECTION**
1/2"=1'-0"



B **SECTION**
1/2"=1'-0"

NOTES:

1. SEE DWG E-01-04 FOR ELECTRICAL PAD DETAIL AND DWG C-01-01 FOR CIVIL LAYOUT.

CH2MHILL.

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

APPROVED BY	
	SO
	SUPV
	DSGN
	DWN JAMROS
	CHKD
	OK
	DATE
	SCALES

TOPOCK GROUNDWATER REMEDIATION PROJECT
HNWR-1 WELL HEAD PIPING AND ELECTRICAL PAD PLAN AND SECTION
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM	
BILL OF MATL	
DWG LIST	
SUPSDS	
SUPSD BY	
SHEET NO.	of SHEETS
M-01-01	REV

FILENAME: ___DGN ___-___-04 ___

PLOT DATE: 20120824 PLOT TIME: 11:24:04 AM

FILENAME: CH-M-3000-0101AD.dgn

2/41

FOR CONT. SEE DWG. C-07-21
MATCH LINE STA. 71+00

HNWR WELL SITE PLAN
SEE DWG. C-01-01

END PIPELINE "B"
STA. 80+49.06
N 2104163.03
E 7619644.32

CO. HWY 10 OATMAN–TOPOCK HWY.

PIPELINE "B"

71+00 72+00 73+00 74+00 75+00 76+00 77+00 78+00 79+00 80+00

GRAPHIC SCALE: 1"=40'

PLAN
1" = 40'

NOTES

1. DEPTHS OF EXISTING UTILITIES ARE UNKNOWN. ALL POTENTIAL CONFLICTS BETWEEN NEW PIPE CONSTRUCTION AND EXISTING UTILITIES WILL BE POTHOLED PRIOR TO 100% DESIGN. A DETERMINATION WILL BE MADE WHETHER TO RELOCATE EXISTING UTILITIES OR RE-ROUTE NEW PIPE TRENCHES AROUND EXISTING UTILITIES. THIS WILL BE INCORPORATED INTO 100% DESIGN.
2. THE NEW PIPELINE ALIGNMENT SHOWS CENTER OF TRENCH. THE NUMBER AND SIZES OF PIPE IN EACH TRENCH VARIES. REFER TO PIPE SECTION NUMBER ON EACH PLAN AND PROFILE SHEET AND PIPE SCHEDULE ON DRAWING C-07-03 FOR NUMBER AND SIZE OF EACH PIPE. REFER TO TRENCH DETAILS ON DRAWINGS C-07-60, C-07-61 AND C-07-62 FOR ARRANGEMENT OF PIPING IN EACH TRENCH SECTION.
3. MAINTAIN 2' HORIZONTAL CLEARANCE FROM EXISTING COMMUNICATIONS CONDUIT.

TRENCH SECTION B7, DET. 13, DWG. C-07-61

TRENCHLESS CROSSING
BORE AND JACK SECTION B8, DET. 5, DWG. C-07-60

TRENCH SECTION B9
DET. 13, DWG. C-07-61

CO. HWY 10
OATMAN - TOPOCK HWY.

STA. 78+22

STA. 79+67

SEE DWG. C-07-21
MATCH LINE STA. 71+00

3' MIN. COVER

EXIST. GRADE AT
CENTERLINE OF PIPE

PIPELINE "B"
14" FW

14" DIA. HDPE WITH
30" DIA. STEEL CASING

PIPELINE "B"
14" FW

STA. 80+32
BLOW-OFF

1
C-07-07

X
C-07-XX
DETAIL

END PIPELINE "B" STA. 80+49.06

520 510 500 490 480 470 460 450 440 430

GRAPHIC SCALE: 1"=40' HORIZ.
GRAPHIC SCALE: 1"=10' VERT.

PROFILE
1" = 40' HORIZ.
1" = 10' VERT.

E2 Consulting Engineers, Inc.
1800 Powell Street, Ste. 250
Emeryville, CA 94608
(510) 652-1164

CH2MHILL

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
		REVISIONS					

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
		REVISIONS					

APPROVED BY
SD
SUPV
DSGN PT
DWN WITH
CHKD PT
QA
DATE
SCALES

TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE "B" PLAN AND PROFILE
STA. 71+00 TO STA. 80+49.06

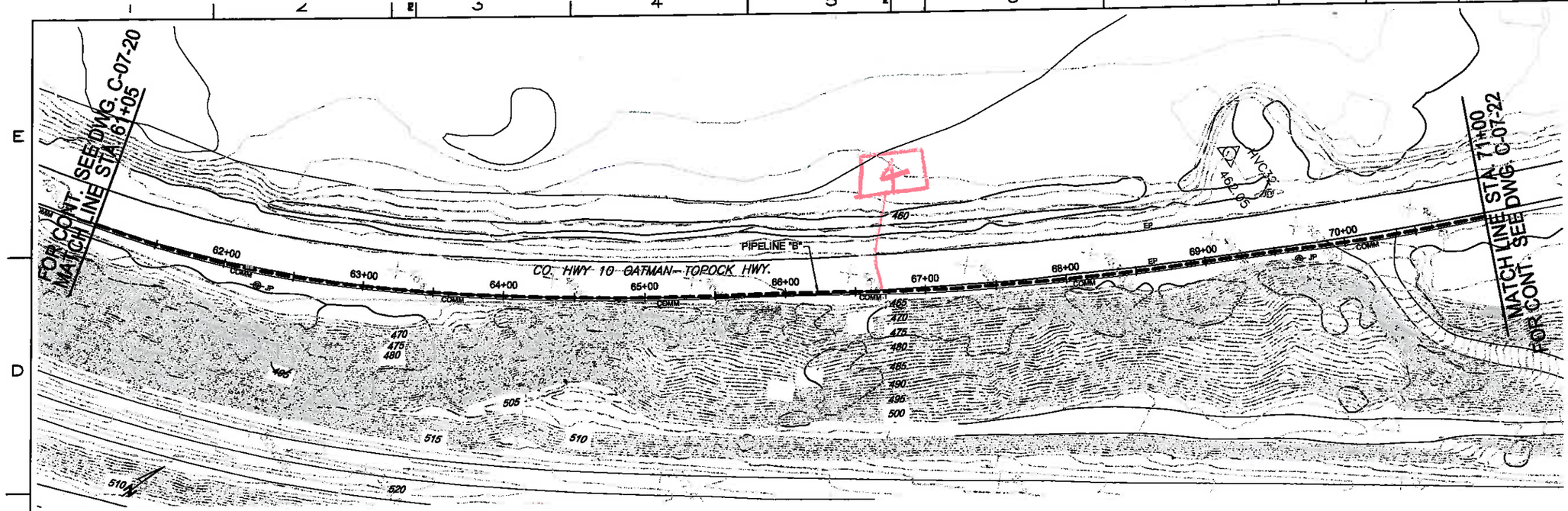
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

L

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. of SHEETS
C-07-22
REV

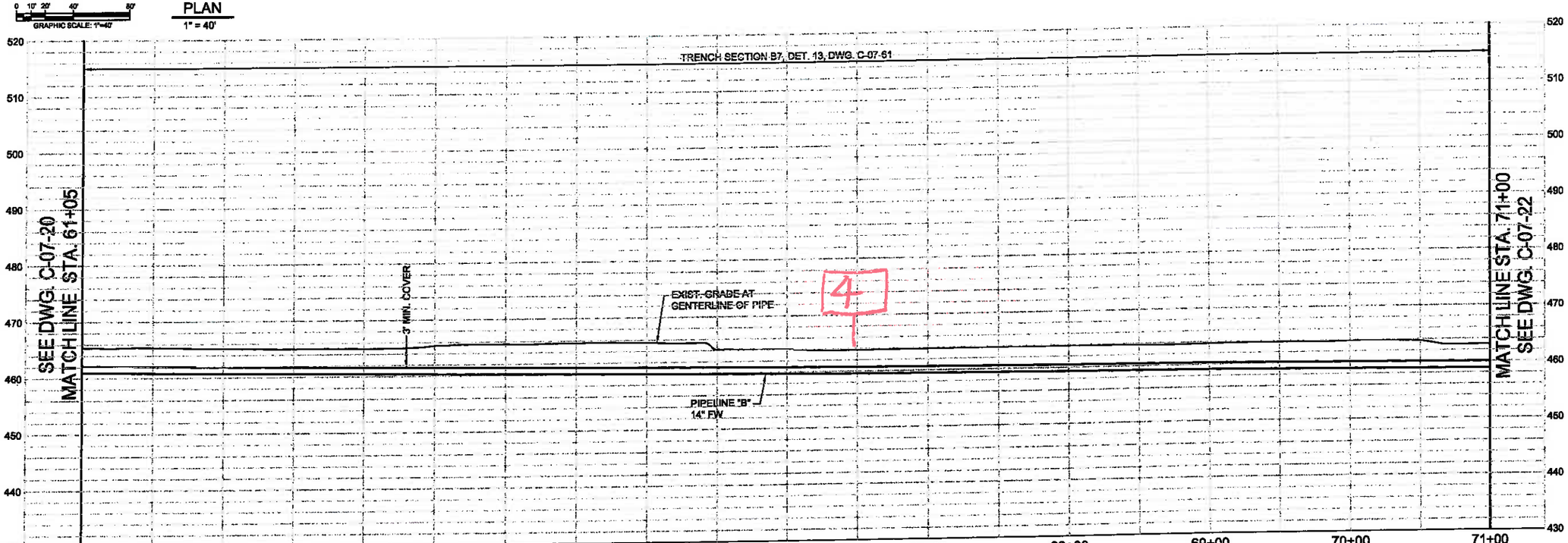
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GRAPHIC SCALE: 1"=40'

PLAN
1" = 40'



GRAPHIC SCALE: 1"=40' HORIZ.
GRAPHIC SCALE: 1"=10' VERT.

PROFILE
1" = 40' HORIZ.
1" = 10' VERT.

NOTES

1. DEPTHS OF EXISTING UTILITIES ARE UNKNOWN. ALL POTENTIAL CONFLICTS BETWEEN NEW PIPE CONSTRUCTION AND EXISTING UTILITIES WILL BE POTHOLED PRIOR TO 100% DESIGN. A DETERMINATION WILL BE MADE WHETHER TO RELOCATE EXISTING UTILITIES OR RE-ROUTE NEW PIPE TRENCHES AROUND EXISTING UTILITIES. THIS WILL BE INCORPORATED INTO 100% DESIGN.
2. THE NEW PIPELINE ALIGNMENT SHOWS CENTER OF TRENCH. THE NUMBER AND SIZES OF PIPE IN EACH TRENCH VARIES. REFER TO PIPE SECTION NUMBER ON EACH PLAN AND PROFILE SHEET AND PIPE SCHEDULE ON DRAWING C-07-03 FOR NUMBER AND SIZE OF EACH PIPE. REFER TO TRENCH DETAILS ON DRAWINGS C-07-60, C-07-61 AND C-07-62 FOR ARRANGEMENT OF PIPING IN EACH TRENCH SECTION.
3. MAINTAIN 2' HORIZONTAL CLEARANCE FROM EXISTING COMMUNICATIONS CONDUIT.

E2 Consulting Engineers, Inc.
1000 Pond Street, Ste. 250
Emeryville, CA 94608
(510) 652-1164

CH2MHILL.

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

APPROVED BY
ISO
SUPV
DSGN PT
DWN WTH
CHKD PT
QX
DATE
SCALES

TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE "B" PLAN AND PROFILE
STA. 61+05 TO STA. 71+00
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

L

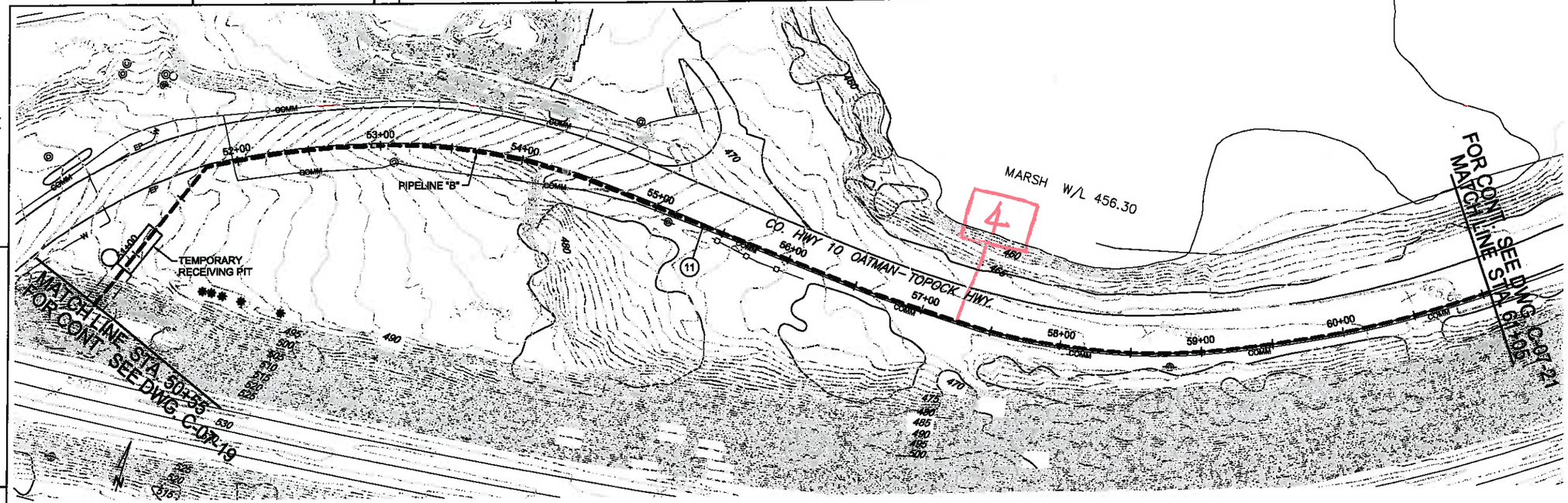
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BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. of SHEETS
C-07-21
REV

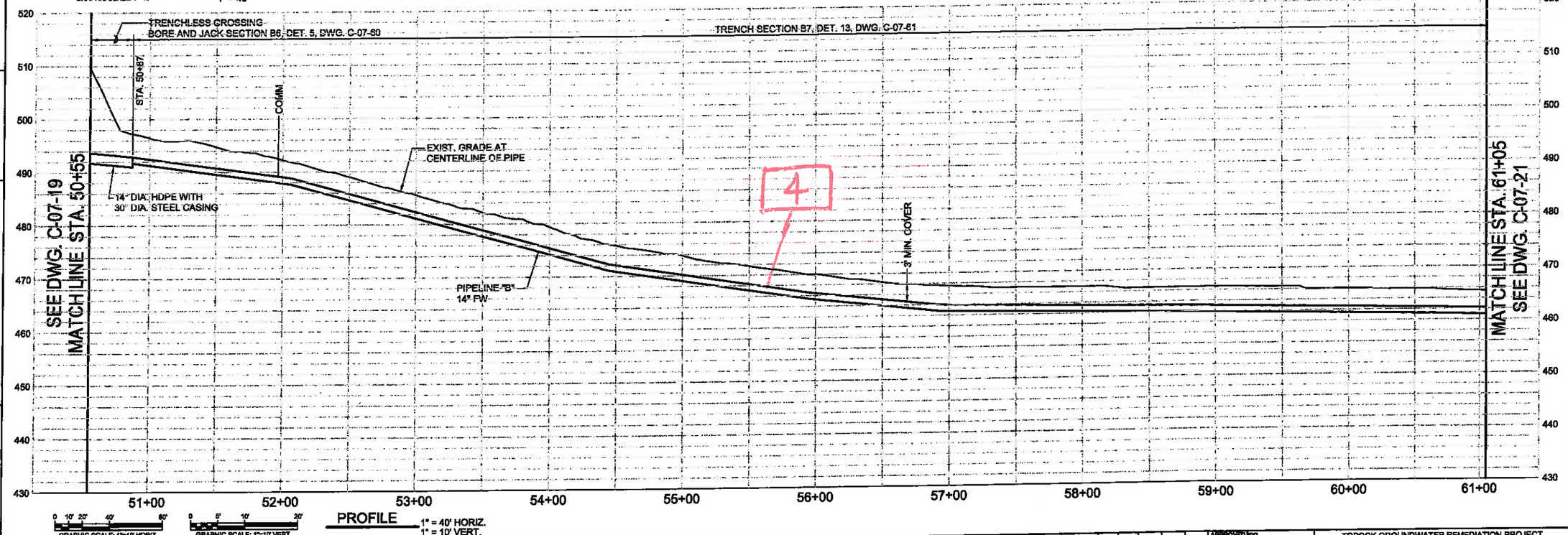
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FILENAME: E2-C-XXX-0720.dwg

4/41

NOTES

1. DEPTHS OF EXISTING UTILITIES ARE UNKNOWN. ALL POTENTIAL CONFLICTS BETWEEN NEW PIPE CONSTRUCTION AND EXISTING UTILITIES WILL BE POTHOLED PRIOR TO 100% DESIGN. A DETERMINATION WILL BE MADE WHETHER TO RELOCATE EXISTING UTILITIES OR RE-ROUTE NEW PIPE TRENCHES AROUND EXISTING UTILITIES. THIS WILL BE INCORPORATED INTO 100% DESIGN.
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3. MAINTAIN 2' HORIZONTAL CLEARANCE FROM EXISTING COMMUNICATIONS CONDUIT.





E2 Consulting Engineers, Inc.
1900 Powell Street, Ste. 250
Emeryville, CA 94608
(510) 652-1164

CH2MHILL.

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

APPROVED BY
SO
SUPV
DSGN PT
DWN WTH
CHKD PT
QC
DATE
SCALES

TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE "B" PLAN AND PROFILE
STA. 50+55 TO STA. 61+05
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

L

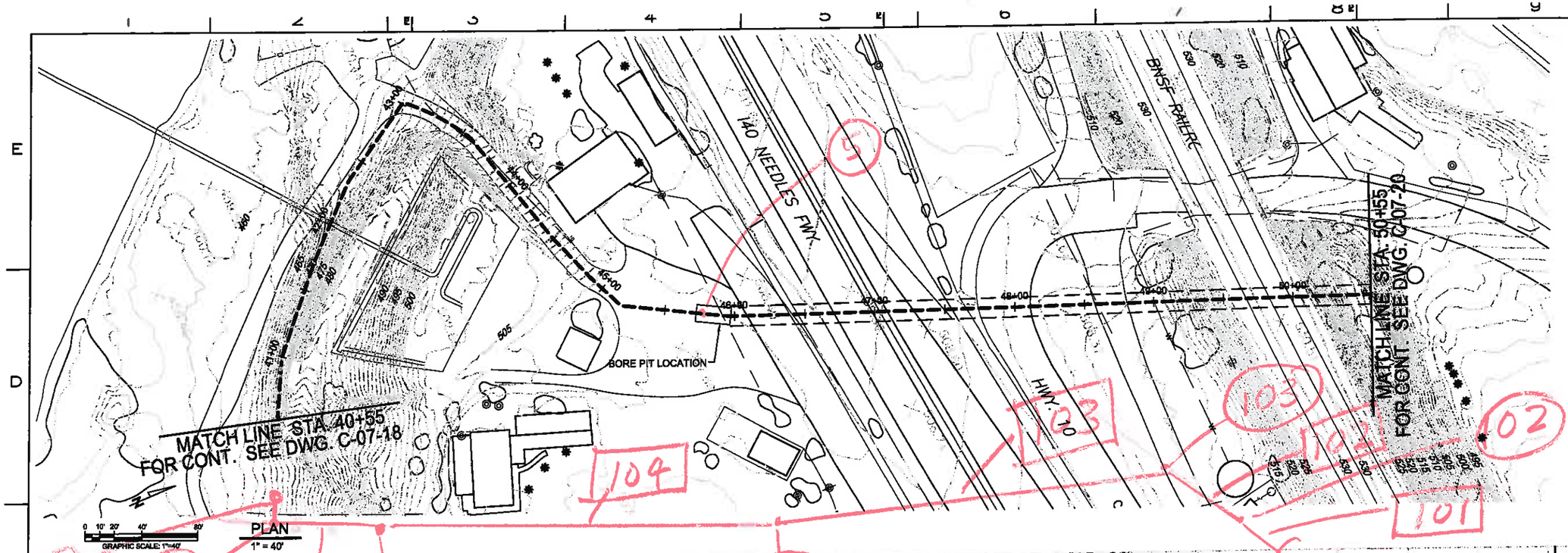
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BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. of SHEETS
C-07-20
REV

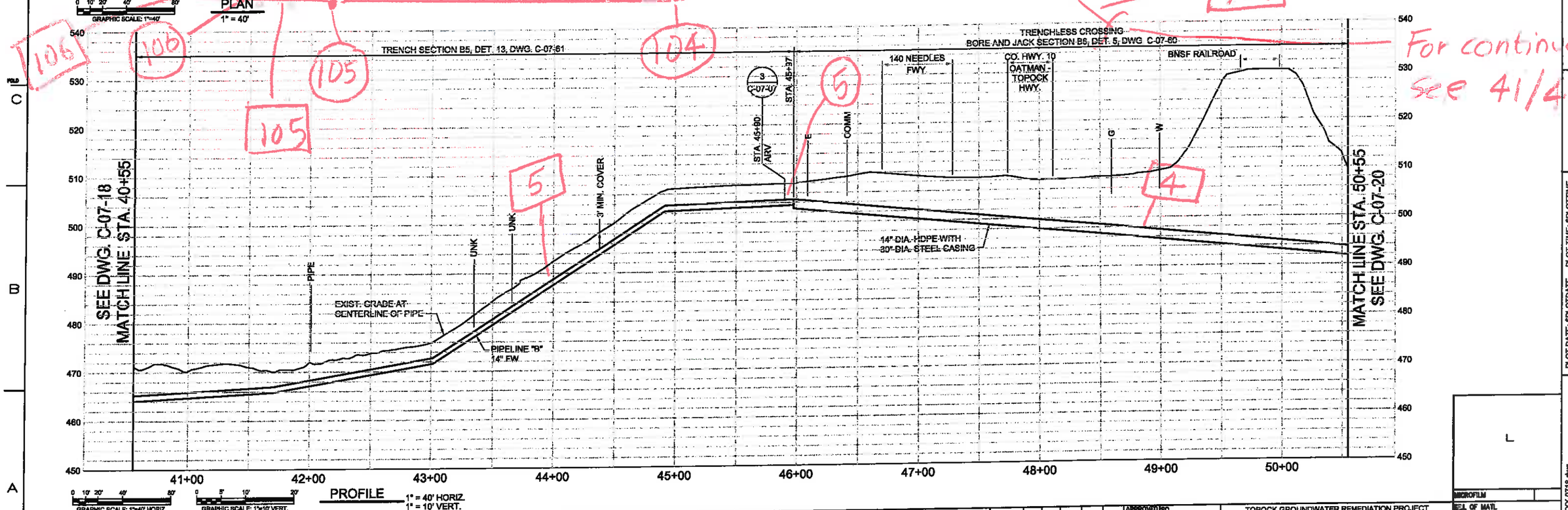
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5/41

NOTES

1. DEPTHS OF EXISTING UTILITIES ARE UNKNOWN. ALL POTENTIAL CONFLICTS BETWEEN NEW PIPE CONSTRUCTION AND EXISTING UTILITIES WILL BE POTHOLED PRIOR TO 100% DESIGN. A DETERMINATION WILL BE MADE WHETHER TO RELOCATE EXISTING UTILITIES OR RE-ROUTE NEW PIPE TRENCHES AROUND EXISTING UTILITIES. THIS WILL BE INCORPORATED INTO 100% DESIGN.
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For continuation see 41/41

E2 Consulting Engineers, Inc.
1900 Powell Street, Ste. 200
Emeryville, CA 94608
(510) 652-1164

CH2MHILL.

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
		REVISIONS					

APPROVED BY	
ISO	
SUPV	
DSGN	PT
DWN	WTH
CHKD	PT
QX	
DATE	
SCALES	

TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE "B" PLAN AND PROFILE
STA. 40+55 TO STA. 50+55

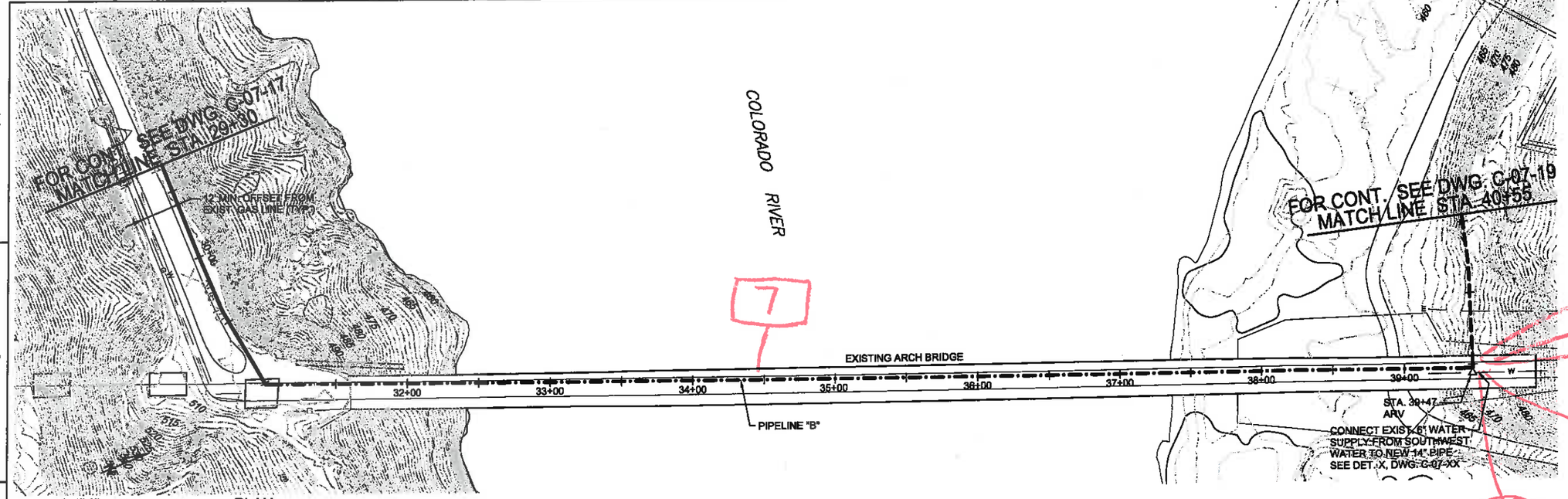
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

L

MICROFILM
SEJL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. C-07-19 of SHEETS
REV

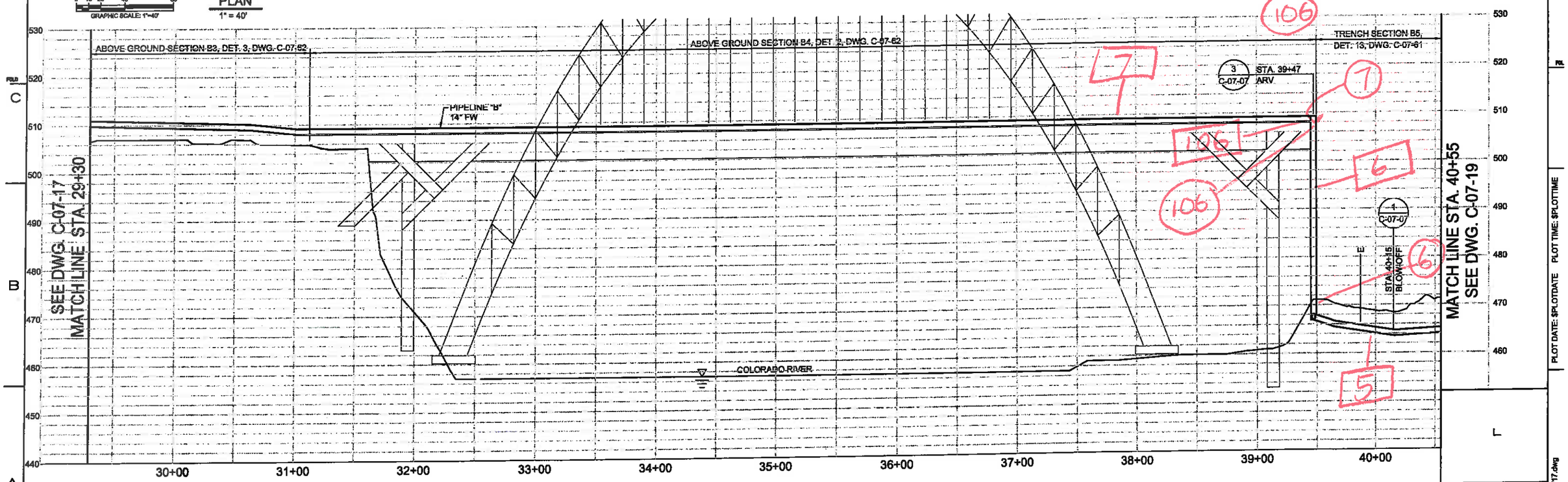
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FILENAME: E2-C-XXX-0718.dwg

6/41



NOTES

1. DEPTHS OF EXISTING UTILITIES ARE UNKNOWN. ALL POTENTIAL CONFLICTS BETWEEN NEW PIPE CONSTRUCTION AND EXISTING UTILITIES WILL BE POTHOLED PRIOR TO 100% DESIGN. A DETERMINATION WILL BE MADE WHETHER TO RELOCATE EXISTING UTILITIES OR RE-ROUTE NEW PIPE TRENCHES AROUND EXISTING UTILITIES. THIS WILL BE INCORPORATED INTO 100% DESIGN.
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3. MINIMUM OFFSET FROM EXISTING GAS PIPELINE = 12'.



E2 Consulting Engineers, Inc.
1900 Powell Street, Ste. 250
Emeryville, CA 94608
(510) 652-1164

CH2MHILL.

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
		REVISIONS					

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
		REVISIONS					

APPROVED BY
ISD
SUPV
DSGN PT
DWN WTH
CHKD PT
RX
DATE
SCALES

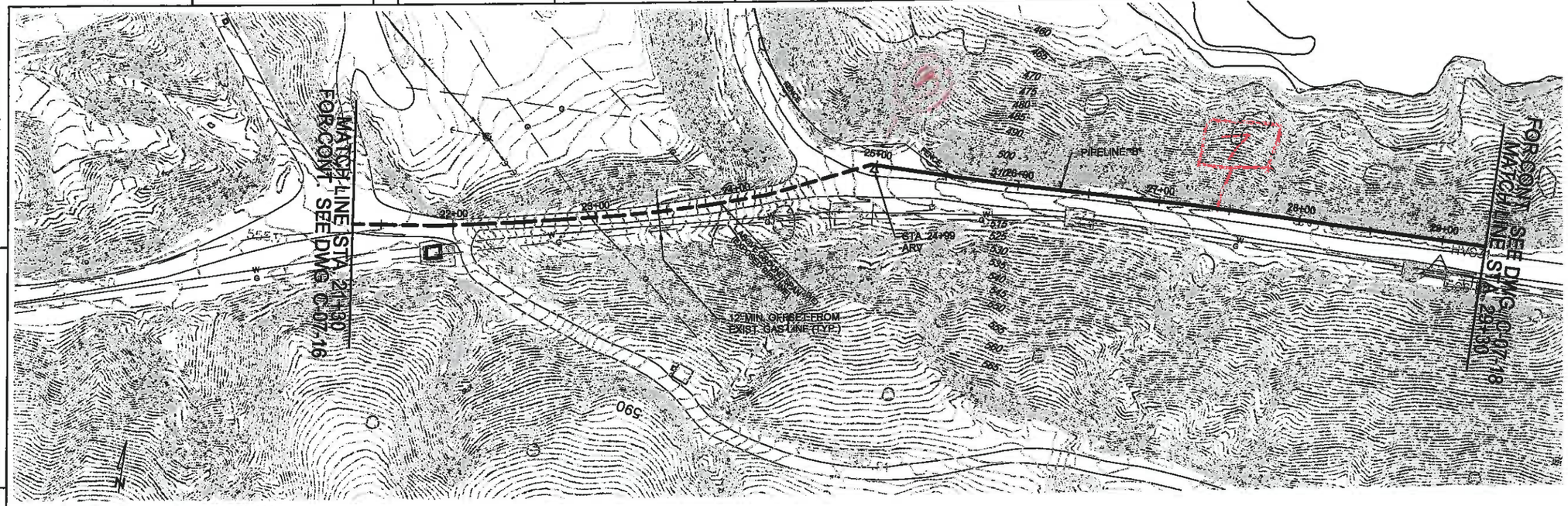
TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE "B" PLAN AND PROFILE
STA. 29+30 TO STA. 40+55

GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL.
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. C-07-18 of SHEETS REV

PLOT DATE: $PLOTDATE PLOT TIME: $PLOTTIME
FILENAME: E2-C-XXX-0717.dwg

7/41

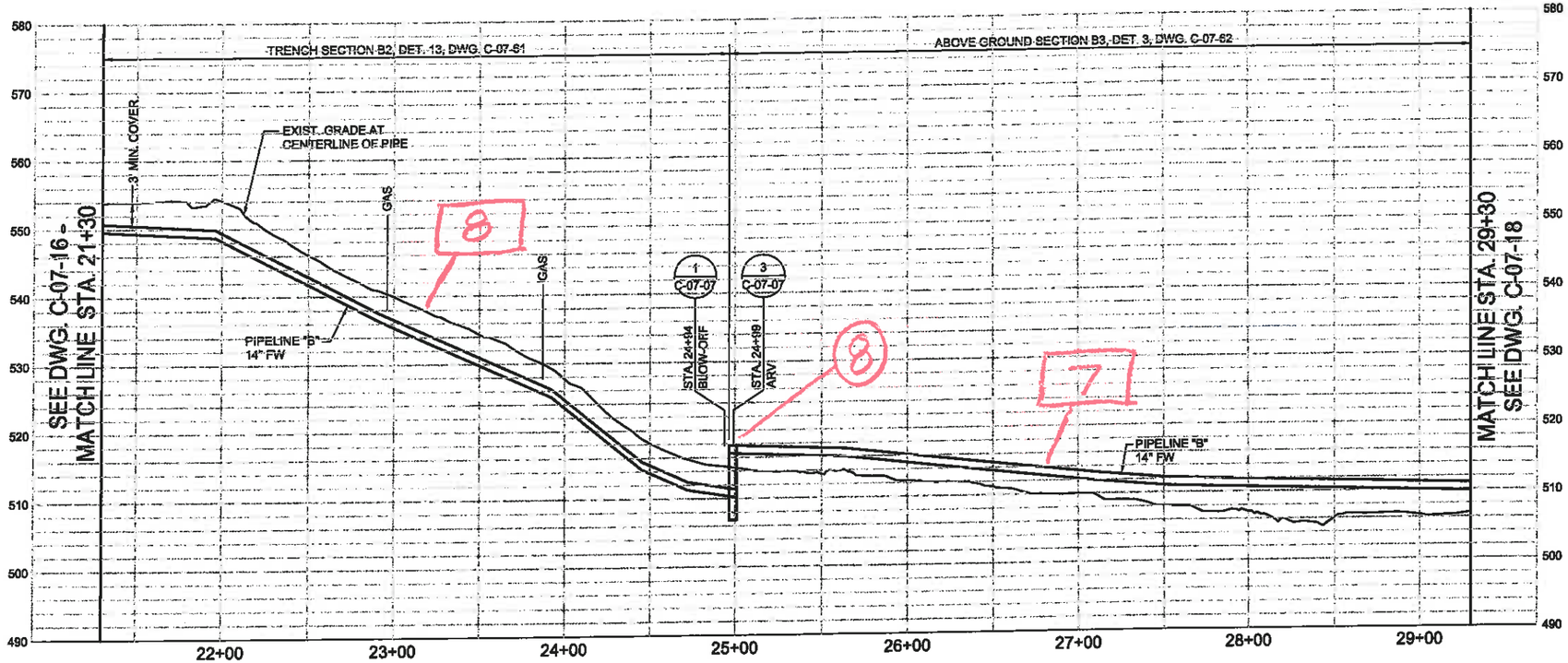


GRAPHIC SCALE: 1"=40'

PLAN
1" = 40'

NOTES

1. DEPTHS OF EXISTING UTILITIES ARE UNKNOWN. ALL POTENTIAL CONFLICTS BETWEEN NEW PIPE CONSTRUCTION AND EXISTING UTILITIES WILL BE POTHOLED PRIOR TO 100% DESIGN. A DETERMINATION WILL BE MADE WHETHER TO RELOCATE EXISTING UTILITIES OR RE-ROUTE NEW PIPE TRENCHES AROUND EXISTING UTILITIES. THIS WILL BE INCORPORATED INTO 100% DESIGN.
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3. MINIMUM OFFSET FROM EXISTING GAS PIPELINE = 12'.



GRAPHIC SCALE: 1"=40' HORIZ.
GRAPHIC SCALE: 1"=10' VERT.

PROFILE
1" = 40' HORIZ.
1" = 10' VERT.

L

E2 Consulting Engineers, Inc.
1600 Powell Street, Ste. 250
Emeryville, CA 94608
(510) 652-1164

CH2MHILL.

REVISIONS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

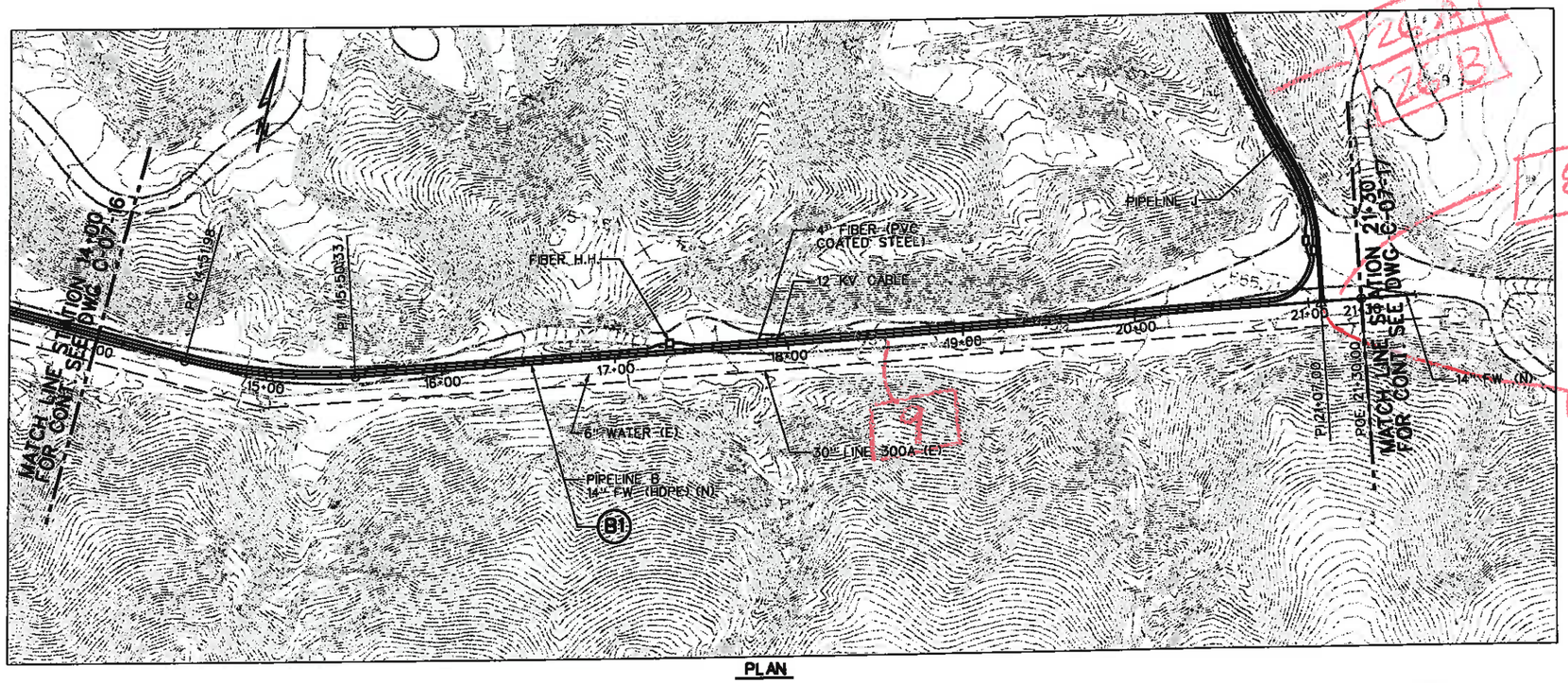
APPROVED BY	
GO	
SUPV	
DSGN	PT
DWN	WTH
CHKD	PT
QTY	
DATE	
SCALES	

TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE "B" PLAN AND PROFILE
STA. 21+30 TO STA. 29+30
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

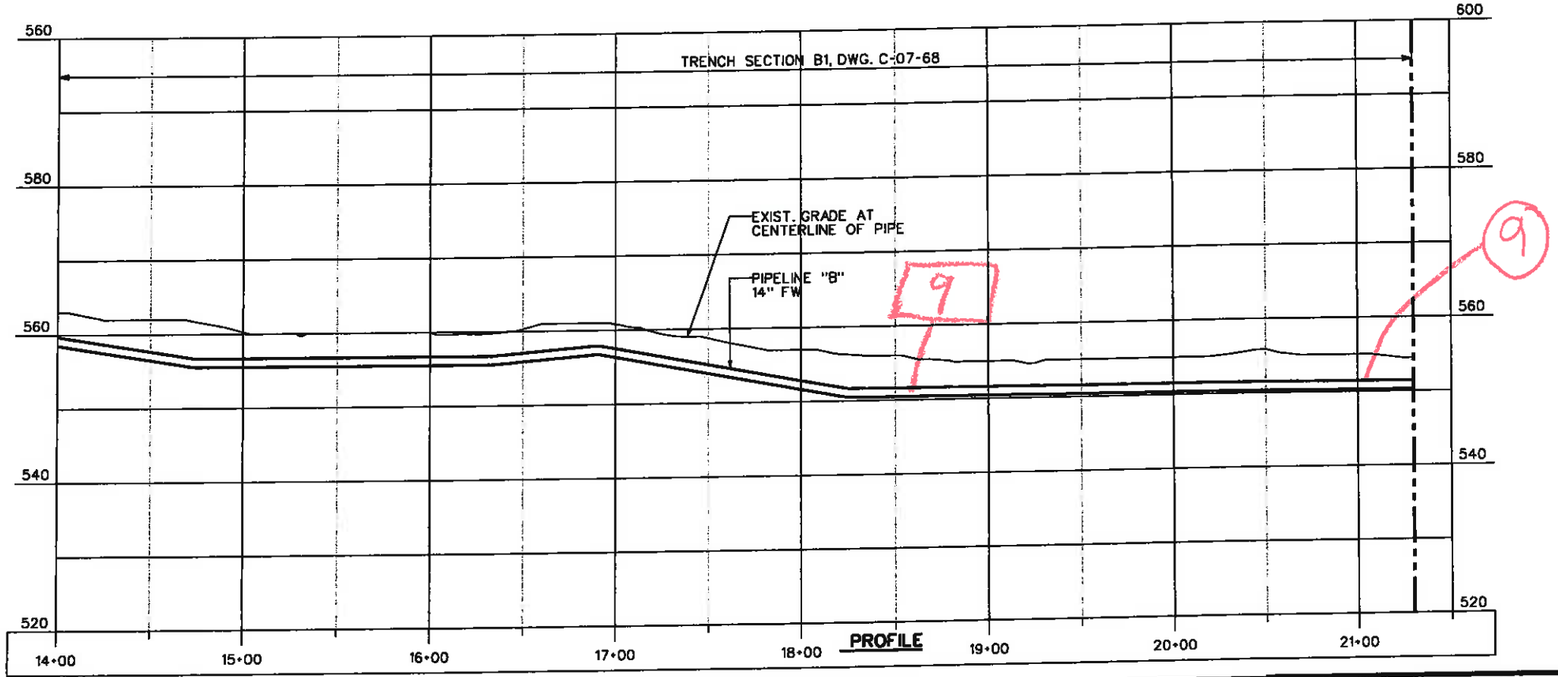
MICROFILM	
SHEET LIST OF MATL	
DWG LIST	
SUPSDS	
SUPSD BY	
SHEET NO.	of SHEETS
C-07-17	REV

PLOT DATE: $PLOTDATE PLOT TIME: $PLOTTIME
FILENAME: E2-C-XXX-0716.dwg

8/41



PLAN



PROFILE

AECOM
2101 WEBSTER STREET SUITE 1000
OAKLAND, CA 94612-3068
PROJECT NO. 60272335

0 40 80 FT
SCALE: 1" = 40'-0" H
SCALE: 1" = 10'-0" V

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

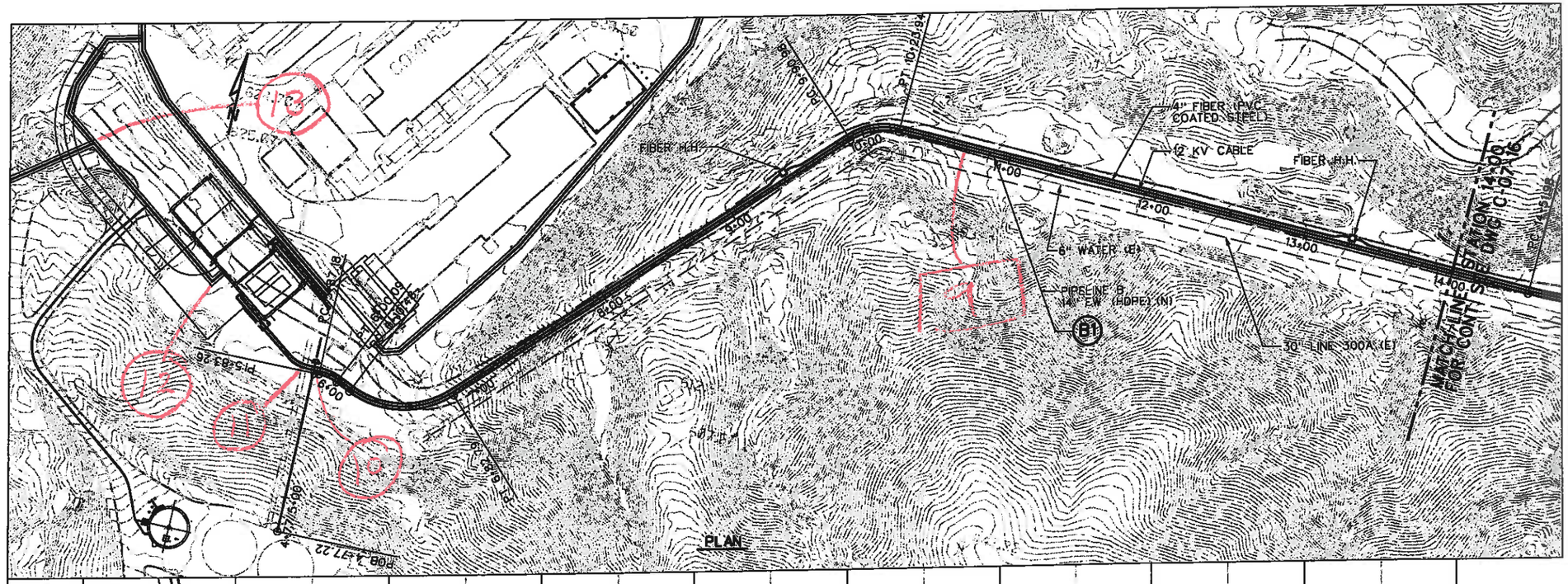
APPROVED BY

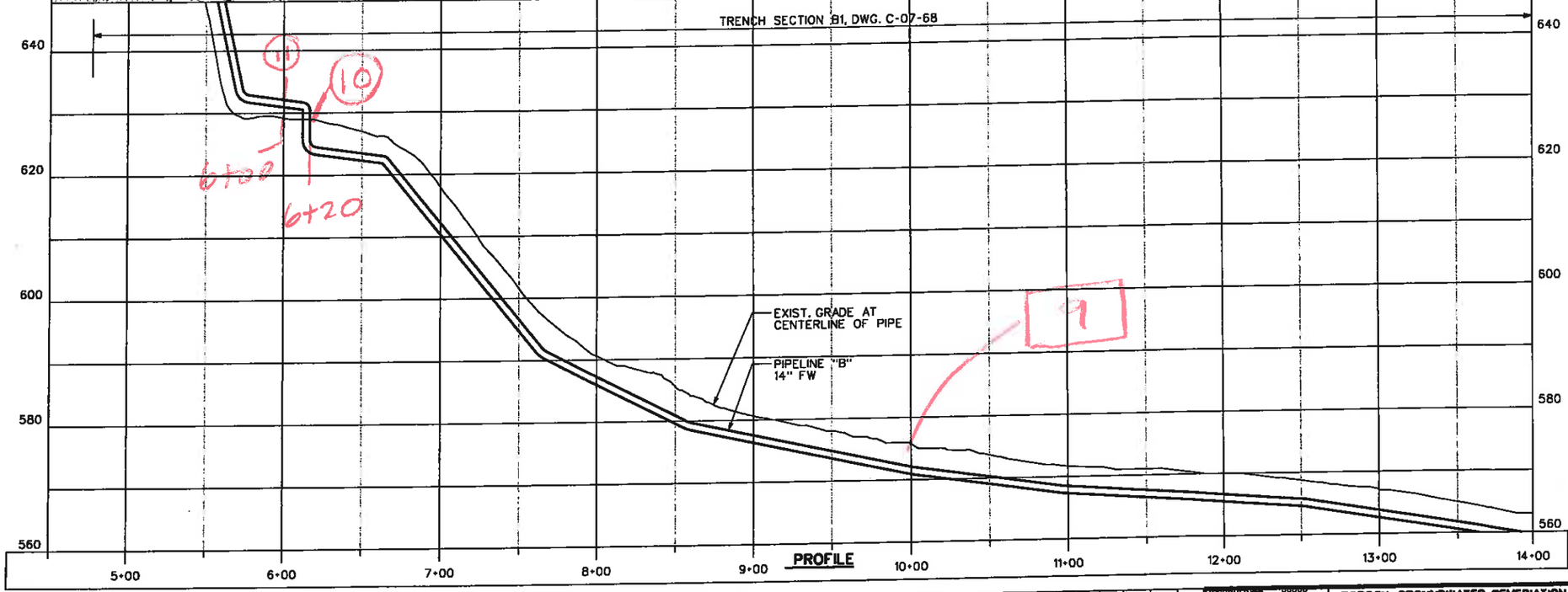
JOB	XXXXX
SUPV	PD
DSGN	TL
DWN	TL
CHKD	JM
CK	
DATE	07-27-12
SCALES	1" = 40'-0"

TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE B
PLAN AND PROFILE
14+00 TO 21+30
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. C-07-16 OF SHEETS REV

9141





AECOM
2101 WEBSTER STREET SUITE 1900
OAKLAND, CA 94612-3063
PROJECT NO. 60272335

0 40 80 FT
SCALE: 1" = 40'-0" H
SCALE: 1" = 10'-0" V

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

APPROVED BY

GD	XXXXX
SUPV	PD
DSGN	TL
DWN	TL
CHKD	JM
QC	
DATE	07-27-12
SCALES	1" = 40'-0"

TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE B
PLAN AND PROFILE
4+77 TO 14+00
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. C-07-15 OF SHEETS REV

MATCH LINE
FOR CONT. SEE DWG C-10-03

10/4.1

2" TW (CONNECTING TO EXISTING BLOWDOWN)

4" FIBER
6" RW
3" CA
4" FW
2" TW
4" 480V

HAZMAT STORAGE

PIPELINE 1
SEE DWG C-07-52

METER VAULT

4" RW
3" FW

4" 480V
4" FIBER
4" RW
6" DR
4" FW
2" WS
2" TW

8" RW
3" CA
6" DR
2" WS
2" TW

2" RW
2" SL
2" RW
2" ACD
2" COG
2" CAU
2" UA

2" UA

INFLUENT STORAGE TANK FARM

2" TW
8" RW
6" FW
3" CHILLED WATER
4" FIBER
4" ELECT

480V H.H.
FIBER H.H.

4" RW
3" FW
2" WS
2" TW
2" TW
2" CAU
2" ACD
4" FIBER
4" 480V

FIBER H.H.
480V H.H.

CONDITIONED WATER STORAGE TANK FARM

2" WS

TRANSFORMER

2" TW
2" TW
2" CAU
2" ACD
6" FW
4" FIBER
4" 480V

2" TW
2" TW
6" DR

4" FIBER
12" KV
14" FW

REMEDY-PRODUCED WATER CONDITIONING PLANT

8" FW

CONDITIONED WATER STORAGE TANK

16 15 15 16 14 14 13 13 12 12 11 11 10 10 10A 10B 10C 9 10/7 109

AECOM
2101 WEBSTER STREET SUITE 1000
OAKLAND, CA 94612-3066
PROJECT NO. 60272335

0 20 40 FT
SCALE: 1" - 20'-0"

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

APPROVED BY	GD	10/2012
	SUPV	PD
	DSGN	TL
	DWN	TL
	CHKD	JH
	QA	
	DATE	08-03-12
	SCALES	1" = 20'-0"

TOPOCK GROUNDWATER REMEDIATION PROJECT

PIPE LAYOUT

GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. OF SHEETS
C-10-02
REV

NOTE
1. SEE DWG. C-10-02 FOR PIPING LAYOUT

L1
L2
L3
L4
℄ PIPELINE 'L'
PI 80+10.61
PI 80+00.00
PI 81+39.75
PI 82+43.62
PI 82+90.73
PI 83+71.72
PI 83+87.41
PI 84+10.84
POE 84+35.62
PIPELINE \ METER VAULT
81+00
82+00
84+00

PLAN

TRENCH SECTION L1, DWG. C-07-71
TRENCH SECTION L2, DWG. C-07-71
TRENCH SECTION L3, DWG. C-07-71
TRENCH SECTION L4, DWG. C-07-72

EXIST. GRADE AT CENTERLINE OF PIPE
PIPELINE "L" APPROX. BOTTOM OF TRENCH

640
630
620
610
600
80+00
81+00
82+00
83+00
84+00

PROFILE

AECOM
2101 WEBSTER STREET SUITE 1900
OAKLAND, CA 94612-3066
PROJECT NO. 60272336

SCALE: 1" = 20'-0" H
SCALE: 1" = 5'-0" V

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

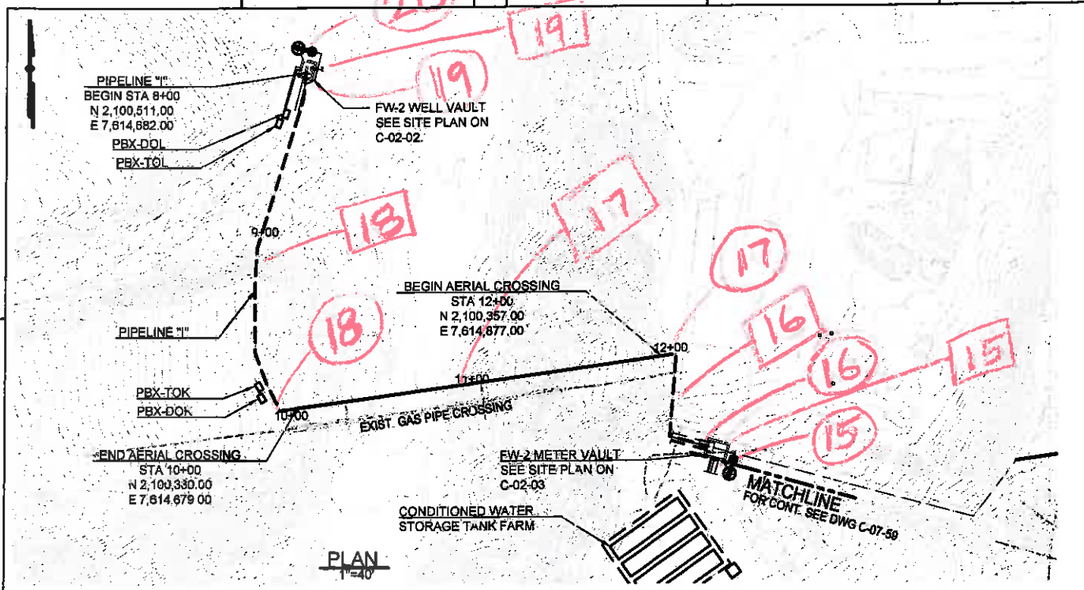
REVISIONS

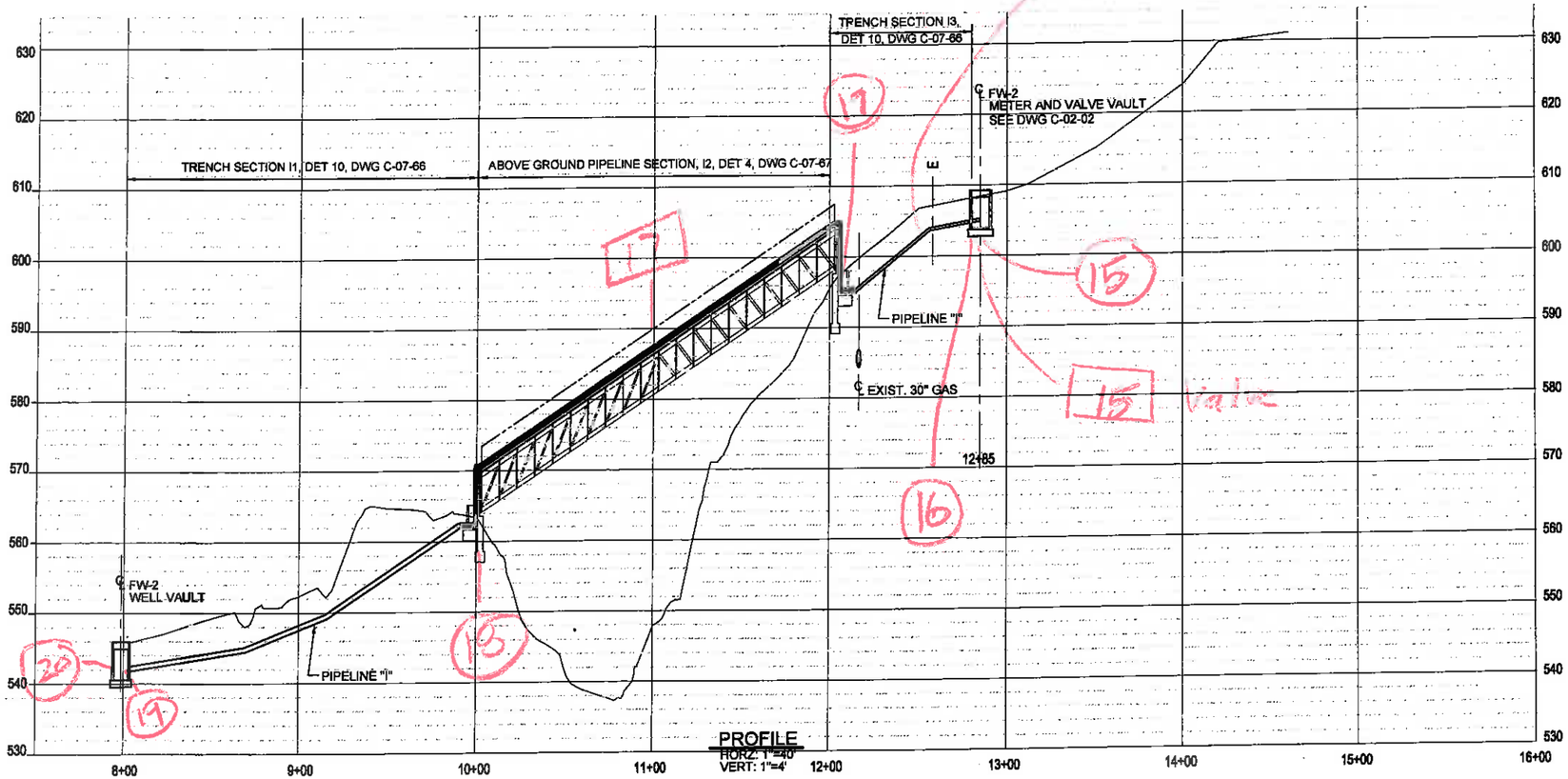
TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE L
PLAN AND PROFILE
80+00 TO 84+46
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

APPROVED BY: XXXXX

DRAWING NO. C-07-48
SHEET NO. OF SHEETS

C-07-59





NOTES

1. DEPTHS OF EXISTING UTILITIES ARE UNKNOWN. ALL POTENTIAL CONFLICTS BETWEEN NEW PIPE CONSTRUCTION AND EXISTING UTILITIES WILL BE POTHOLED PRIOR TO THE 100% DESIGN. A DETERMINATION WILL BE MADE WHETHER TO RELOCATE EXISTING UTILITIES OR RE-ROUTE NEW PIPE TRENCHES AROUND EXISTING UTILITIES. THIS WILL BE INCORPORATED INTO THE 100% DESIGN.
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HORZ: SCALE: 1"=40'-0"
VERT: SCALE: 1"=10'-0"

DRAFT
NOT FOR
CONSTRUCTION

E2 Consulting Engineers, Inc.

CH2MHILL

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

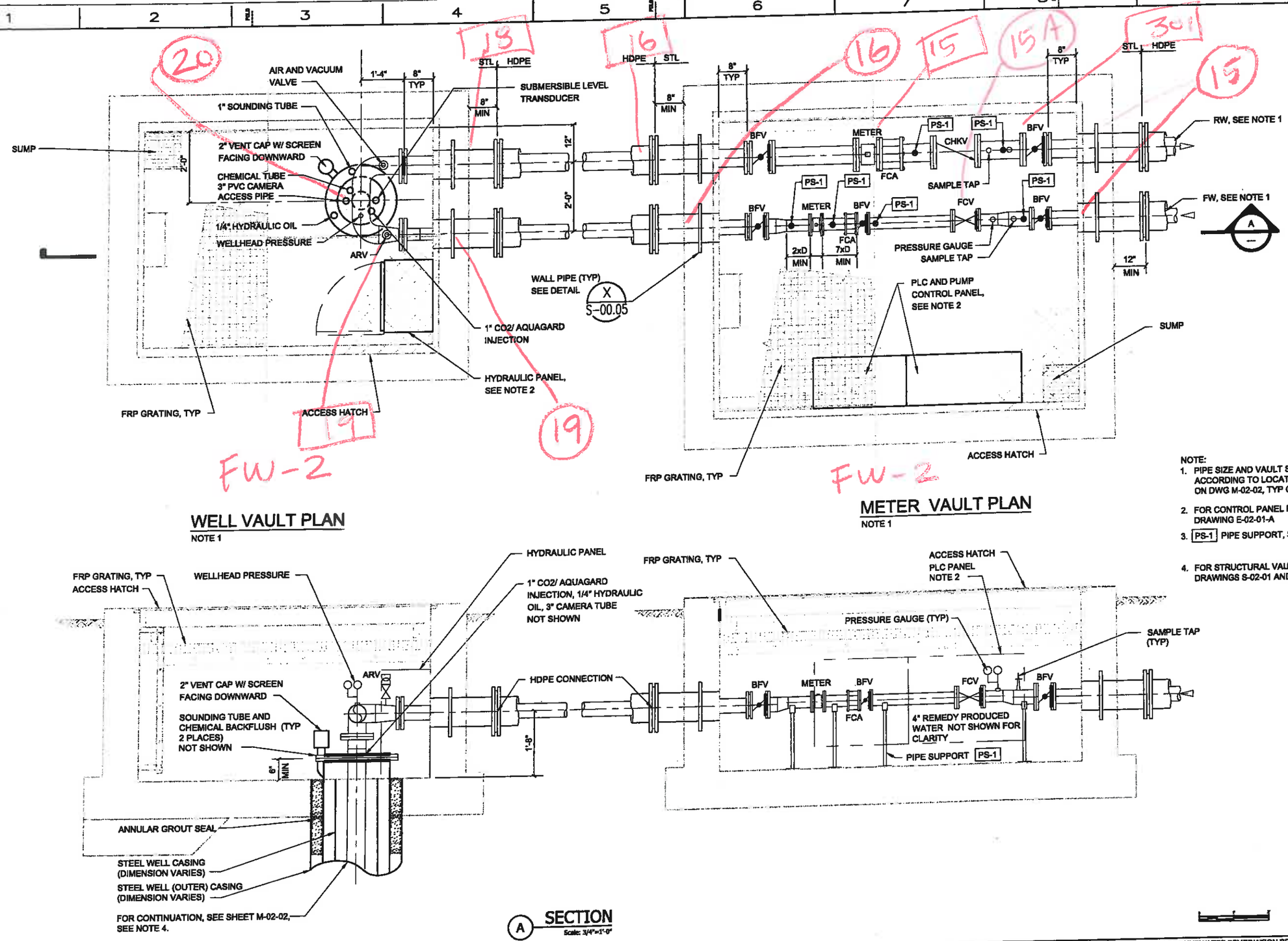
REVISIONS

APPROVED BY	
SO	
SUPV	
DSGN	PT
DWN	PC
CHKD	PT
OK	PT
DATE	9/12/12
SCALES	1"=40'

TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE "I" - PLAN AND PROFILE
STA 8+00 TO STA 12+85
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM	
BILL OF MATL	
DWG LIST	
SUPSDS	
SUPSD BY	
SHEET NO.	of SHEETS
C-07-53	REV

PLOT DATE: $PLOTDATE PLOT TIME: $PLOTTIME
FILENAME: E2-C-XXX-07S3AD.DWG



WELL VAULT PLAN

NOTE 1

A SECTION
Scale: 3/4"=1'-0"

METER VAULT PLAN

NOTE 1

NOTE:
1. PIPE SIZE AND VAULT SIZES VARY ACCORDING TO LOCATION, SEE TABLE 2 ON DWG M-02-02, TYP OF 6 SETS OF VAULTS
2. FOR CONTROL PANEL PLACEMENT SEE ELECTRICAL DRAWING E-02-01-A
3. PS-1 PIPE SUPPORT, SEE DETAIL 2 S-00.05
4. FOR STRUCTURAL VAULT DIMENSIONS SEE DRAWINGS S-02-01 AND S-02-02.

CH2MHILL.

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
A		ONBOARD REVIEW					

REVISIONS

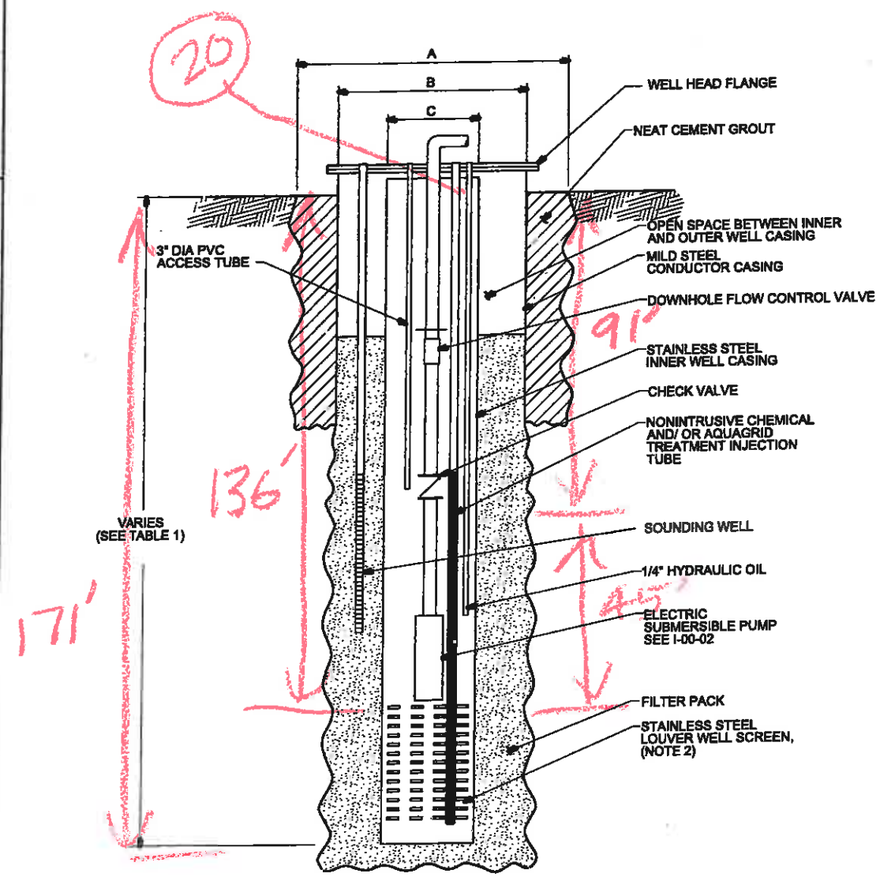
APPROVED
PC BY
PC
PT
PT

SO
SUPV
DSGN
DWN RCH
CHKD JP
CCK
DATE
SCALES

TOPOCK GROUNDWATER REMEDIATION PROJECT
FRESHWATER INJECTION WELL AND METER VAULT
PLAN AND SECTIONS
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
AS-BUILTS
SUPED BY
SHEET NO. of SHEETS
M-02-01
REV

FILENAME: CH-M-XXX-02012AD.dwg
PLOT DATE: 8/27/2012
PLOT TIME: 11:50:04 AM



NOTE:

1. WELL DEPTH AND WELL CASING DIMENSIONS (A,B & C) SHOWN IN TABLE 1 ON THIS SHEET
2. ENGINEER WILL DESIGN LOUVER SLOT SIZE AND FILTER PACK GRADE BASED ON GRAIN SIZE DISTRIBUTION ANALYSIS OF FORMATION SAMPLES

FRESH WATER INJECTION WELL WITH BACKWASH PUMP

NTS

TABLE 1

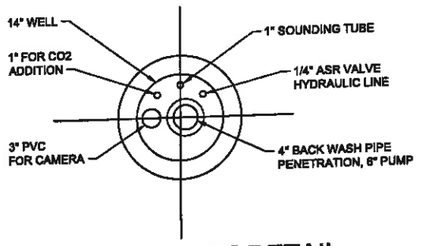
Well ID	Depth of Conductor Casing (ft)	Surface Elevation (ft, msl)	A Diameter of Conductor Borehole (inches)	Depth of Borehole (ft)	B Borehole Diameter (in)	C Well Casing Diameter (inches)	Model Saturated Thickness (ft)	Depth to Water (ft)	Depth to Pump (ft)	Well Depth (ft)	Well Screen Length (ft)	Pump Submergence (ft)
FW-001	50	561	32	376	24	14	250	106	168.5	356	187.5	62.5
FW-002 *Note 1*	50	546	32	171	24	14	60	91	136	151	45	45
IRL-001	50	501	32	336	24	14	270	46	113.5	316	202.5	67.5
IRL-002	50	547	32	372	24	14	260	92	157	352	195	65
IRL-003	50	555	32	350	24	14	230	100	157.5	330	172.5	57.5
IRL-004	50	561	32	326	24	14	200	106	156	306	150	50

Note 1. It is assumed that pump in FW-002 will be equipped with a cooling shroud so that pump can be inst alled deeper in the well to increase pump submergence.

TABLE 2

	Pipe Sizes/ MOC/ Civil Drawing Reference							
	FW Into Meter Vault	FW Inside Meter Vault	FW Out of Meter Vault/ Into Well Vault	FW Inside Well Vault	RW Out of Well Vault/ Into Meter Vault	RW In Meter Vault	RW Out of Meter Vault	*Reference to Civil Site Plan*
MOC	*HPDE*	*CPVC*	*HDPE*	*CPVC*	*Double Contained HDPE*	*CPVC*	*Double Contained HDPE*	
FW-001	4"	4"	4"	4"	6" in 10"	6"	6" in 10"	C-02-03
FW-002	2"	3"	2"	3"	4" in 8"	4"	4" in 8"	C-02-04
IRL-001	4"	4"	4"	4"	6" in 10"	6"	6" in 10"	C-05-04
IRL-002	4"	4"	4"	4"	6" in 10"	6"	6" in 10"	C-05-05
IRL-003	4"	4"	4"	4"	6" in 10"	6"	6" in 10"	C-05-06
IRL-004	4"	4"	4"	4"	6" in 10"	6"	6" in 10"	C-05-07

NOTE Six Vaults are represented by this drawing.
RW (remedy water) pipe is double contained leaving the vaults.
All HDPE piping is Standard Dimension Ratio - SDR-11
All CPVC piping is Schedule 80



WELL FLANGE DETAIL

NTS

NOTES:

1. FOR DISTANCE BETWEEN VAULTS, SEE TABLE 2 FOR CIVIL DRAWING REFERENCE.

PRELIMINARY PLANS-NOT FOR CONSTRUCTION

CH2MHILL.

REVISIONS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

APPROVED BY: SD, SUPV, DSGN, DWN RCH, CHKD JP, QA, DATE, SCALES

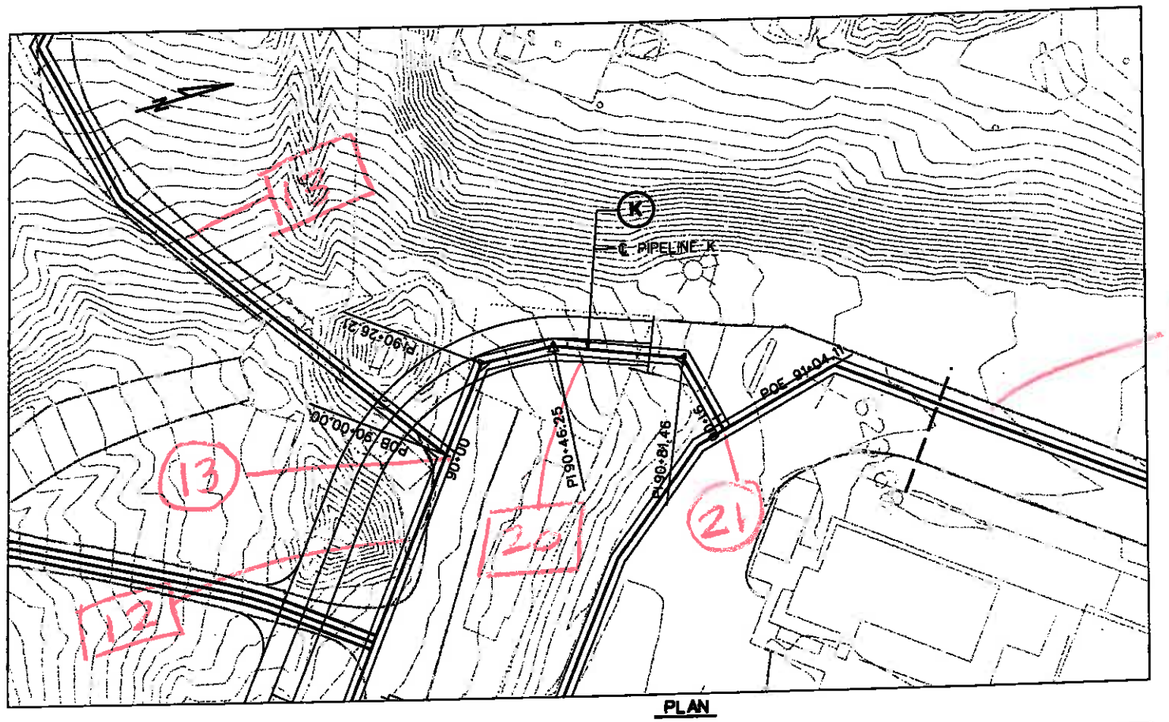
TOPOCK GROUNDWATER REMEDIATION PROJECT
FRESHWATER INJECTION WELL CONSTRUCTION DETAILS
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

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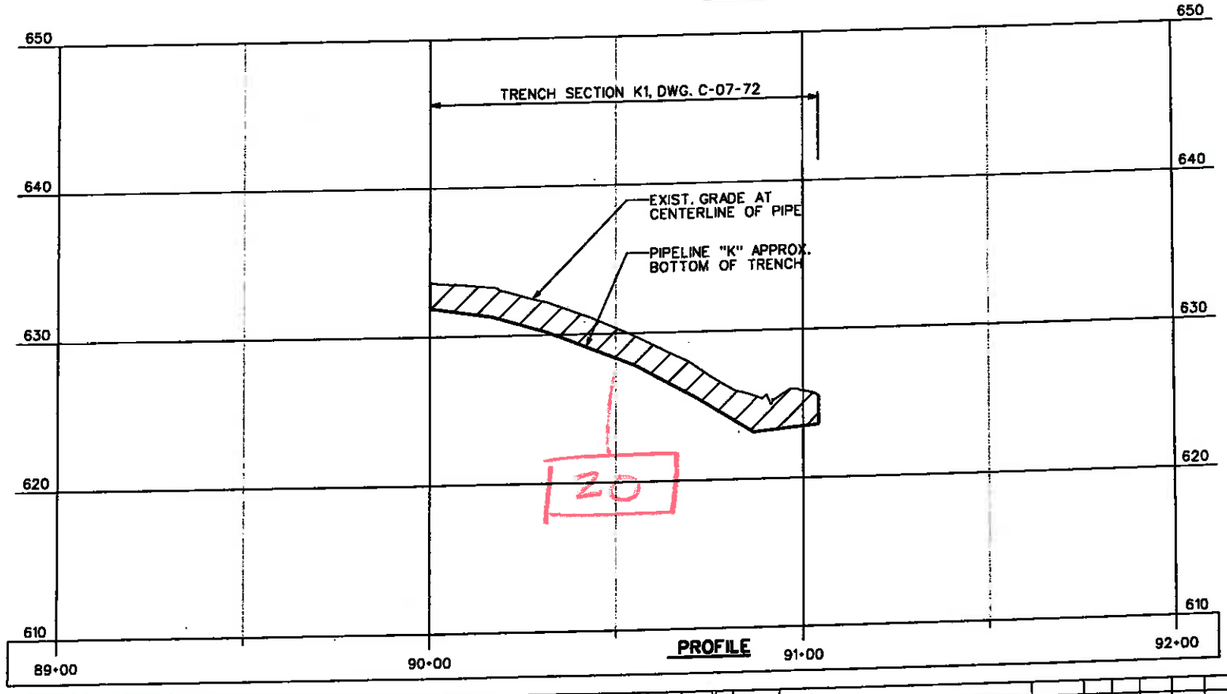
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BILL OF MATL
DWG LIST
SUPERS
SUPED BY
SHEET NO. of SHEETS
M-02-02 REV

PLOT TIME: 11:51:36 AM
PLOT DATE: 8/27/2012
FILENAME: CH-M-XXX-0202AD.dwg

15/41



PLAN



PROFILE

AECOM
2101 WEBSTER STREET SUITE 1900
OAKLAND, CA 94612-3066
PROJECT NO. 60272335

0 20 40 FT
SCALE: 1" = 20'-0" H
SCALE: 1" = 5'-0" V

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

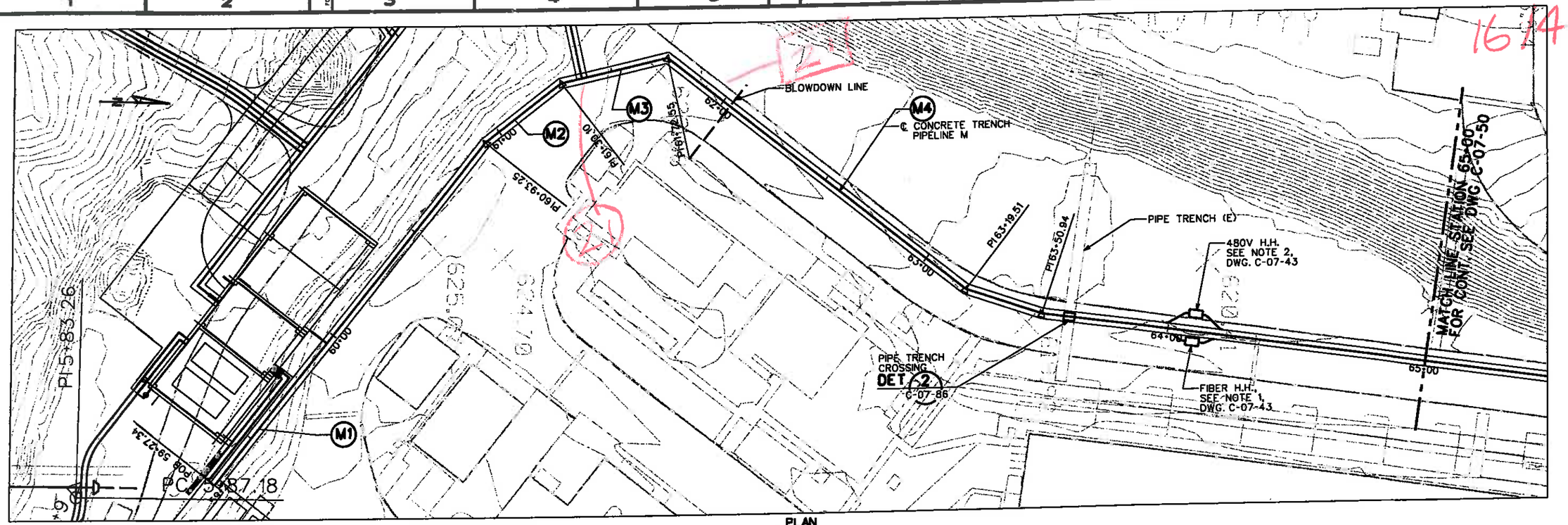
APPROVED BY
DATE

TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE K
PLAN AND PROFILE
90+00 TO 91+04
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
SURVEY
SUPER BY
SHEET NO. OF SHEETS
C-07-47
REV

C-07-58

16141



AECOM
2101 WEBSTER STREET SUITE 1000
OAKLAND, CA 94612-3066
PROJECT NO. 60272335

0 20 40 FT
SCALE: 1" = 20'-0" H
SCALE: 1" = 5'-0" V

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

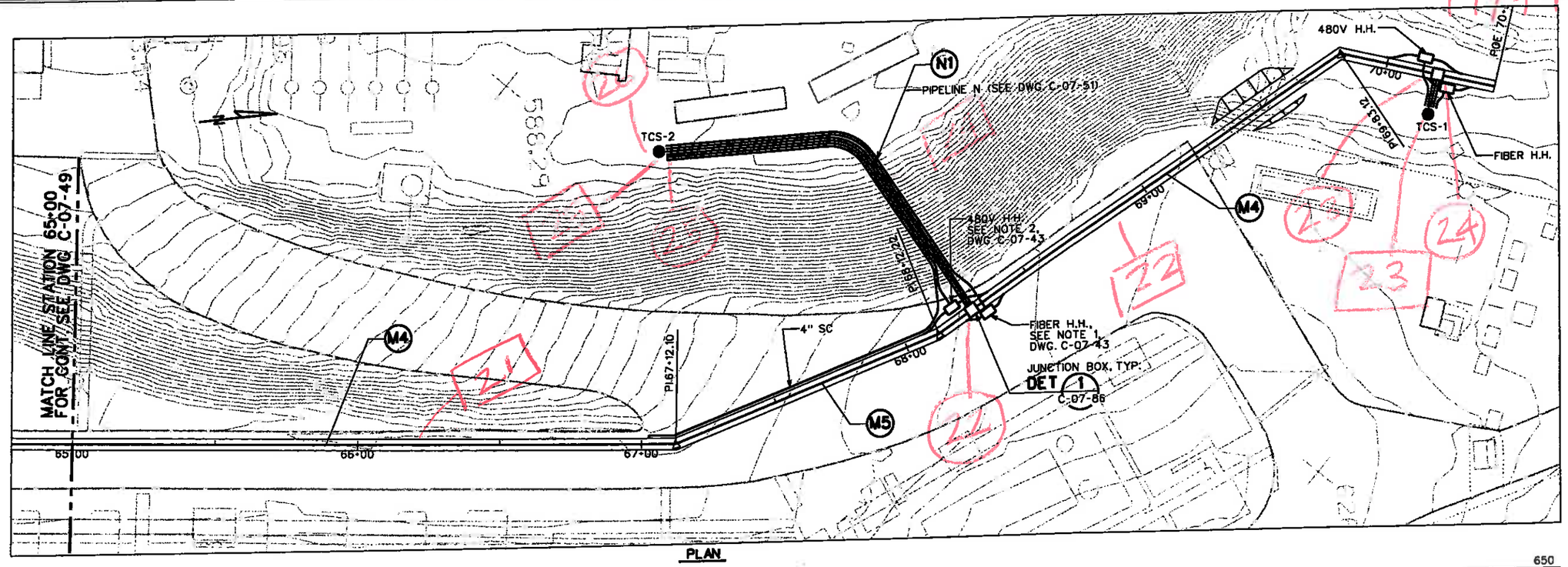
NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

APPROVED BY	XXXXX
	PD
	TL
	TL
	JM
DATE	07-27-12
SCALES	1" = 20'-0"

TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE M
PLAN AND PROFILE
60+00 TO 65+00
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

DRAWING NO.	C-07-49
SHEET NO. OF SHEETS	
REV	



AECOM
2101 WEBSTER STREET SUITE 1000
OAKLAND, CA 94612-2668
PROJECT NO. 60272335

0 20 40 FT
SCALE: 1" = 20'-0" H
SCALE: 1" = 5'-0" V

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

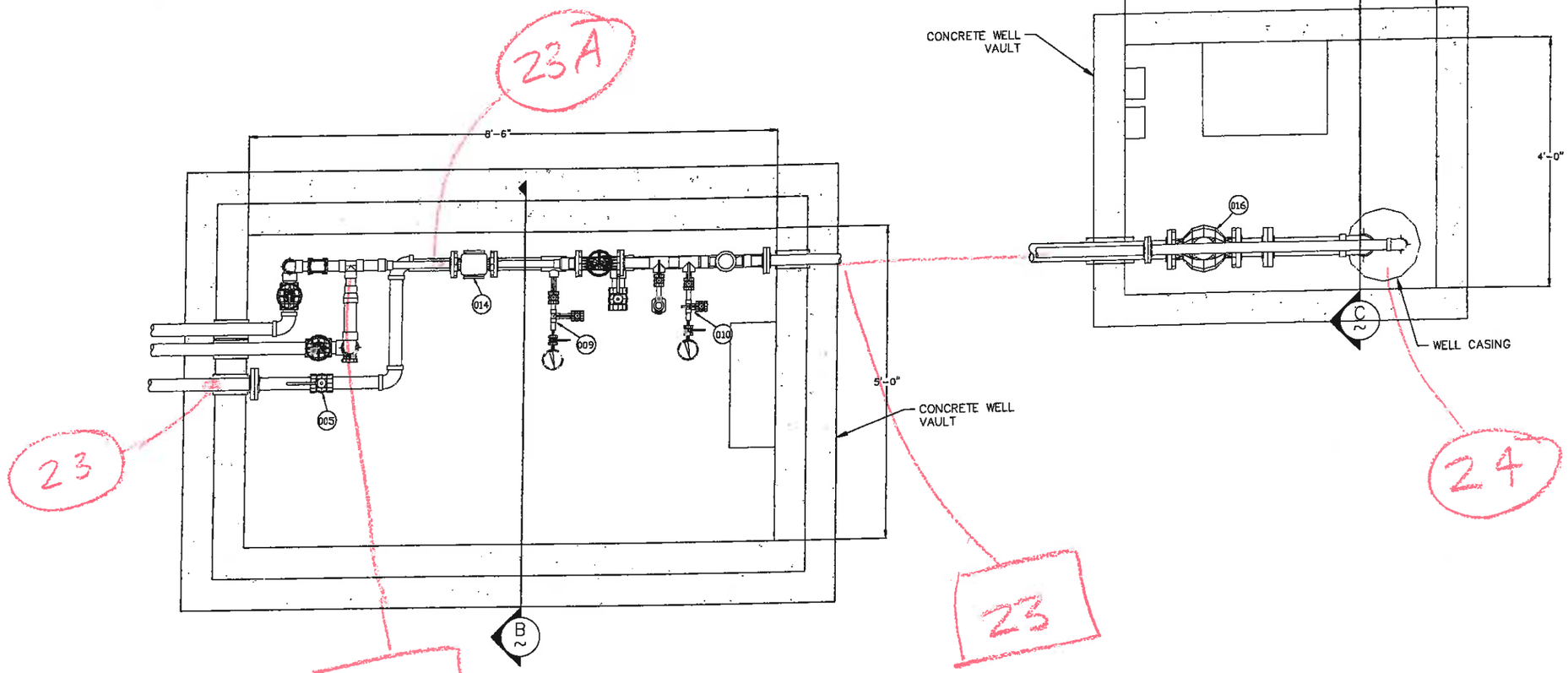
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APPROVED BY: XXXXX
DSPV PD
DSGN TL
DRN TL
CHKD JM
QA
DATE 07-27-12
DRAWING SCALE 1" = 20'-0"

TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE M
PLAN AND PROFILE
65+00 TO 70+05
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

DRAWING	
ROLL OF MAPS	
DWG LIST	
SHAPES	
SHAPES BY	
DRAWING NO.	C-07-50
OF SHEETS	
REV	

18/41



INJECTION VALVE VAULT AND INJECTION VAULT PLAN

0 1' 2' 5'
1"=1'

NOTES:
1. ALL PIPING, INSTRUMENTATION, AND OTHER COMPONENTS SHALL BE INSTALLED AS PER THE MANUFACTURER'S GUIDELINES.
2. ALL PIPING AND INSTRUMENTATION SHALL BE INSTALLED PER P&IDS.
3. INSTALLATION OF ELECTRIC COMPONENTS SHALL COMPLY WITH ALL APPLICABLE NEC AND LOCAL CODES.
4. CROSS SECTIONS SHOW ONLY THOSE COMPONENTS NECESSARY TO INDICATE ELEVATIONS AND SPACE REQUIREMENTS FOR PIPING AND MAJOR COMPONENTS. INSTALL PIPING AND INSTRUMENTATION AS PER THE P&IDS.
5. ALL INSTRUMENTATION SHALL BE INSTALLED SUCH THAT IT MAY BE READ WITHOUT ENTERING THE WELL VAULT.
6. ALL VALVE HANDLES SHALL BE INSTALLED SUCH THAT THEY ARE ACCESSIBLE WITHOUT ENTERING THE WELL VAULT AND OPERABLE THROUGH ENTIRE STROKE.
7. ALL PIPING AND CONDUIT SHALL BE SECURED TO THE WALLS OF THE CONCRETE WELL VAULT WITH ANCHOR BOLTS AND UNI-STRUT. SUPPORTS SHALL BE INSTALLED WHEREVER NECESSARY TO PROPERLY SUPPORT PIPING AND CONDUIT.
8. PIPE SIZES AND MATERIALS ARE SHOWN ON THE P&IDS.
9. PIPING KNOCKOUTS AND ROUTING OF PIPING SHOWN AS PROPOSED AND APPROXIMATE. ACTUAL ROUTING TO BE FIELD DETERMINED AND IS SUBJECT TO ENGINEER'S APPROVAL.
10. ALL FLANGES SHALL BE CLASS 150 RAISED FACE FLANGES UNLESS OTHERWISE NOTED.
11. ALL TRANSITION FITTINGS FOR HDPE PIPING SHALL BE FLANGED WITH BACKING RINGS.

ETIC ENGINEERING

ARCADIS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	8/24/12	60% DESIGN LAYOUT					

REVISIONS

APPROVED BY
SO
SUPV
DSGN
DWN
CHKD
OK
DATE
SCALES AS NOTED

TOPOCK GROUNDWATER REMEDIATION PROJECT

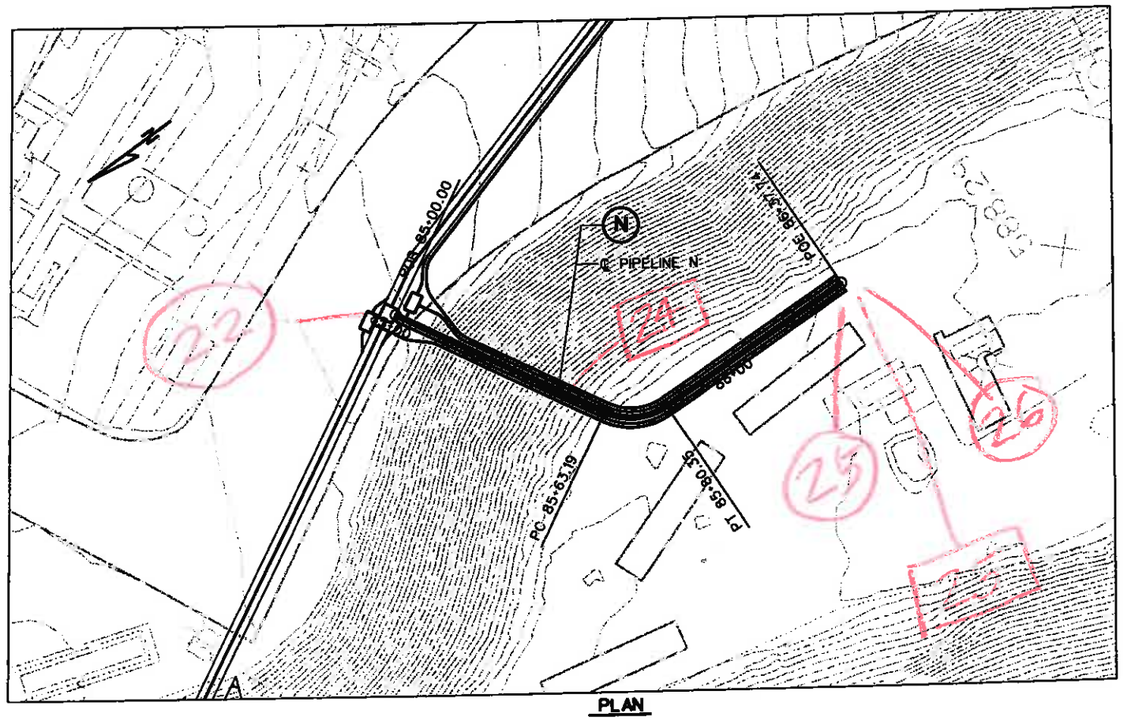
TCS LOOP INJECTION WELL VAULTS MECHANICAL DETAILS

GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

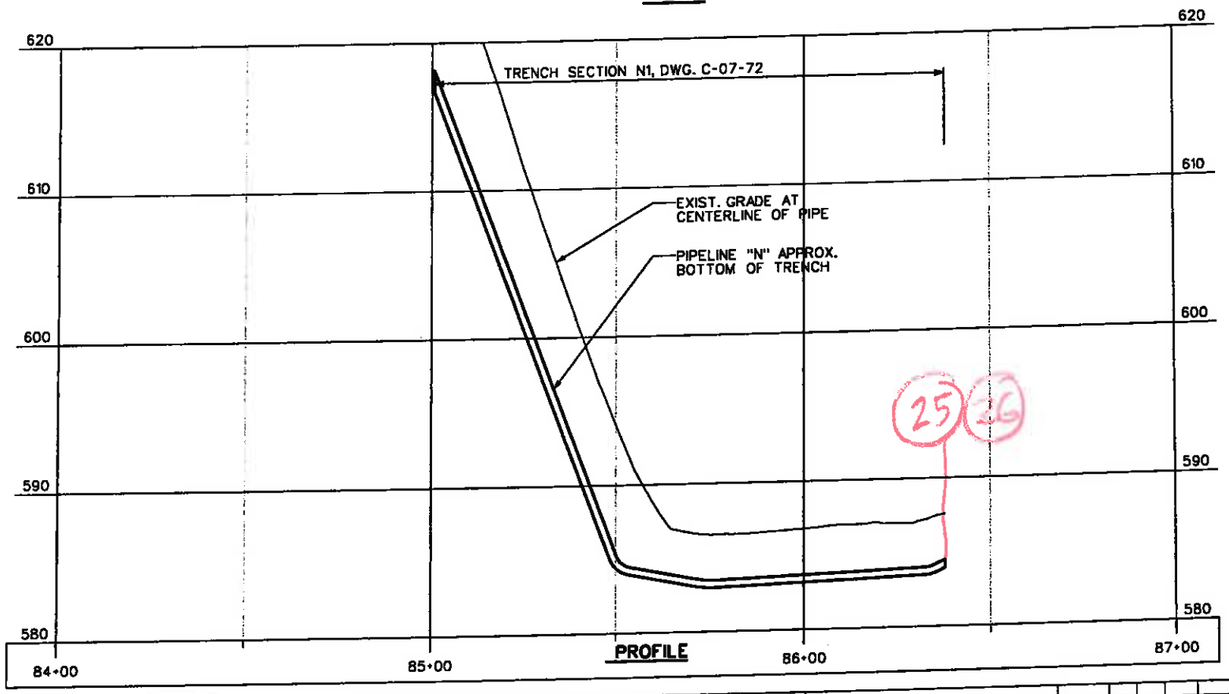
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BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. of SHEETS
M-03-05
REV

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19/41



PLAN



PROFILE

AECOM
2101 WEBSTER STREET SUITE 1900
OAKLAND, CA 94612-3060
PROJECT NO. 60272335

0 20 40 FT
SCALE: 1" = 20'-0" H
SCALE: 1" = 5'-0" V

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

APPROVED BY
GM/SPEC XXXX
SUPV
DSGN
DWN
CHKD
TEST
DATE
SCALES

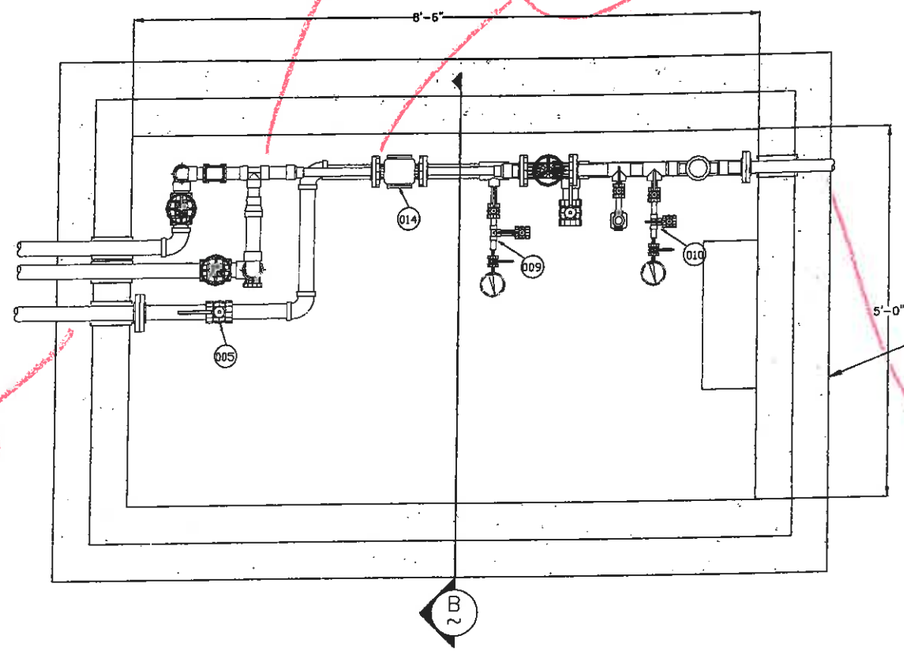
TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE N
PLAN AND PROFILE
85+00 TO 88+38
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
SUPSD
SUPSD BY
SHEET NO. C-07-51 OF SHEETS REV

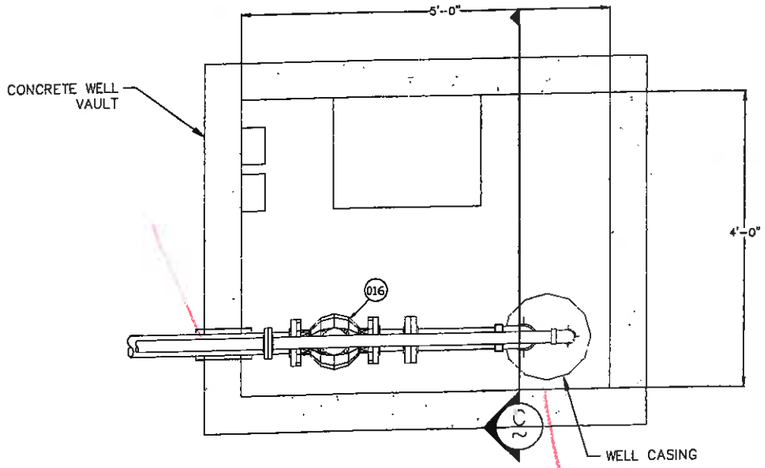
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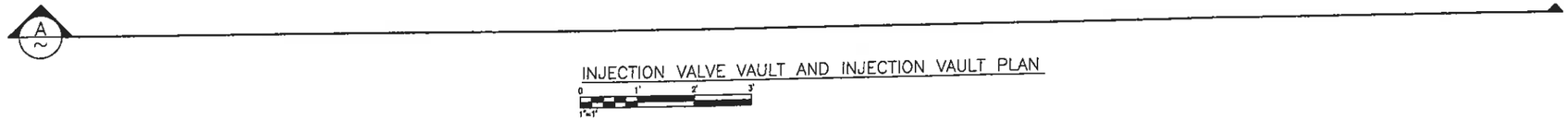


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26

25



INJECTION VALVE VAULT AND INJECTION VAULT PLAN

0 1' 2' 3'
1"=1'

NOTES:
1. ALL PIPING, INSTRUMENTATION, AND OTHER COMPONENTS SHALL BE INSTALLED AS PER THE MANUFACTURER'S GUIDELINES.
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11. ALL TRANSITION FITTINGS FOR HDPE PIPING SHALL BE FLANGED WITH BACKING RINGS.

ETIC ENGINEERING

ARCADIS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	8/24/12	60% DESIGN LAYOUT					

REVISIONS

APPROVED BY: SO, SUPV, DSGN, DWN, CHKD, OK, DATE, SCALES: AS NOTED

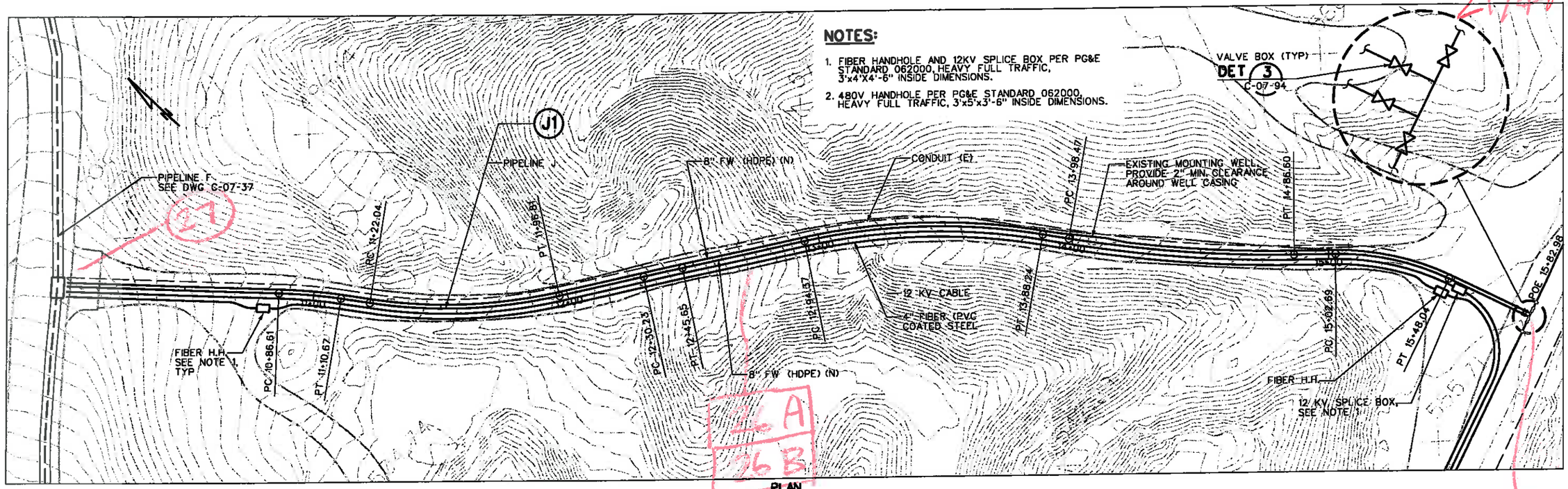
TOPOCK GROUNDWATER REMEDIATION PROJECT

TCS LOOP INJECTION WELL VAULTS MECHANICAL DETAILS

GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. of SHEETS
M-03-05
REV

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AECOM
2101 WEBSTER STREET SUITE 1900
OAKLAND, CA 94612-3066
PROJECT NO. 60272335

SCALE: 1" = 20'-0" H
SCALE: 1" = 5'-0" V

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

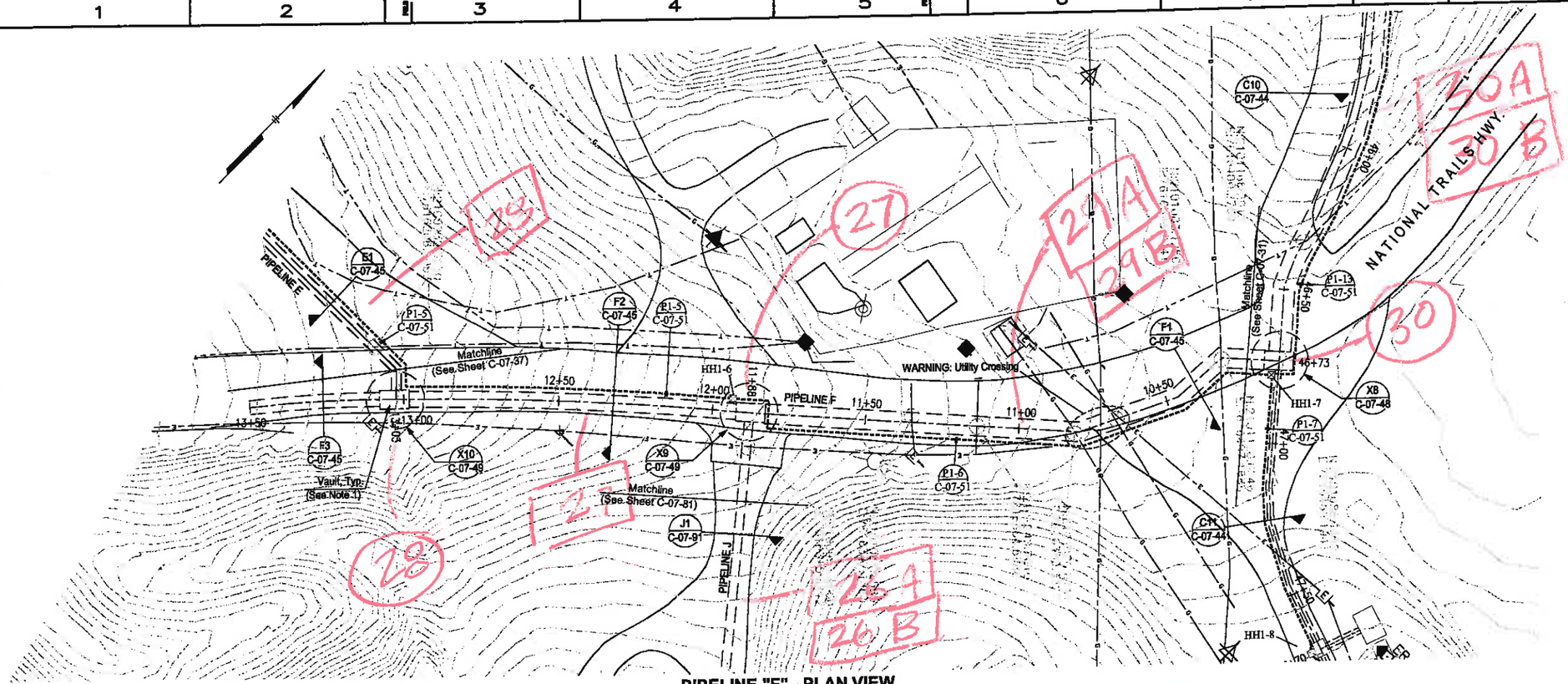
REVISIONS

APPROVED BY		
GM	XXXXX	
SUPV	PD	
DSGN	TL	
DWN	TL	
CHKD	JM	
QA		
DATE	07-27-12	
SCALES	1" = 20'-0"	

TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE J
PLAN AND PROFILE
10+00 TO 15+83
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

XREFS/PLM	
BILL OF MATL	
ENG LIST	
TRUPRINT	
SURVEY BY	
DRAWING NO.	C-07-43
SHEET NO. OF SHEETS	
REV	

C-07-54



PIPELINE "F" - PLAN VIEW

(SCALE: 1" = 20')

LEGEND

- 10+00 — TRENCH ALIGNMENT AND STATIONING
- INJECTION WELL
- EXTRACTION WELL
- IN-SITU REDUCTION ZONE WELL
- FUTURE IN-SITU REDUCTION ZONE WELL
- OFFSET PIPE AND TRENCH TO IRZ WELL
- CAPPED OFFSET PIPE (FUTURE CONNECTION)
- CONCRETE VAULT BOX (See Note 1)
- XFMR 004 — TRANSFORMER (APPROX. LOCATION)
- BURY TRENCH AND ELECTRIC HAND HOLE
- P1-1 — ELECTRICAL NODE AND SECTION (See Note 2)

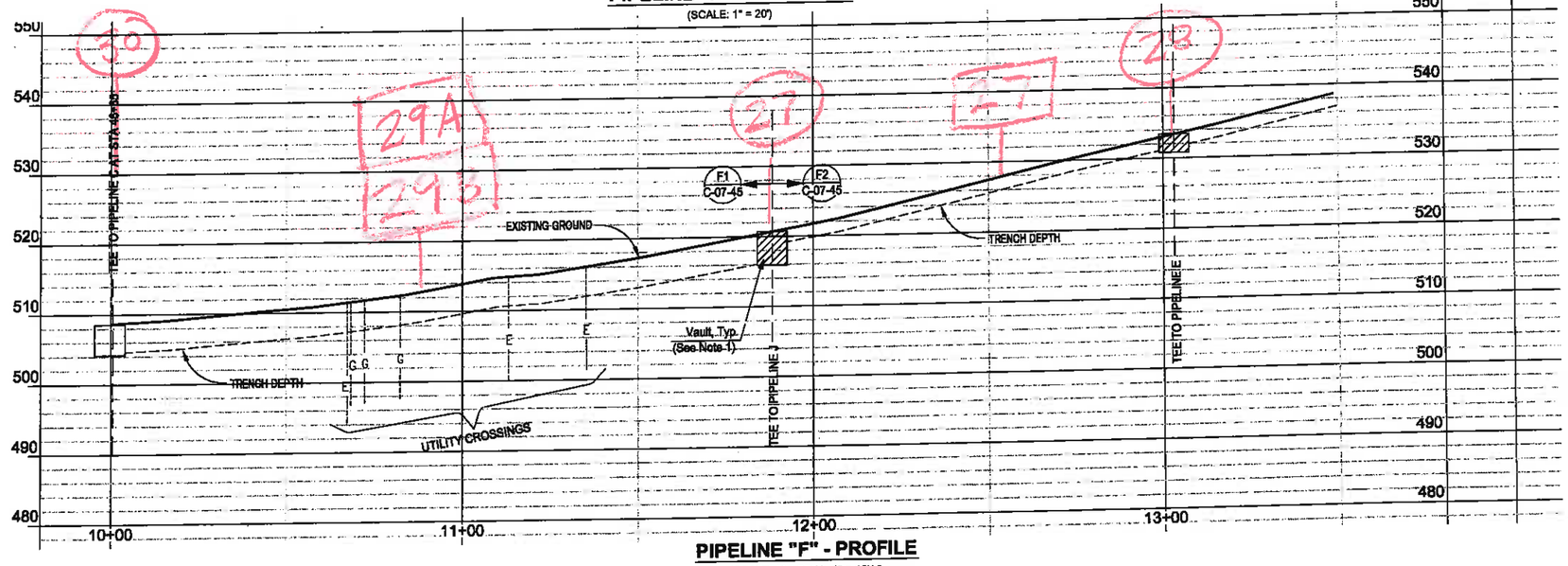
UTILITY KEY:

- FOUND LAND MONUMENT
- E — ELECTRIC
- G — GAS
- T(OH) — TELECOMM
- T — TELECOMM (UNDERGROUND)
- W — WATER

NOTES

1. VAULT DETAILS SHOWN ON SHEETS M-X-X AND S-X-X.
2. SEE CONDUIT AND CABLE SCHEDULES AND SINGLE LINE DIAGRAMS ON SHEETS E-00-05 THRU E-00-13.

20 10 0 20 40 60
SCALE IN FEET



PIPELINE "F" - PROFILE

(SCALE: 1" = 20' H; 1" = 10' V)

ETIC ENGINEERING

ARCADIS

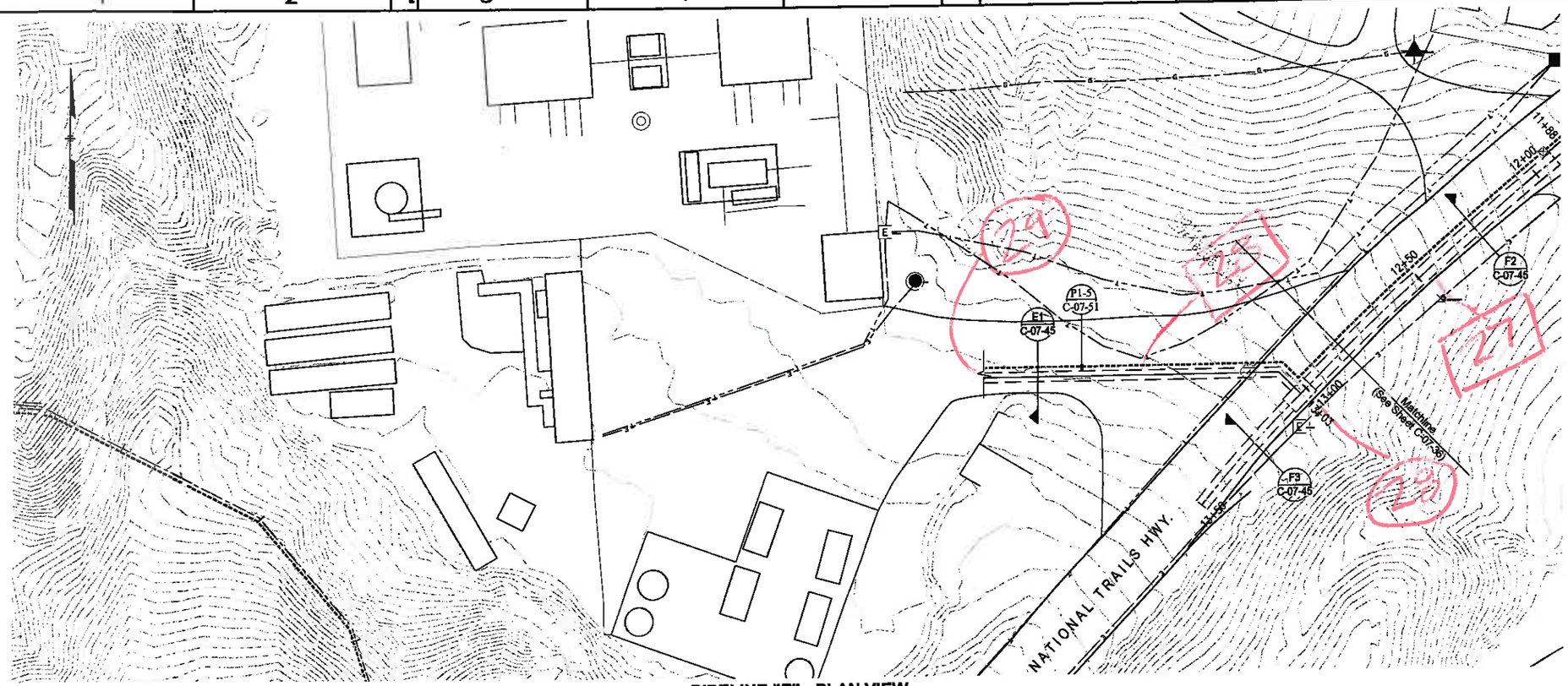
REVISIONS									
NO.	DATE	DESCRIPTION	GM/SPEC	DSN	CHKD	SUPV	APVD BY		
0	8/24/12	60% DESIGN LAYOUT	AJW						

APPROVED BY	
GM/SPEC	
SUPV	
DSGN	PES
DRWN	AJW
CHKD	
QCK	
DATE	
SCALE(S)	1" = 20'

TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE
PIPELINE "F"
STA 10+00 TO STA 13+50
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

COORD FILE	
FILL OF MATL	
DGB LIST	
SUPPDGB	
SUPED BY	
SHEET NO. of	SHEETS
C-07-36	REV

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PIPELINE "E" - PLAN VIEW

(SCALE: 1" = 20')

LEGEND

- 10+00 — TRENCH ALIGNMENT AND STATIONING
- INJECTION WELL
- EXTRACTION WELL
- IN-SITU REDUCTION ZONE WELL
- FUTURE IN-SITU REDUCTION ZONE WELL
- OFFSET PIPE AND TRENCH TO IRZ WELL
- CAPPED OFFSET PIPE (FUTURE CONNECTION)
- CONCRETE VAULT BOX (See Note 1)
- XFMR 004 — TRANSFORMER (APPROX. LOCATION)
- BURY TRENCH AND ELECTRIC HAND HOLE
- P1-1 — ELECTRICAL NODE AND SECTION (See Note 2)

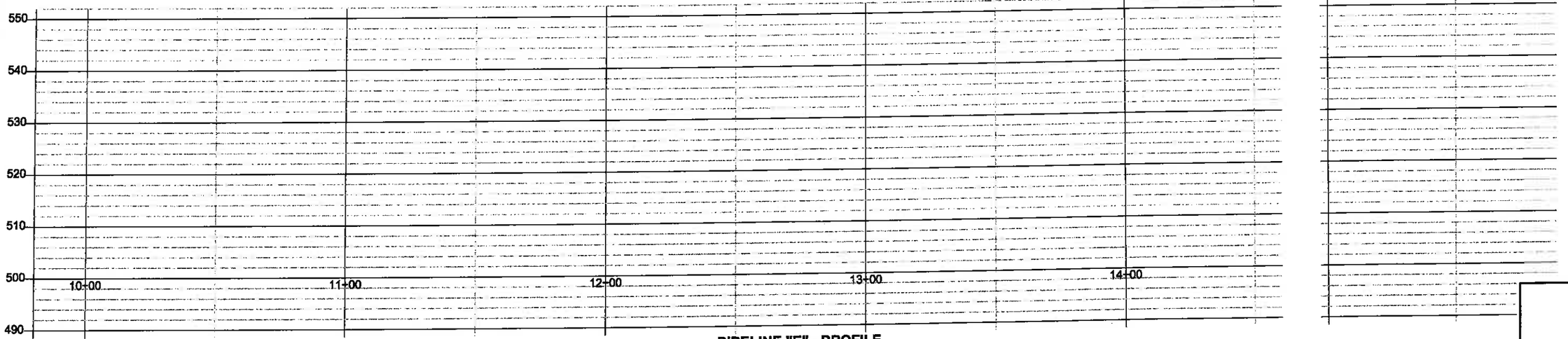
UTILITY KEY:

- FOUND LAND MONUMENT
- E — ELECTRIC
- G — GAS
- T(OH) — TELECOMM
- T — TELECOMM (UNDERGROUND)
- W — WATER

NOTES

1. VAULT DETAILS SHOWN ON SHEETS M-X-X AND S-X-X.
2. SEE CONDUIT AND CABLE SCHEDULES AND SINGLE LINE DIAGRAMS ON SHEETS E-00-05 THRU E-00-13.

20 10 0 20 40 60
SCALE IN FEET



PIPELINE "E" - PROFILE

(SCALE: 1" = 20' H; 1" = 10' V)

ETIC ENGINEERING

ARCADIS

NO.	DATE	DESCRIPTION	GIS/SPEC	DSN	CHKD	SUPV	APVD BY
0	8/24/12	60% DESIGN LAYOUT		AJW			

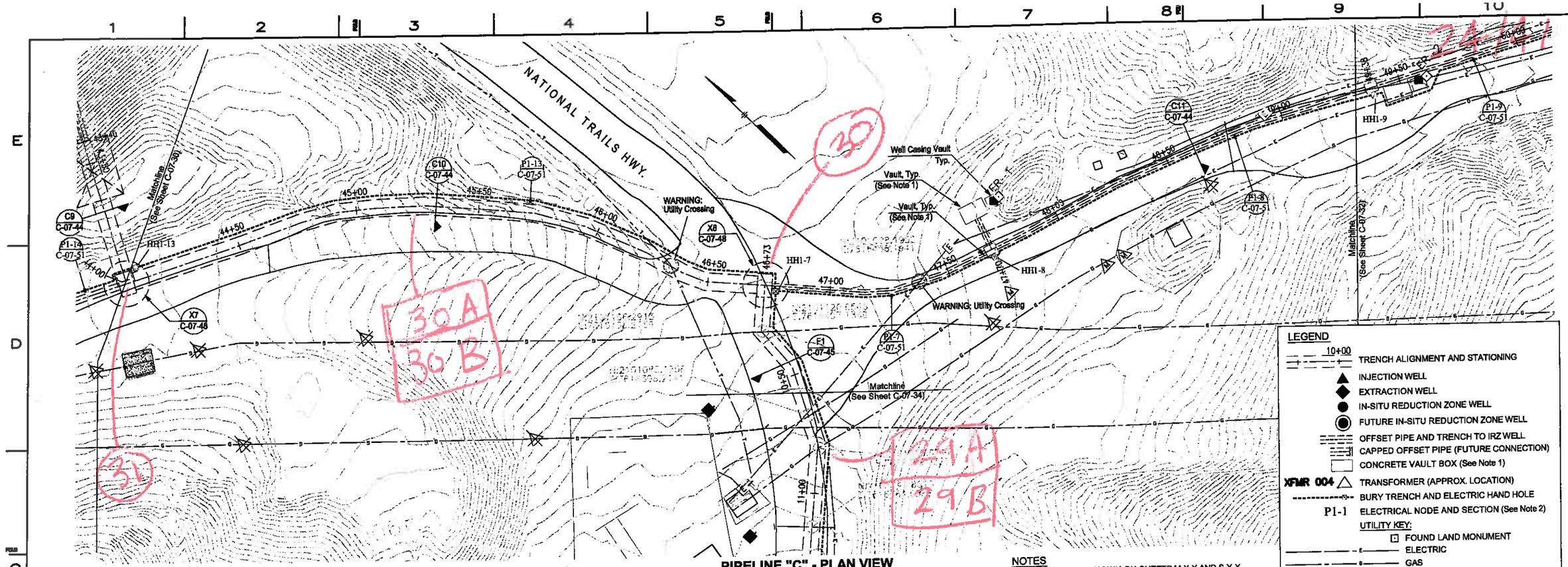
REVISIONS

APPROVED BY: SD, SUPV, DSGN PCS, DRN AJW, CHKD, CK, DATE, SCALES 1" = 20'

TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE
PIPELINE "E"
STA 10+00 TO STA 14+60
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM | BILL OF MAIL | DWG LIST | SUPSDS | SUPSD BY | SHEET NO. C-07-37 of SHEETS | REV

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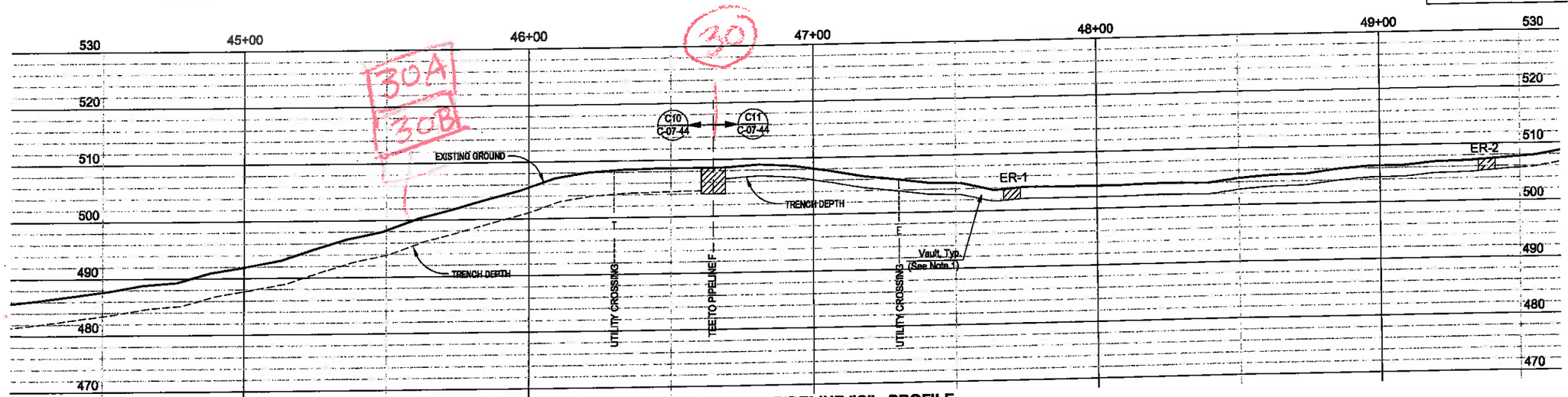


PIPELINE "C" - PLAN VIEW

(SCALE: 1" = 20')

20 10 0 20 40 60
SCALE IN FEET

NOTES
1. VAULT DETAILS SHOWN ON SHEETS M-X-X AND S-X-X.
2. SEE CONDUIT AND CABLE SCHEDULES AND SINGLE LINE DIAGRAMS ON SHEETS E-00-05 THRU E-00-13.



PIPELINE "C" - PROFILE

(SCALE: 1" = 20' H; 1" = 10' V)

ETIC ENGINEERING

ARCADIS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	8/24/12	60% DESIGN LAYOUT	AJW				

REVISIONS

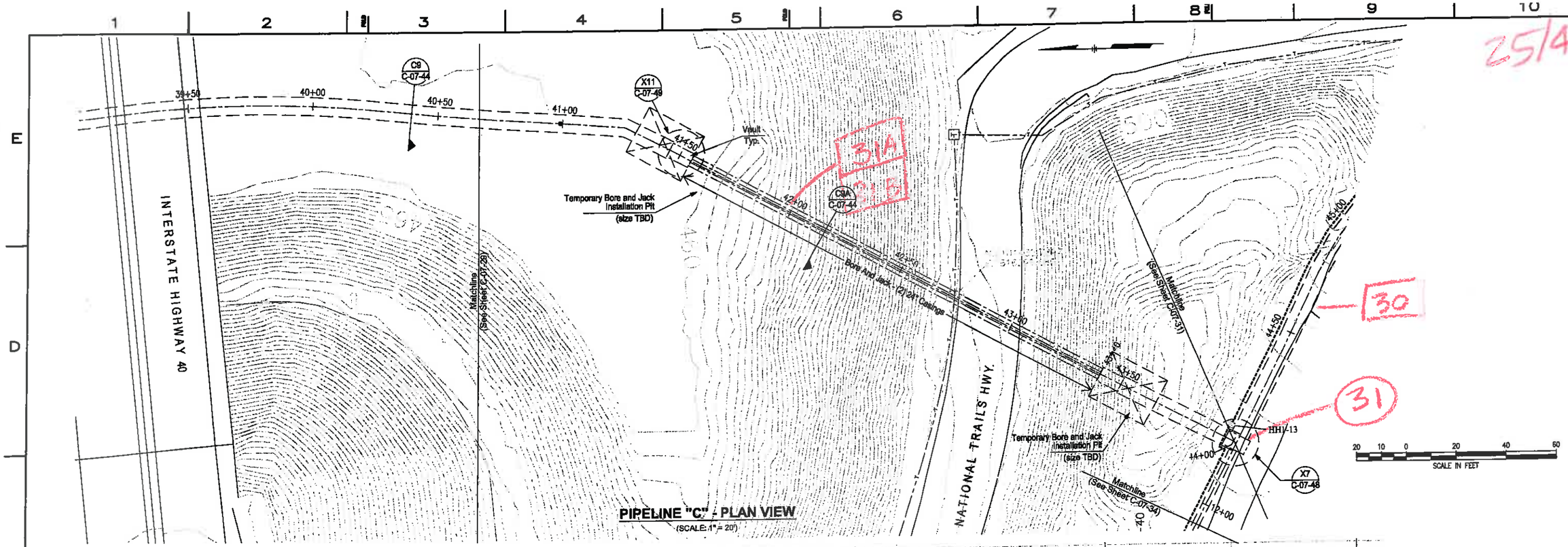
APPROVED BY	
GM/PM	
SUPV	
DSGN	PES
DWN	AJW
CHKD	
QA	
DATE	
SCALES	1" = 20'

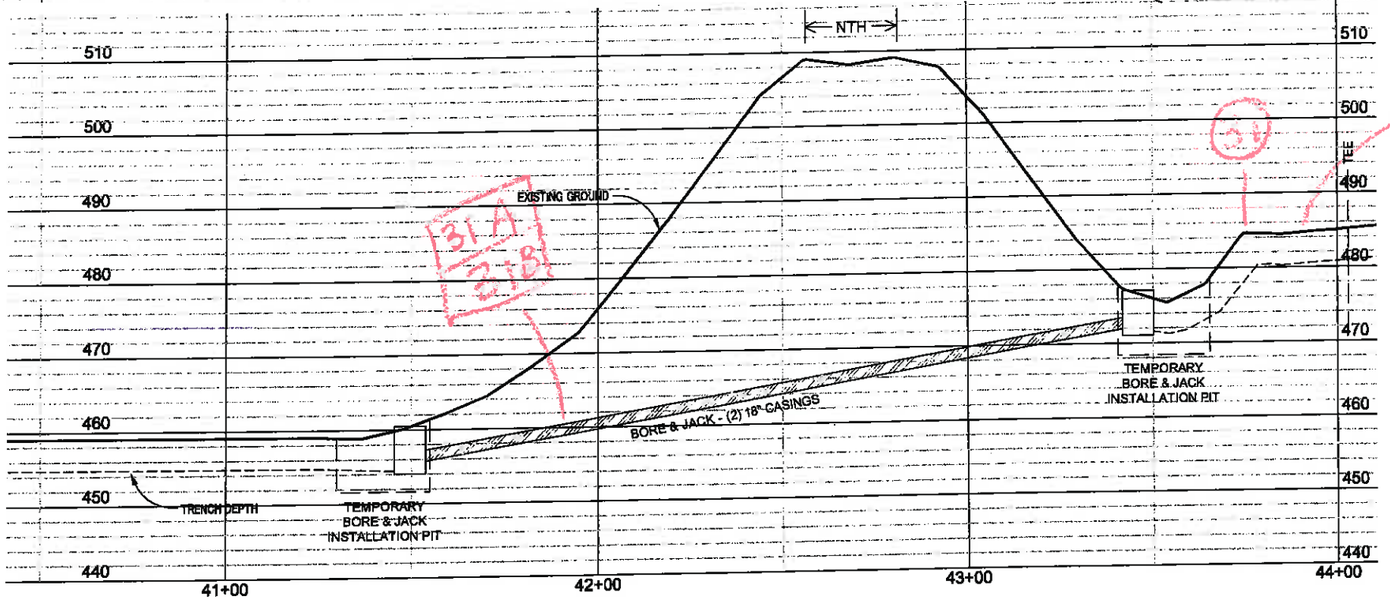
TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE
PIPELINE "C10 & C11"
STA 44+00 TO STA 49+20
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

COORD'D	
BILL OF MATL	
DGN LIST	
SHEETS	
SUPED BY	
DRGET NO.	of SHEETS
C-07-31	REV

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25/41





PIPELINE "C" - PROFILE
(SCALE: 1" = 20' H; 1" = 10' V)

LEGEND

- 10+00 — TRENCH ALIGNMENT AND STATIONING
- INJECTION WELL
- EXTRACTION WELL
- IN-SITU REDUCTION ZONE WELL
- FUTURE IN-SITU REDUCTION ZONE WELL
- OFFSET PIPE AND TRENCH TO IRZ WELL
- CAPPED OFFSET PIPE (FUTURE CONNECTION)
- CONCRETE VAULT BOX (See Note 1)
- XFMR 004 — TRANSFORMER (APPROX. LOCATION)
- BURY TRENCH AND ELECTRIC HAND HOLE
- P1-1 — ELECTRICAL NODE AND SECTION (See Note 2)

UTILITY KEY:

- FOUND LAND MONUMENT
- ELECTRIC
- GAS
- TELECOMM
- TELECOMM (UNDERGROUND)
- WATER

NOTES
1. VAULT DETAILS SHOWN ON SHEETS M-X-X AND S-X-X.
2. SEE CONDUIT AND CABLE SCHEDULES AND SINGLE LINE DIAGRAMS ON SHEETS E-00-05 THRU E-00-13.

ETIC ENGINEERING

ARCADIS

CO.	DATE	DESCRIPTION	GIL/SPEC	DWN	CHKD	SUPV	APVD BY
0	8/24/12	60% DESIGN LAYOUT		AJW			

REVISIONS

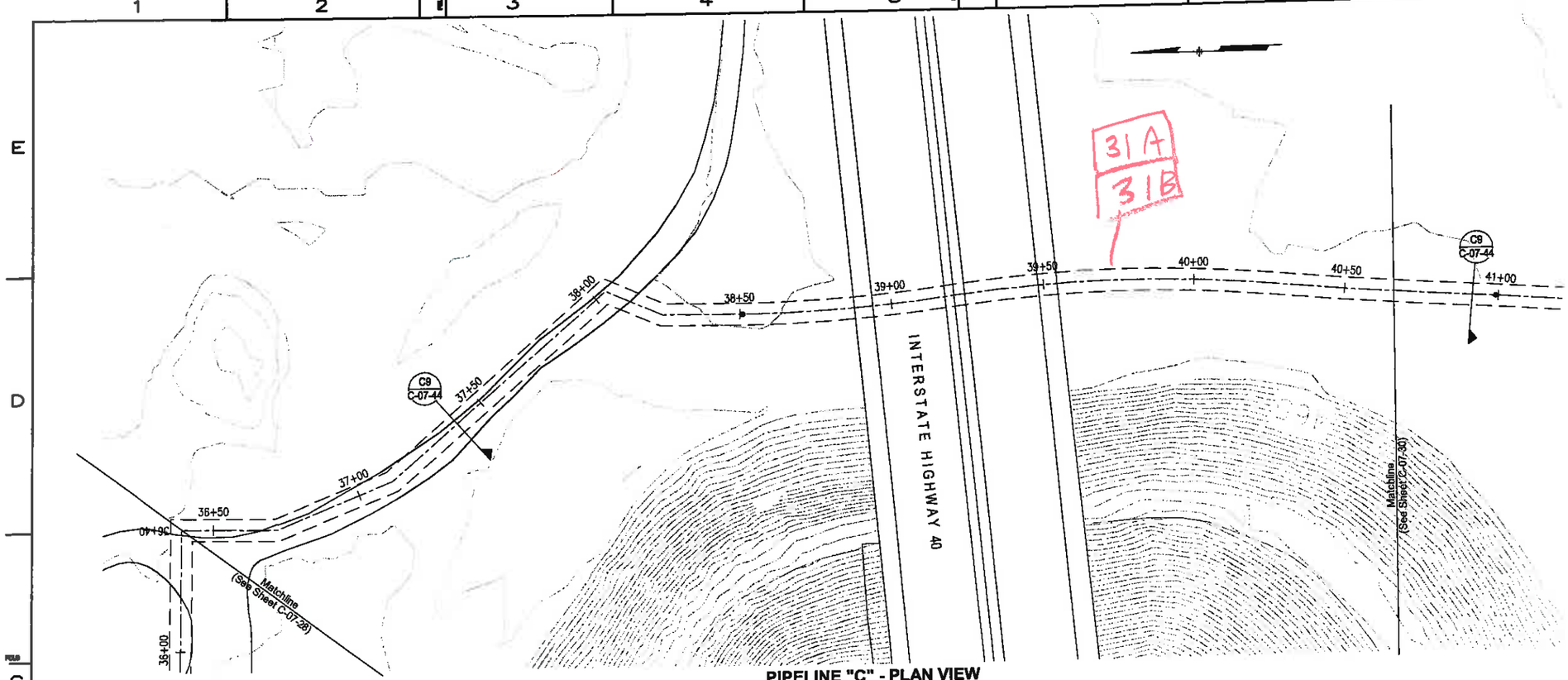
TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE
PIPELINE "C9A"
STA 40+60 TO STA 44+00
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

APVD BY	
DES	
DSGN	PES
DRWN	AJW
CHKD	
QC	
DATE	
SCALES	1" = 20'
ACCEPTED BY	
FILL OF MAIL	
PRO LIST	
SURVEYED	
SURVEYED BY	
SHEET NO.	C-07-30
of SHEETS	
REV	

30A
30B

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26/41



PIPELINE "C" - PLAN VIEW
(SCALE: 1" = 20')

LEGEND

- 10+00 — TRENCH ALIGNMENT AND STATIONING
- INJECTION WELL
- EXTRACTION WELL
- IN-SITU REDUCTION ZONE WELL
- FUTURE IN-SITU REDUCTION ZONE WELL
- OFFSET PIPE AND TRENCH TO IRZ WELL
- CAPPED OFFSET PIPE (FUTURE CONNECTION)
- CONCRETE VAULT BOX (See Note 1)
- XFMR 004 — TRANSFORMER (APPROX. LOCATION)
- BURY TRENCH AND ELECTRIC HAND HOLE
- P1-1 — ELECTRICAL NODE AND SECTION (See Note 2)

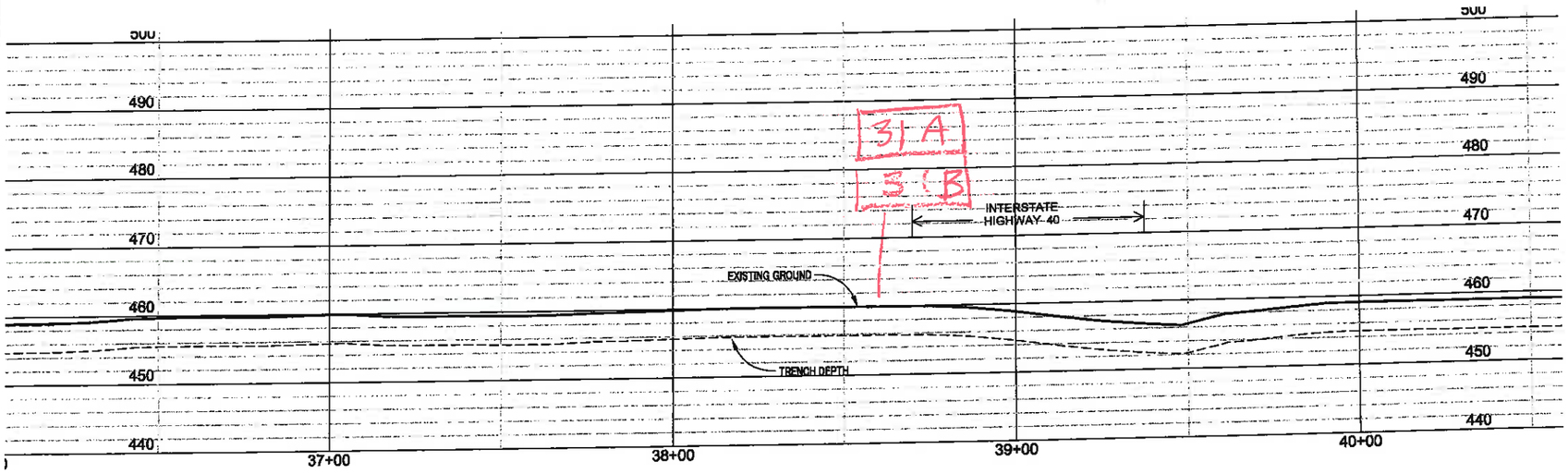
UTILITY KEY:

- FOUND LAND MONUMENT
- E — ELECTRIC
- G — GAS
- T(OH) — TELECOMM
- T — TELECOMM (UNDERGROUND)
- W — WATER

NOTES
1. VAULT DETAILS SHOWN ON SHEETS M-X-X AND S-X-X.
2. SEE CONDUIT AND CABLE SCHEDULES AND SINGLE LINE DIAGRAMS ON SHEETS E-00-05 THRU E-00-13.

20 10 0 20 40 60
SCALE IN FEET

31A
31B



PIPELINE "C" - PROFILE
(SCALE: 1" = 20' H; 1" = 10' V)

ETIC ENGINEERING

ARCADIS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	8/24/12	60% DESIGN LAYOUT		AJW			

REVISIONS

APPROVED BY: ED, SUPV, CHKD PES, DWN AJW, CHKD, QA, DATE, SCALE 1" = 20'

TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE
PIPELINE "C9"
STA 36+40 TO STA 40+60
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

DESIGNATION
CALL OF MAIL
DWG LIST
SUPERS
SUPED BY
SHEET NO. of SHEETS
C-07-29 REV

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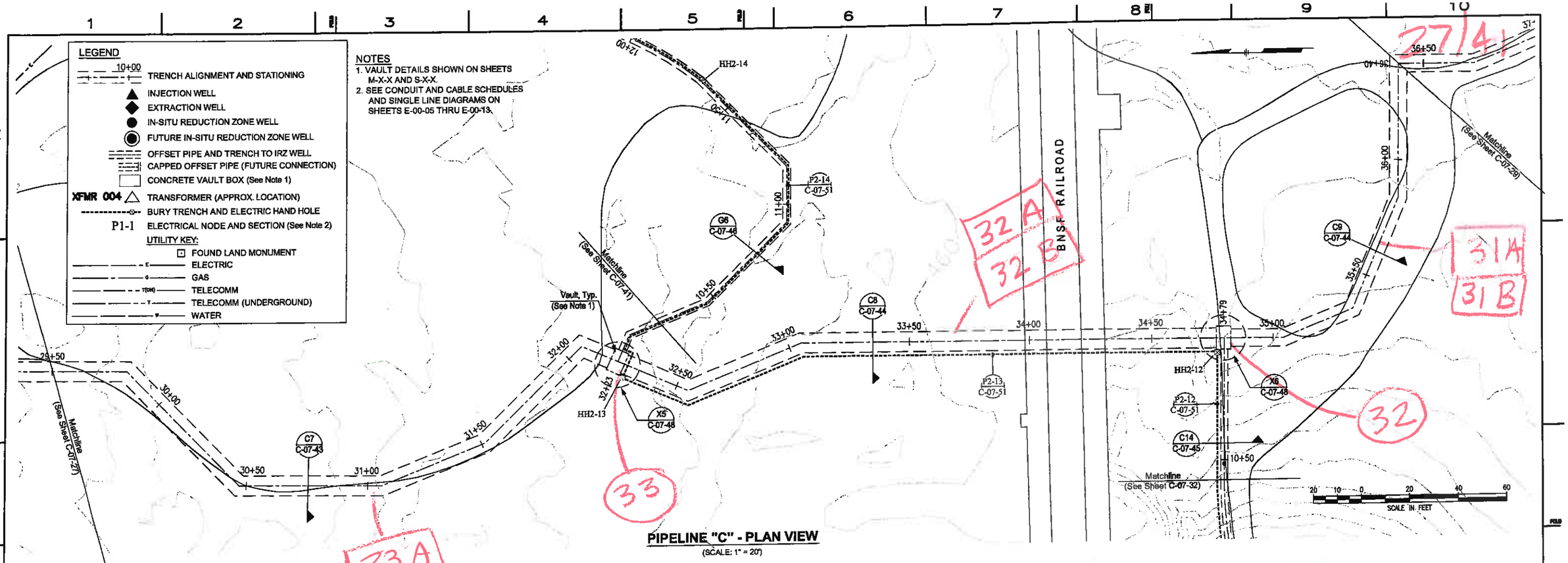
- 10+00 — TRENCH ALIGNMENT AND STATIONING
- INJECTION WELL
- EXTRACTION WELL
- IN-SITU REDUCTION ZONE WELL
- FUTURE IN-SITU REDUCTION ZONE WELL
- OFFSET PIPE AND TRENCH TO IRZ WELL
- CAPPED OFFSET PIPE (FUTURE CONNECTION)
- CONCRETE VAULT BOX (See Note 1)
- XFMR 004 — TRANSFORMER (APPROX. LOCATION)
- BURY TRENCH AND ELECTRIC HAND HOLE
- P1-1 — ELECTRICAL NODE AND SECTION (See Note 2)

UTILITY KEY:

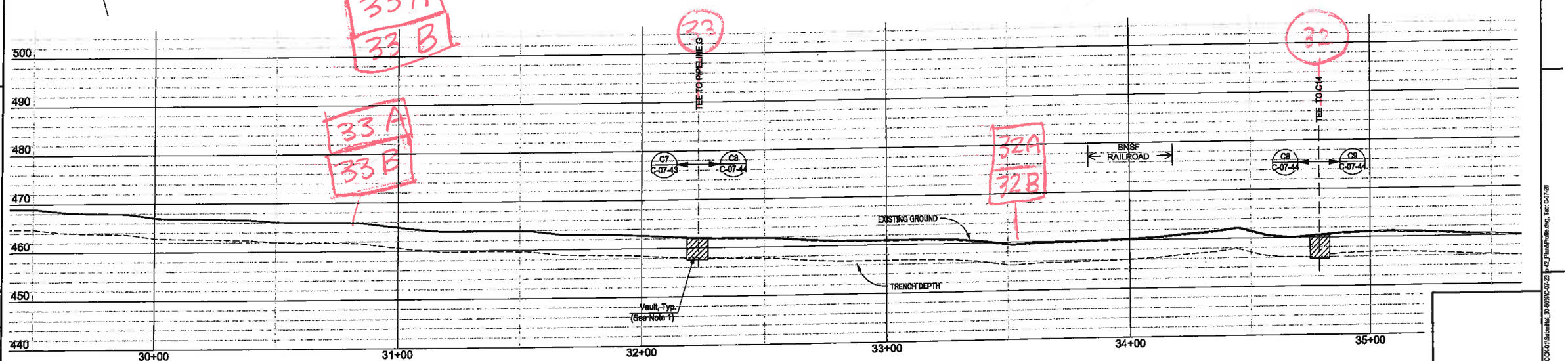
- FOUND LAND MONUMENT
- E — ELECTRIC
- G — GAS
- T(DM) — TELECOMM
- T — TELECOMM (UNDERGROUND)
- W — WATER

NOTES

1. VAULT DETAILS SHOWN ON SHEETS M-X-X AND S-X-X.
2. SEE CONDUIT AND CABLE SCHEDULES AND SINGLE LINE DIAGRAMS ON SHEETS E-00-05 THRU E-00-13.



PIPELINE "C" - PLAN VIEW
(SCALE: 1" = 20')



PIPELINE "C" - PROFILE
(SCALE: 1" = 20' H; 1" = 10' V)

ETIC ENGINEERING

ARCADIS

NO.	DATE	DESCRIPTION	GM/SPEC	DVN	CHKD	SUPV	APVD BY
0	8/24/12	60% DESIGN LAYOUT	AJW				

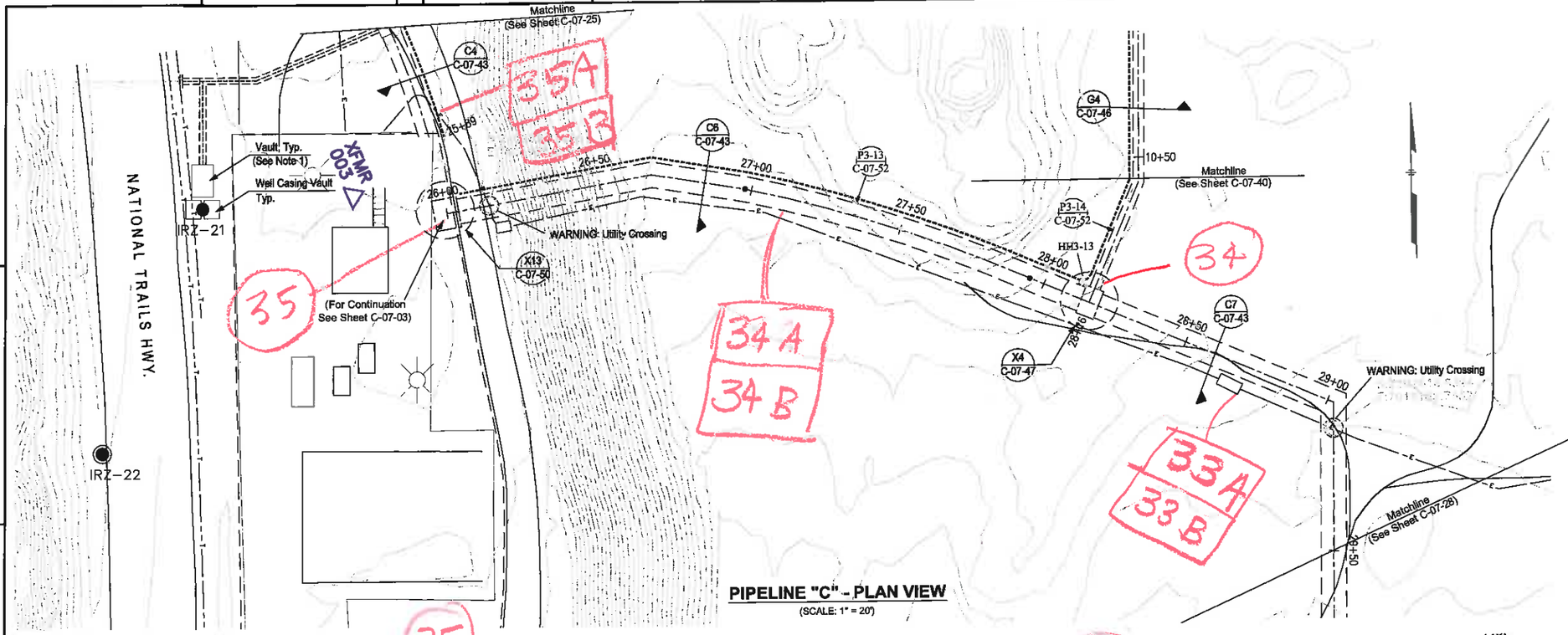
REVISIONS

APPROVED BY
ED
SUPV
DESIGN PES
DRWN AJW
CHKD
QA
DATE
SCALES 1" = 20'

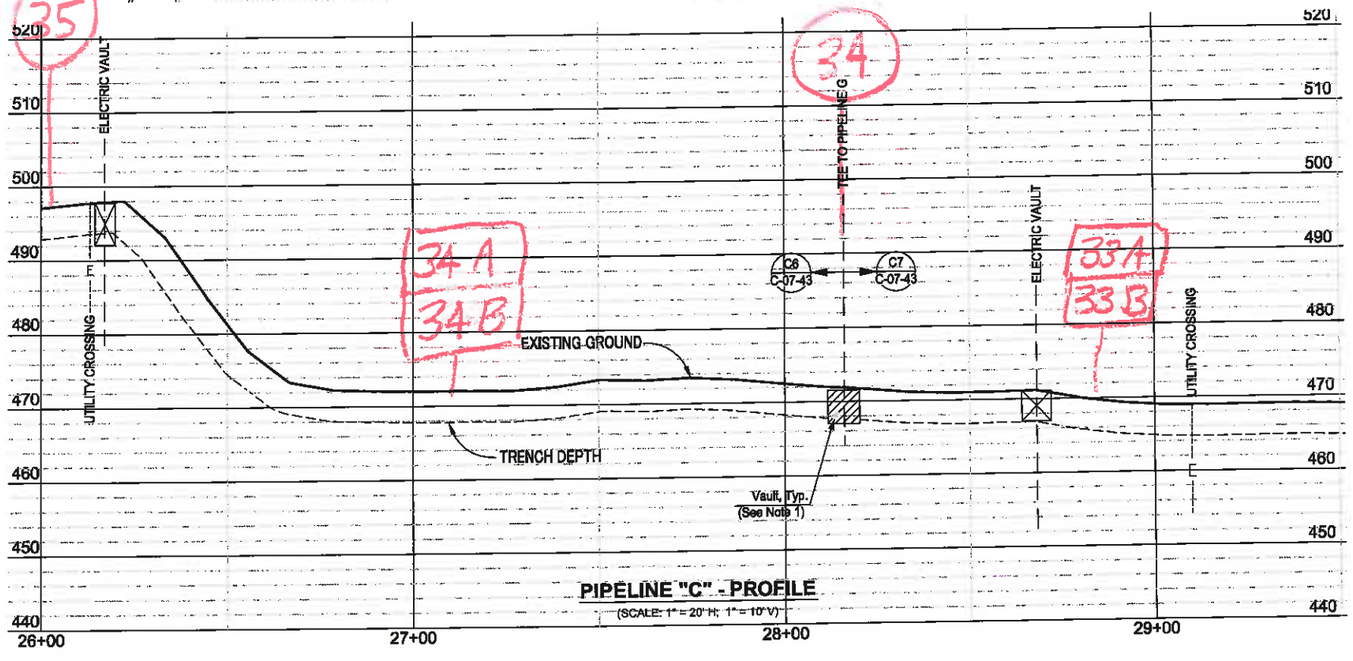
TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE
PIPELINE "C7, C8 & C9"
STA 26+50 TO 35+60
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

ADDENDUM
ILL OF MATL.
STD LIST
SUPERS
HELPER BY
SHEET NO. of SHEETS
C-07-28
REV

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PIPELINE "C" - PLAN VIEW
(SCALE: 1" = 20')



PIPELINE "C" - PROFILE
(SCALE: 1" = 20' H; 1" = 10' V)

LEGEND

- 10+00 — TRENCH ALIGNMENT AND STATIONING
- INJECTION WELL
- EXTRACTION WELL
- IN-SITU REDUCTION ZONE WELL
- FUTURE IN-SITU REDUCTION ZONE WELL
- OFFSET PIPE AND TRENCH TO IRZ WELL
- CAPPED OFFSET PIPE (FUTURE CONNECTION)
- CONCRETE VAULT BOX (See Note 1)
- XFMR 004 — TRANSFORMER (APPROX. LOCATION)
- BURY TRENCH AND ELECTRIC HAND HOLE
- P1-1 — ELECTRICAL NODE AND SECTION (See Note 2)

UTILITY KEY:

- FOUND LAND MONUMENT
- E — ELECTRIC
- G — GAS
- T(OH) — TELECOMM
- T — TELECOMM (UNDERGROUND)
- W — WATER

NOTES
1. VAULT DETAILS SHOWN ON SHEETS M-X-X AND S-X-X.
2. SEE CONDUIT AND CABLE SCHEDULES AND SINGLE LINE DIAGRAMS ON SHEETS E-00-05 THRU E-00-13.

20 10 0 20 40 60
SCALE IN FEET

ETIC ENGINEERING

ARCADIS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	8/24/12	60% DESIGN LAYOUT	GM/SPEC	AJW	CHKD	SUPV	APVD BY

REVISIONS

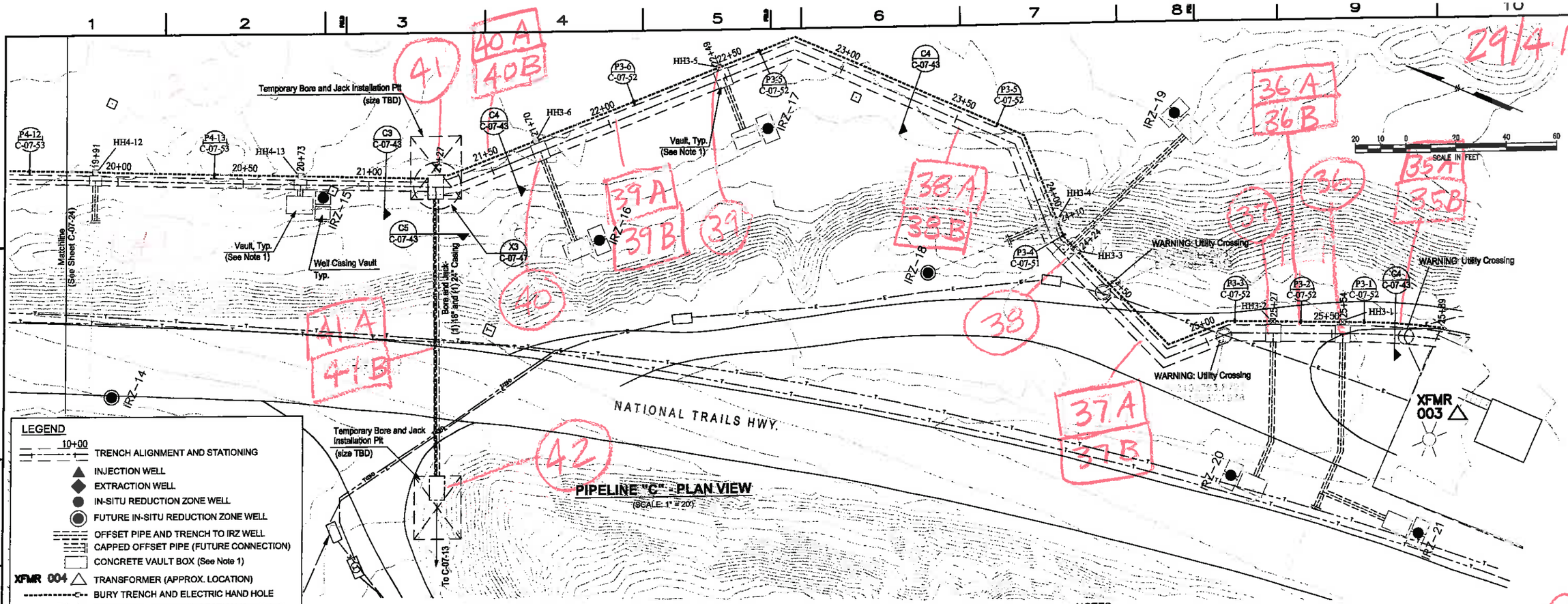
APPROVED BY: SO, SUPV, DSGN PES, DWN AJW, CHKD, CK, DATE, SCALES 1" = 20'

TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE
PIPELINE "C6 & C7"
STA 26+00 TO STA 29+50
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM, BILL OF MATL, DWG LIST, SUPSDS, SUPSD BY, SHEET NO. of SHEETS, REV

C-07-27

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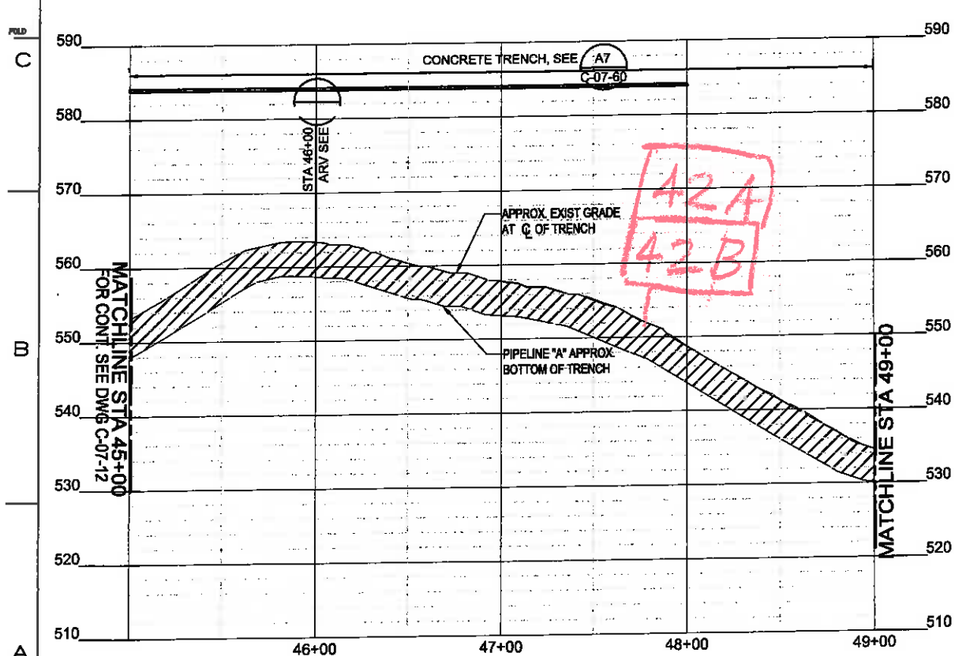

Temporary Bore and Jack Installation Pit (size TBD)
Vault, Typ. (See Note 1)
Well Casing Vault Typ.
Bore and Jack (4) 18" and (4) 24" Casing
Matchline (See Sheet C-07-24)
NATIONAL TRAILS HWY.
WARNING: Utility Crossing
XFMR 003
IRZ-14
IRZ-15
IRZ-16
IRZ-17
IRZ-18
IRZ-19
IRZ-20
IRZ-21
HH4-12
HH4-13
HH3-6
HH3-5
HH3-4
HH3-3
HH3-2
HH3-1
C3 C-07-43
C4 C-07-43
C5 C-07-43
X3 C-07-47
P4-12 C-07-53
P4-13 C-07-53
P3-6 C-07-52
P3-5 C-07-52
P3-4 C-07-51
P3-3 C-07-52
P3-2 C-07-52
P3-1 C-07-52
To C-07-13
SCALE IN FEET
LEGEND
10+00 TRENCH ALIGNMENT AND STATIONING
INJECTION WELL
EXTRACTION WELL
IN-SITU REDUCTION ZONE WELL
FUTURE IN-SITU REDUCTION ZONE WELL
OFFSET PIPE AND TRENCH TO IRZ WELL
CAPPED OFFSET PIPE (FUTURE CONNECTION)
CONCRETE VAULT BOX (See Note 1)
XFMR 004 TRANSFORMER (APPROX. LOCATION)
BURY TRENCH AND ELECTRIC HAND HOLE
P1-1 ELECTRICAL NODE AND SECTION (See Note 2)
UTILITY KEY:
FOUND LAND MONUMENT
ELECTRIC
GAS
TELECOMM
TELECOMM (UNDERGROUND)
WATER
PIPELINE "C" - PLAN VIEW
(SCALE: 1" = 20')
NOTES
1. VAULT DETAILS SHOWN ON SHEETS M-X-X AND S-X-X.
2. SEE CONDUIT AND CABLE SCHEDULES AND SINGLE LINE DIAGRAMS ON SHEETS E-00-05 THRU E-00-13.
TEE FOR BORE & JACK TO PIPELINE A
EXISTING GROUND
TRENCH DEPTH
UTILITY CROSSING
PIPELINE "C" - PROFILE
(SCALE: 1" = 20' H; 1" = 10' V)
ETIC ENGINEERING
ARCADIS
REVISIONS
TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE
PIPELINE "C3 & C4"
STA 19+60 TO STA 25+89
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA
C-07-25

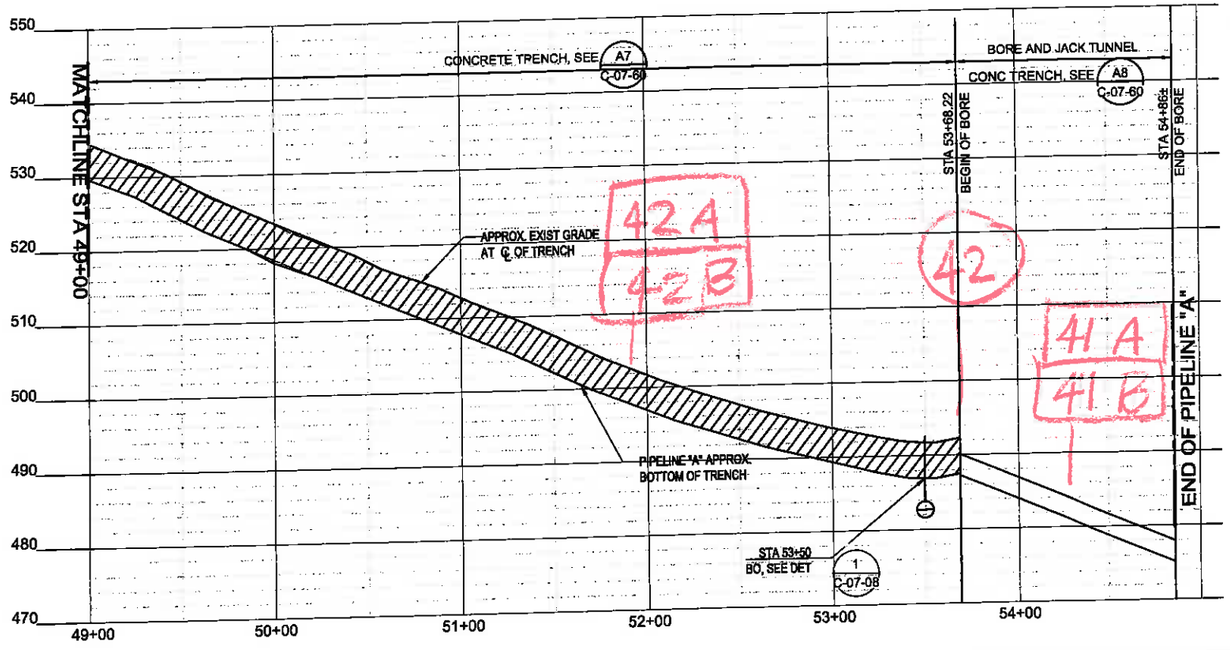


NOTES

1. DEPTHS OF EXISTING UTILITIES ARE UNKNOWN. ALL POTENTIAL CONFLICTS BETWEEN NEW PIPE CONSTRUCTION AND EXISTING UTILITIES WILL BE POTHOLED PRIOR TO 100% DESIGN. A DETERMINATION WILL BE MADE WHETHER TO RELOCATE EXISTING UTILITIES OR RE-ROUTE NEW PIPE TRENCHES AROUND EXISTING UTILITIES. THIS WILL BE INCORPORATED INTO 100% DESIGN.
2. THE NEW PIPELINE ALIGNMENT SHOWS CENTER OF TRENCH. THE NUMBER AND SIZES OF PIPE IN EACH TRENCH VARIES. REFER TO PIPE SECTION NUMBER ON EACH PLAN AND PROFILE SHEET AND PIPE SCHEDULE ON DRAWING C-07-03 FOR NUMBER AND SIZE OF EACH PIPE. REFER TO TRENCH DETAILS ON DRAWINGS C-07-60, C-07-61 AND C-07-62 OR ARRANGEMENT OF PIPING IN EACH TRENCH SECTION.

HORZ SCALE: 1"=40'-0"
VERT SCALE: 1"=10'-0"





E2 Consulting Engineers, Inc.
100 Pine St., Ste. 550
San Francisco, CA 94111
(415) 788-1100

CH2MHILL

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

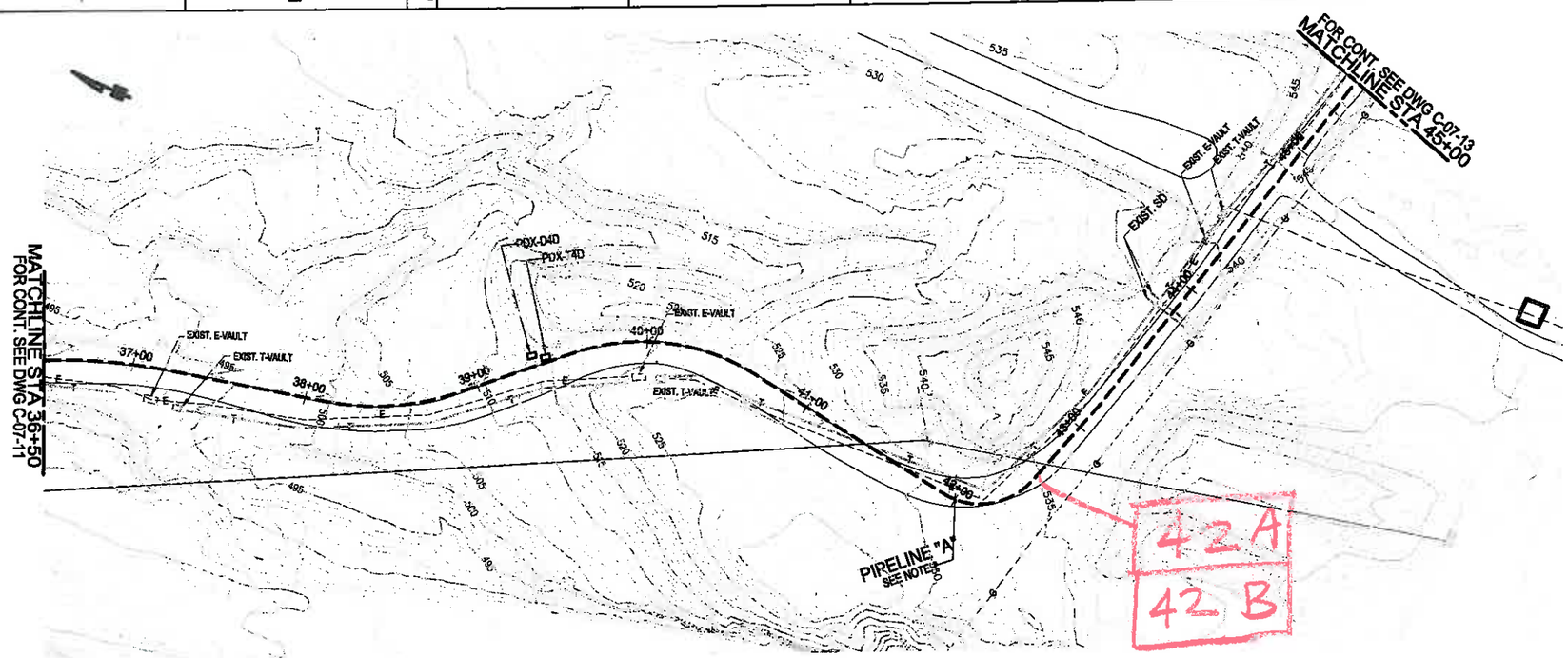
APPROVED BY	
SO	
SUPV	
DSGN	PT
DWN	PC/EE
CHKD	PT
QK	
DATE	
SCALES	

TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE
PIPELINE "A"
STA 45+00 TO STA 54+86
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

PRELIMINARY
NOT FOR CONSTRUCTION

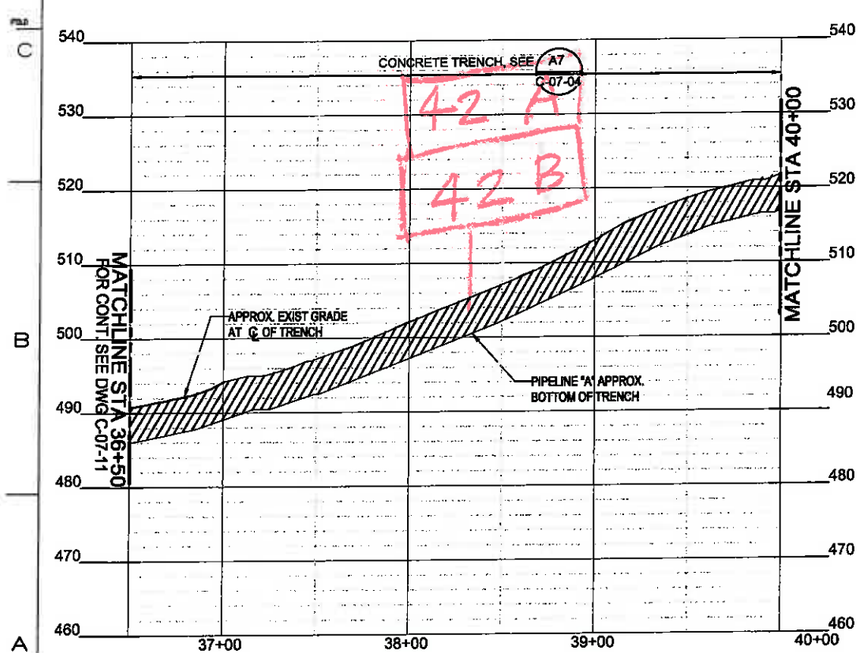
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BILL OF MATL	
DWG LIST	
SUPSDS	
SUPSD BY	
SHEET NO.	of SHEETS
C-07-13	REV

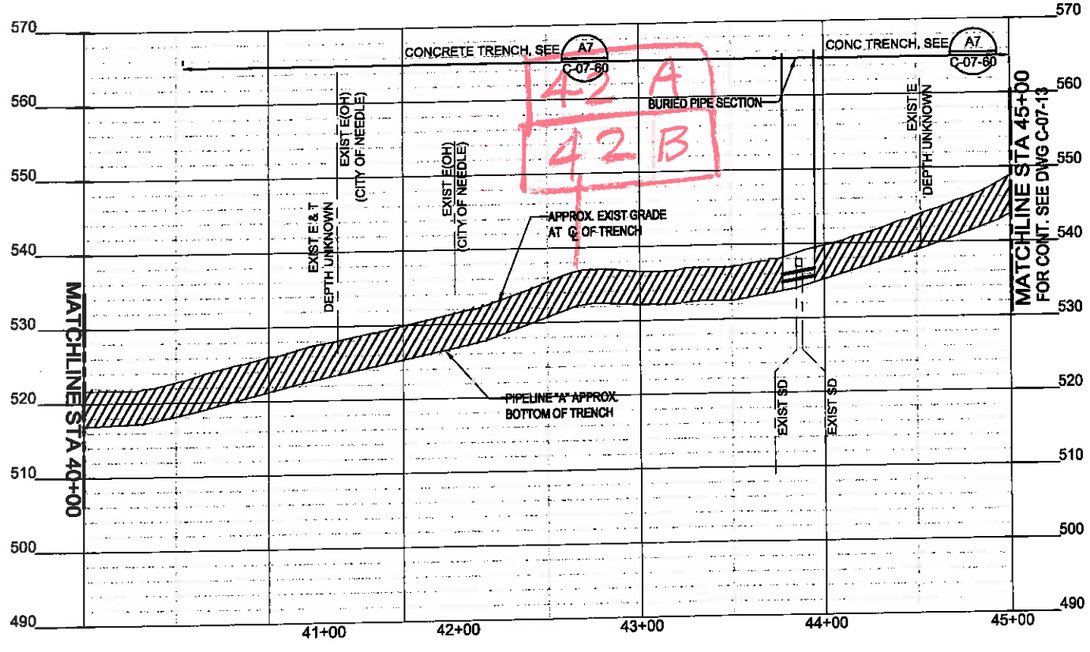
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NOTES

1. DEPTHS OF EXISTING UTILITIES ARE UNKNOWN. ALL POTENTIAL CONFLICTS BETWEEN NEW PIPE CONSTRUCTION AND EXISTING UTILITIES WILL BE POTHOLED PRIOR TO 100% DESIGN. A DETERMINATION WILL BE MADE WHETHER TO RELOCATE EXISTING UTILITIES OR RE-ROUTE NEW PIPE TRENCHES AROUND EXISTING UTILITIES. THIS WILL BE INCORPORATED INTO 100% DESIGN.
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HORZ. SCALE: 1"=40'-0"
VERT. SCALE: 1"=10'-0"

PRELIMINARY NOT FOR CONSTRUCTION

E2 Consulting Engineers, Inc.

CH2MHILL.

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

APPROVED BY	
SO	
SUPV	
DSGN	PT
DWN	PC/EE
CHKD	PT
OK	
DATE	
SCALES	

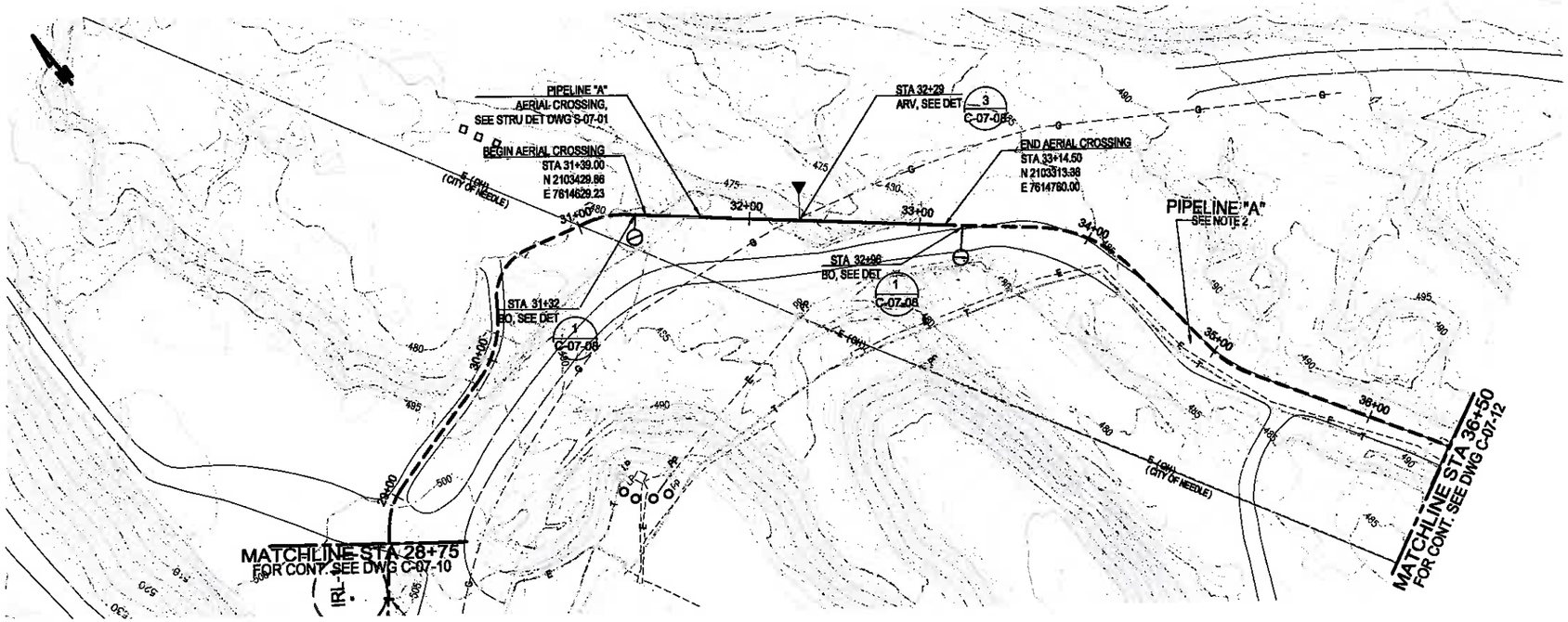
TOPOCK GROUNDWATER REMEDIATION PROJECT

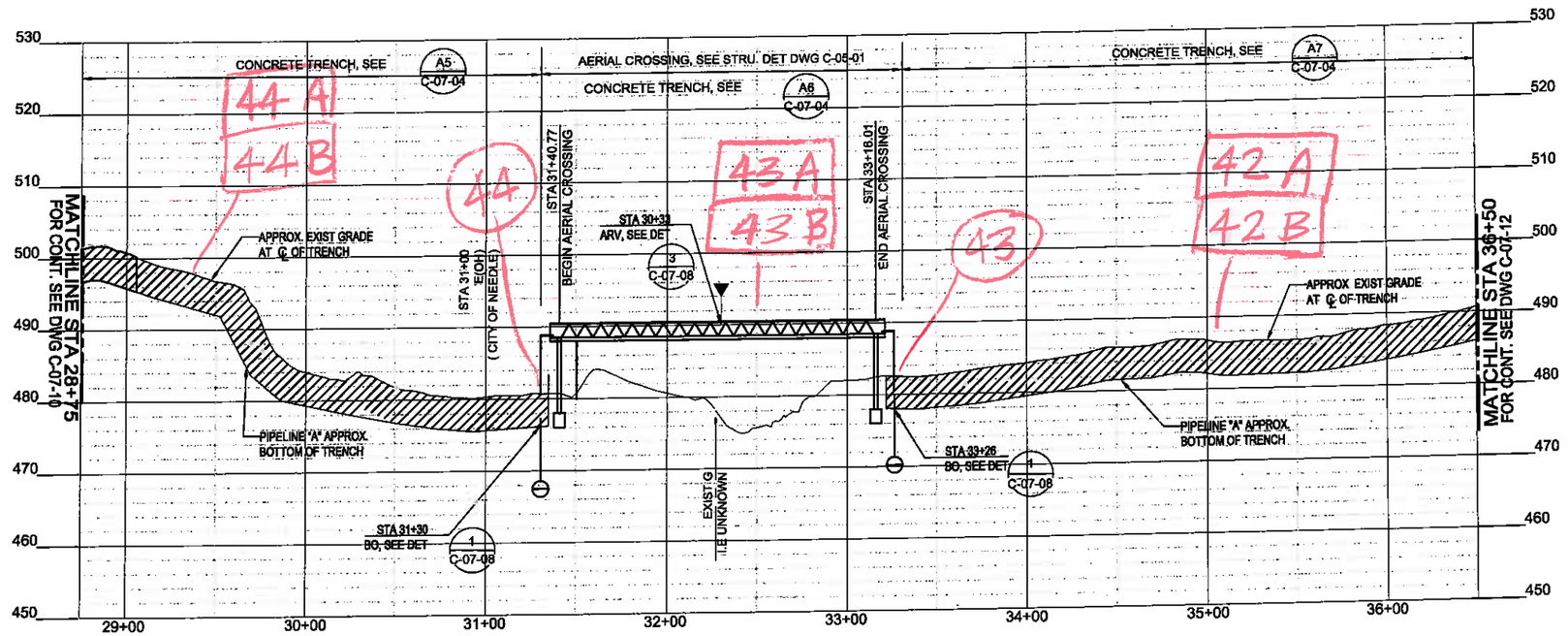
PLAN AND PROFILE
PIPELINE "A"
STA 36+50 TO STA 45+00

GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM	
BILL OF MATL	
DWG LIST	
SUPSDS	
SUPSD BY	
SHEET NO.	of SHEETS
C-07-12	REV

PLOT TIME: $PLOTTIME
PLOT DATE: $PLOTDATE
FILENAME: E2-C-XXX-0712AD.dwg





NOTES

1. DEPTHS OF EXISTING UTILITIES ARE UNKNOWN. ALL POTENTIAL CONFLICTS BETWEEN NEW PIPE CONSTRUCTION AND EXISTING UTILITIES WILL BE POTHOLED PRIOR TO 100% DESIGN. A DETERMINATION WILL BE MADE WHETHER TO RELOCATE EXISTING UTILITIES OR RE-ROUTE NEW PIPE TRENCHES AROUND EXISTING UTILITIES. THIS WILL BE INCORPORATED INTO 100% DESIGN.
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HORZ: SCALE: 1"=40'-0"
VERT: SCALE: 1"=10'-0"

PRELIMINARY
NOT FOR
CONSTRUCTION

E2 Consulting Engineers, Inc.

CH2MHILL

REVISIONS

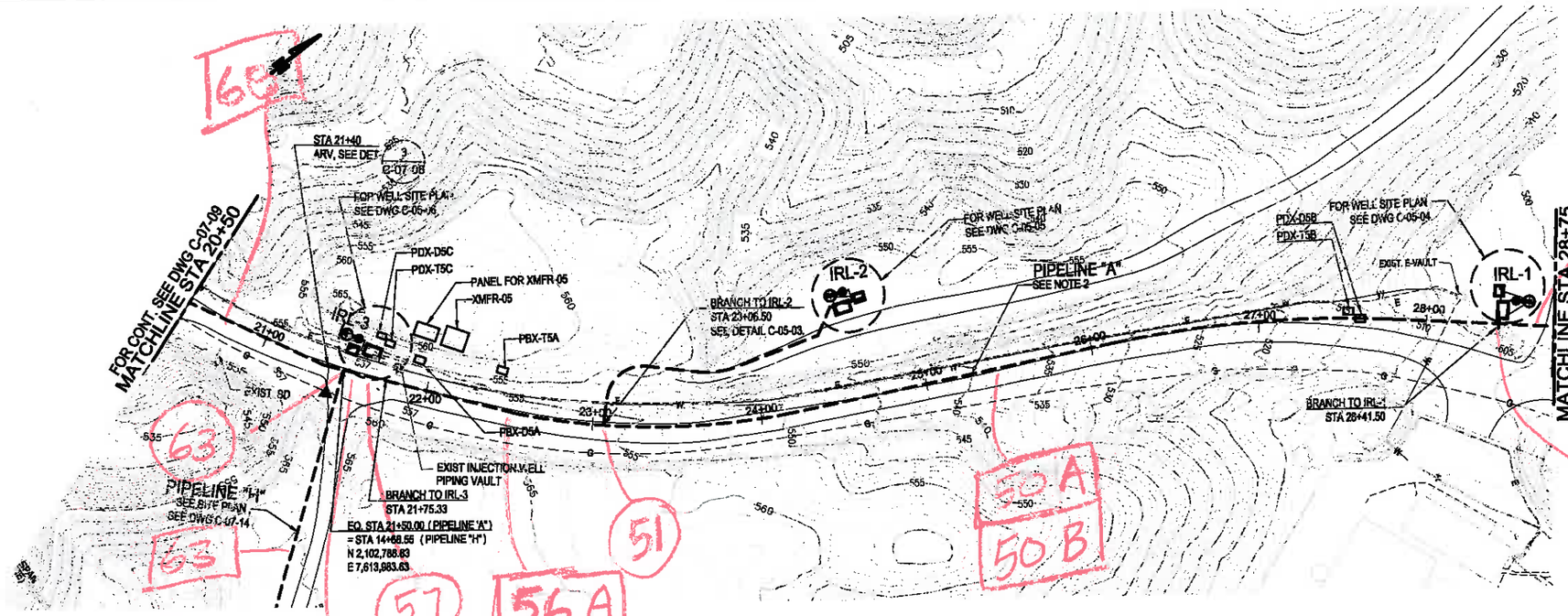
NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

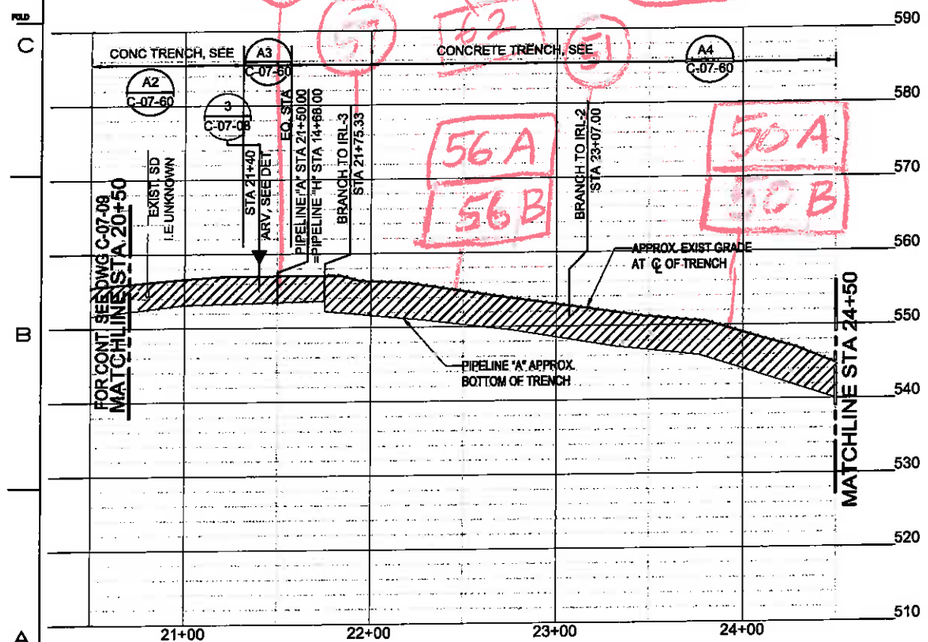
APPROVED BY: SO, SUPV, DSGN PT, DWN PC/EE, CHKD PT, QK, DATE, SCALES

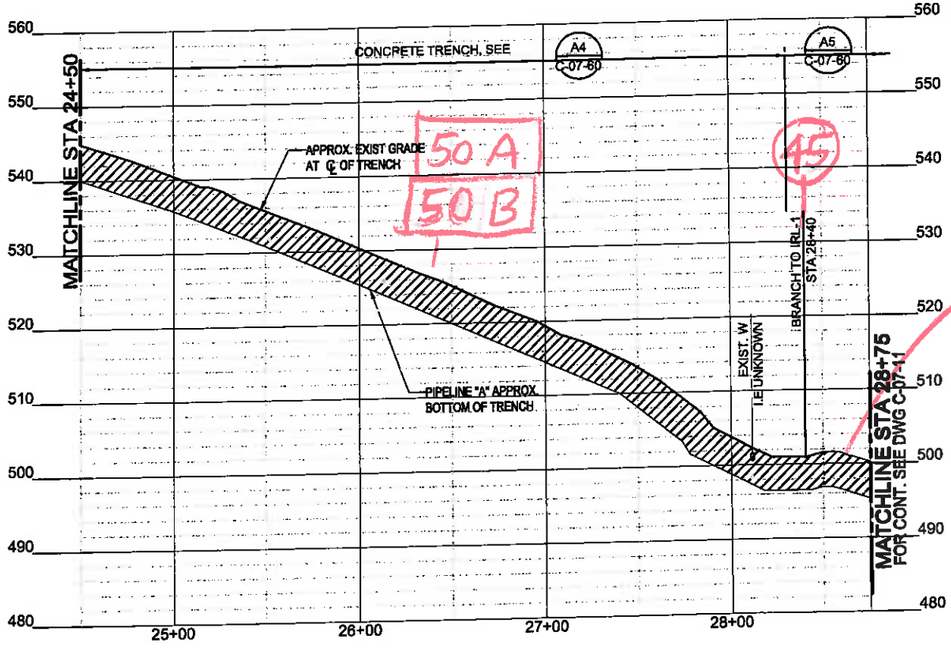
TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE
PIPELINE "A"
STA 28+75 TO STA 36+50
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. C-07-11 of SHEETS REV

PLOT DATE: $PLOTDATE PLOT TIME: $PLOTTIME
FILENAME: E2-C-XXX-0711AD.dwg







NOTES

1. DEPTHS OF EXISTING UTILITIES ARE UNKNOWN. ALL POTENTIAL CONFLICTS BETWEEN NEW PIPE CONSTRUCTION AND EXISTING UTILITIES WILL BE POTHOLED PRIOR TO 100% DESIGN. A DETERMINATION WILL BE MADE WHETHER TO RELOCATE EXISTING UTILITIES OR RE-ROUTE NEW PIPE TRENCHES AROUND EXISTING UTILITIES. THIS WILL BE INCORPORATED INTO 100% DESIGN.
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40' 0 40' 80'
HORZ: SCALE: 1"=40'-0"
10' 0 10' 20'
VERT: SCALE: 1"=10'-0"

PRELIMINARY
NOT FOR CONSTRUCTION

E2 Consulting Engineers, Inc.
1000 Front Street, Ste. 200
Benicia, CA 94510
(707) 865-7100

CH2MHILL

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
		REVISIONS					

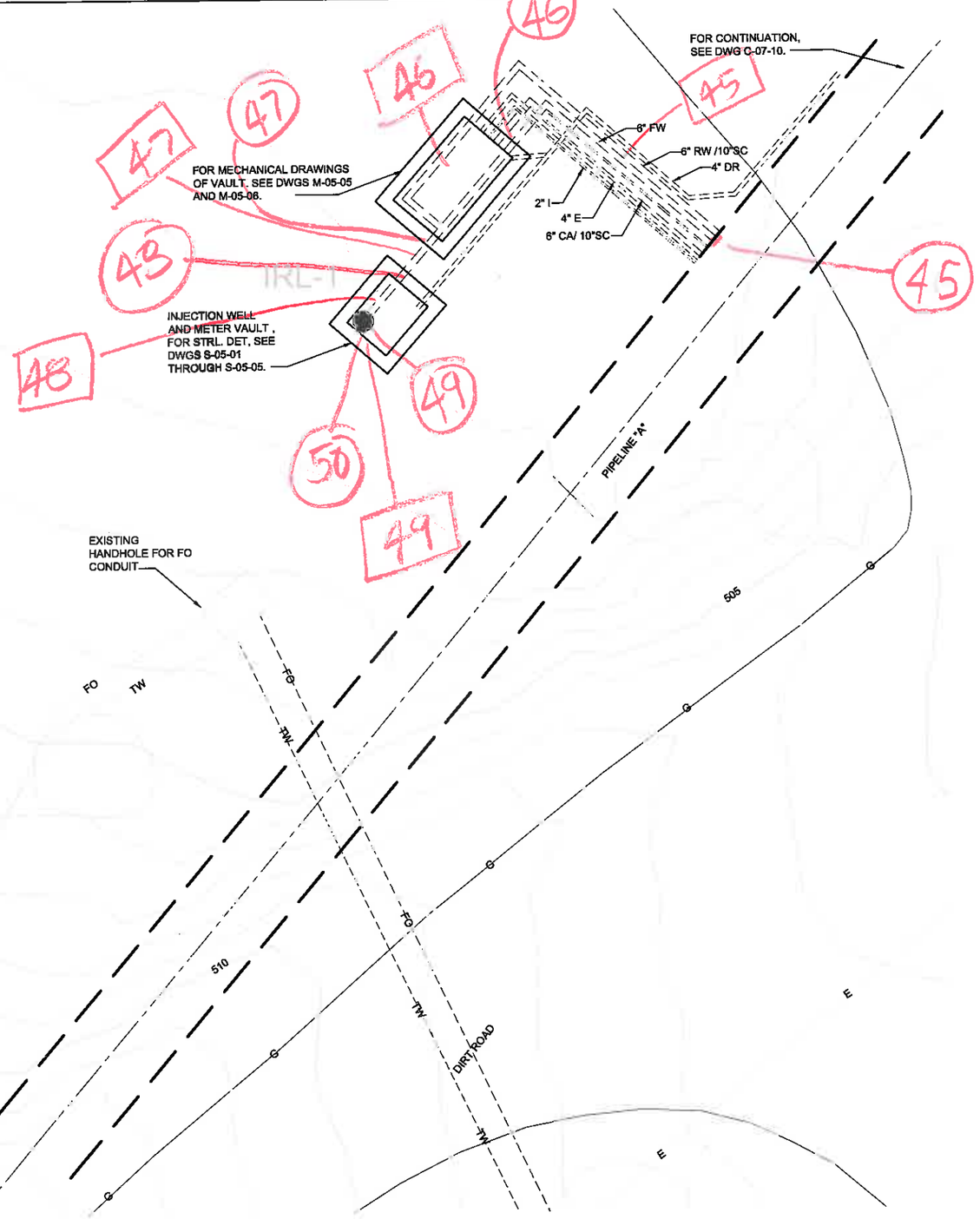
APPROVED BY
SO
SUPV
DSGN PT
DWN PC/EE
CHKD PT
CK
DATE
SCALES

TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE
PIPELINE "A"
STA 20+50 TO STA 28+75
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. C-07-10 of SHEETS REV

PLOT DATE: $PLOTDATE PLOT TIME: $PLOTTIME
FILENAME: E2-C-XXX-0710AD.dwg

34/41



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DRAFT
NOT FOR CONSTRUCTION

FRISCH ENGINEERING, INC.
CONSULTING ELECTRICAL ENGINEERS
110 BLUE RAVINE RD, SUITE 101
FOLSOM, CA 95630
PH 916 353 1035 FX 916 353 1026
WWW.FRISCHENGINEERING.COM

CH2MHILL.

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

REVISIONS

APPROVED BY: SO, SUPV, DSGN PT, DWN PC, CHKD PT, QK PT, DATE 9/12/12, SCALES 1" =5'-0"

TOPOCK GROUNDWATER REMEDIATION PROJECT
INNER RECIRCULATION LOOP
INJECTION WELL IRL-1
SITE PLAN
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. C-05-04 of SHEETS REV

PLOT DATE: $PLOTDATE PLOT TIME: $PLOTTIME
FILENAME: E2-C-XXX-050AAD.DWG

35/41

NOTES:

1. INJECTION WELL AND METER VAULT, FOR STRUCTURAL SEE, DWGS S-05-01 THROUGH S-05-05.
2. FOR MECHANICAL DRAWINGS OF WELL AND METER AND VALVE VAULTS, SEE DWGS M-05-05 AND M-05-06.

IRL-2

4" DR
6" RW/ 10" SC
6" FW / CA
4" E
2"
6" FW

FOR CONTINUATION, SEE DWG C-07-10.

PIPELINE "A"
DIRT ROAD
FO
TW
4"DR
544
547
550
552
554
556
G

SCALE: 1"=20'-0"

DRAFT
NOT FOR CONSTRUCTION

FRISCH ENGINEERING, INC.
CONSULTING ELECTRICAL ENGINEERS
110 BLUE RAVINE RD, SUITE 101
FOLSOM, CA 95630
PH 916 353 1025 FX 916 353 1026
WWW.FRISCHENGINEERING.COM

CH2MHILL

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

REVISIONS

APPROVED BY
SD
SUPV
DSGN PT
DWN PC
CHKD PT
QK PT
DATE 9/12/12
SCALES 1" =5'-0"

TOPOCK GROUNDWATER REMEDIATION PROJECT
INNER RECIRCULATION LOOP
INJECTION WELL IRL-2
SITE PLAN
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. C-05-05 of SHEETS REV

PLOT DATE: $PLOTDATE PLOT TIME: $PLOTTIME
FILENAME: E2-C-XXX-0505AD.DWG

36/41

NOTES

1. FOR STRUCTURAL DRAWINGS OF WELL AND METER AND VALVE VAULT, SEE DWGS S-05-01 THROUGH S-05-05.
2. FOR MECHANICAL DRAWINGS OF VAULTS, SEE DWGS M-05-05 AND M-05-06.

E VAULT
C VAULT
E BOX
E BOX
E BOX
E BOX
FO
TW
PIPELINE "A"
4"DR
6" FW
6" CA / 10"SC
6" RW / 10"SC
IRL-3
DIRT ROAD
PIPELINE "H"
G
59
58
60
61
62
57
56

SCALE: 1"=20'-0"

DRAFT
NOT FOR CONSTRUCTION

FRISCH ENGINEERING, INC.
CONSULTING ELECTRICAL ENGINEERS
110 BLUE RAVINE RD, SUITE 101
FOLSOM, CA 95630
PH 916 353 1025 FX 916 353 1028
WWW.FRISCHENGINEERING.COM

CH2MHILL

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

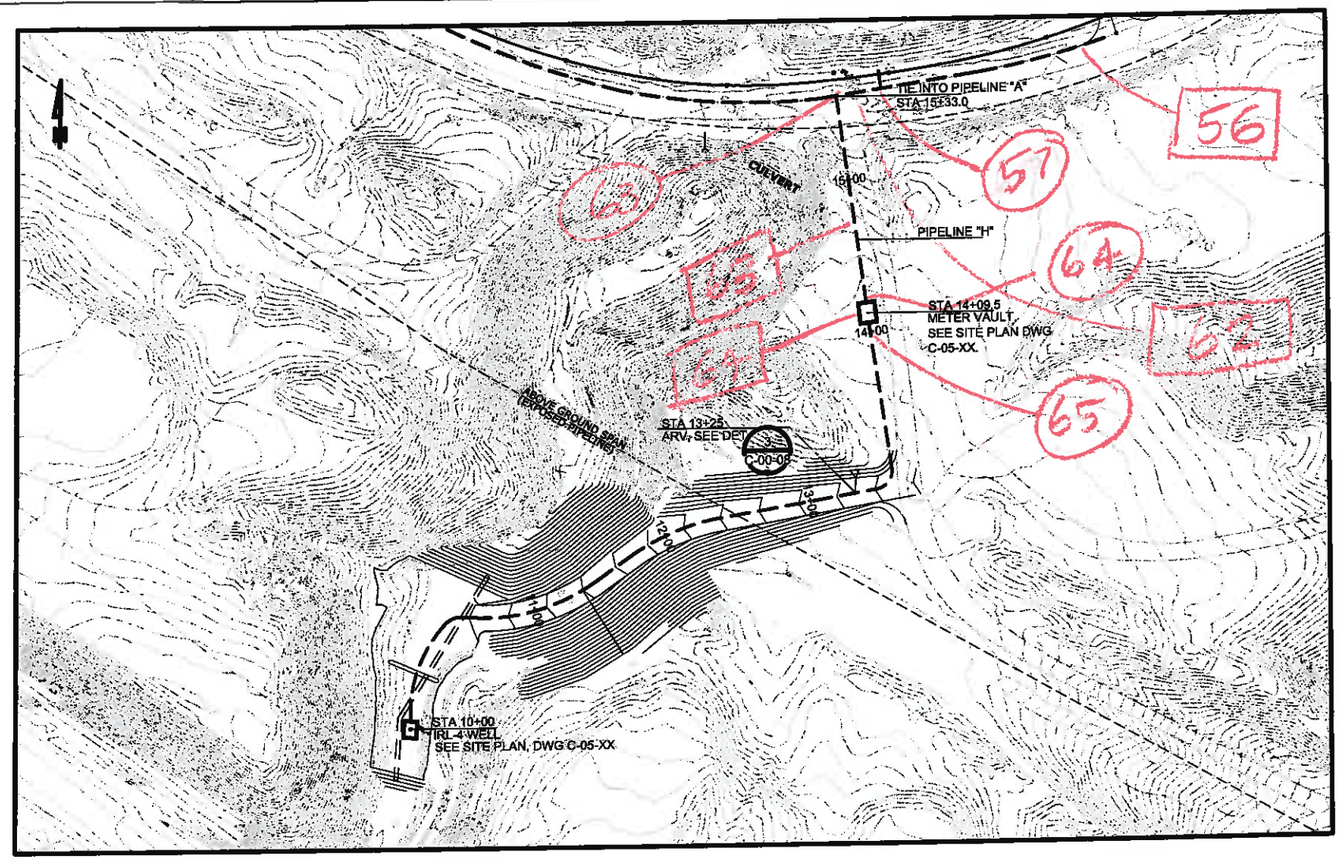
REVISIONS

APPROVED BY
SO
SUPV
DSGN PT
DWN PG
CHKD PT
QK PT
DATE 9/12/12
SCALES 1"=5'-0"

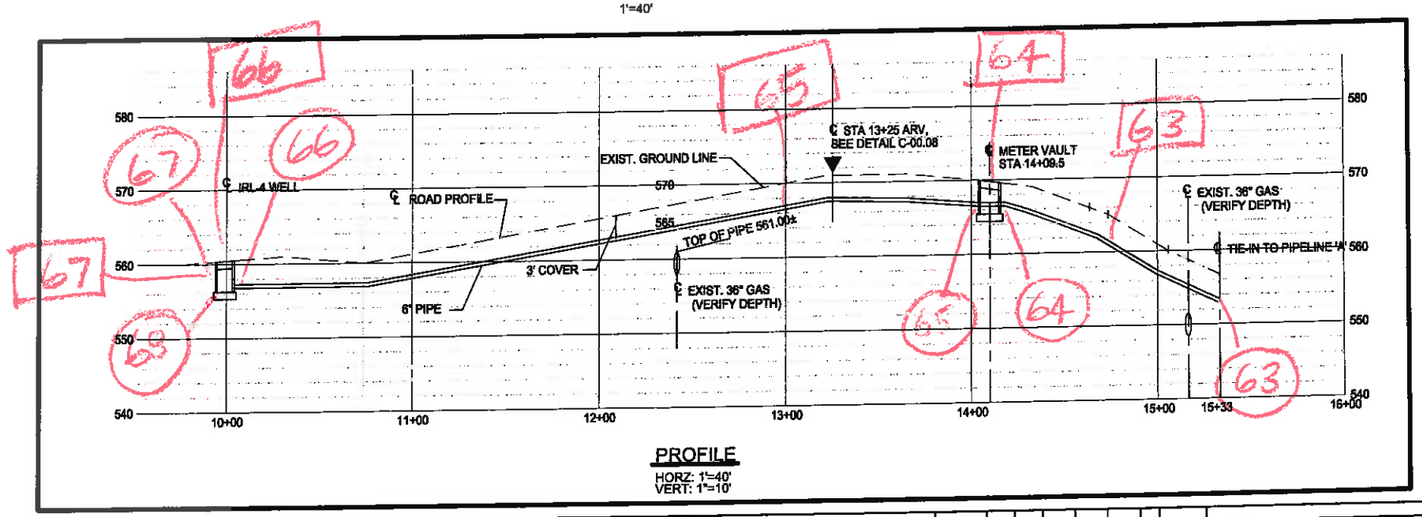
TOPOCK GROUNDWATER REMEDIATION PROJECT
INNER RECIRCULATION LOOP
INJECTION WELL IRL-3
SITE PLAN
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. C-05-06 of SHEETS REV

PLOT DATE: $PLOTDATE PLOT TIME: $PLOTTIME
FILENAME: E2-C-XXX-0506AD.DWG



PLAN
1"=40'



PROFILE
HORZ: 1"=40'
VERT: 1"=10'

NOTES

1. DEPTHS OF EXISTING UTILITIES ARE UNKNOWN. ALL POTENTIAL CONFLICTS BETWEEN NEW PIPE CONSTRUCTION AND EXISTING UTILITIES WILL BE POTHOLED PRIOR TO 100% DESIGN. A DETERMINATION WILL BE MADE WHETHER TO RELOCATE EXISTING UTILITIES OR RE-ROUTE NEW PIPE TRENCHES AROUND EXISTING UTILITIES. THIS WILL BE INCORPORATED INTO 100% DESIGN.
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40' 0 40' 80'
HORZ: SCALE: 1"=40'-0"
10' 0 10' 20'
VERT: SCALE: 1"=10'-0"

PRELIMINARY
NOT FOR
CONSTRUCTION

E2 Consulting Engineers, Inc.

CH2MHILL.

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

APPROVED BY
SO
SUPV
DSGN PT
DWN PC
CHKD PT
QC
DATE
SCALES

G-3 TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

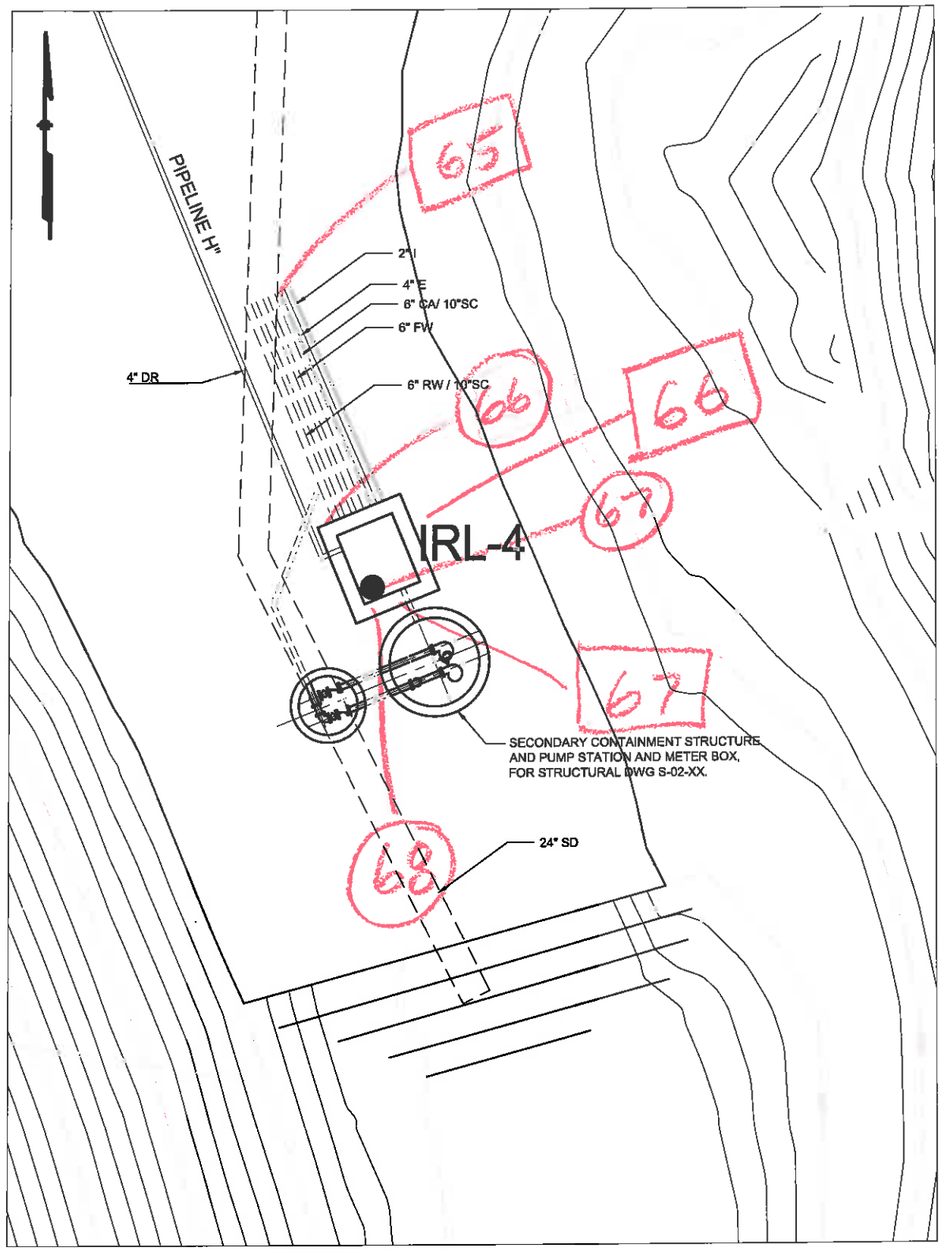
TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE PIPELINE "H"

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. of SHEETS
C-07-14
REV

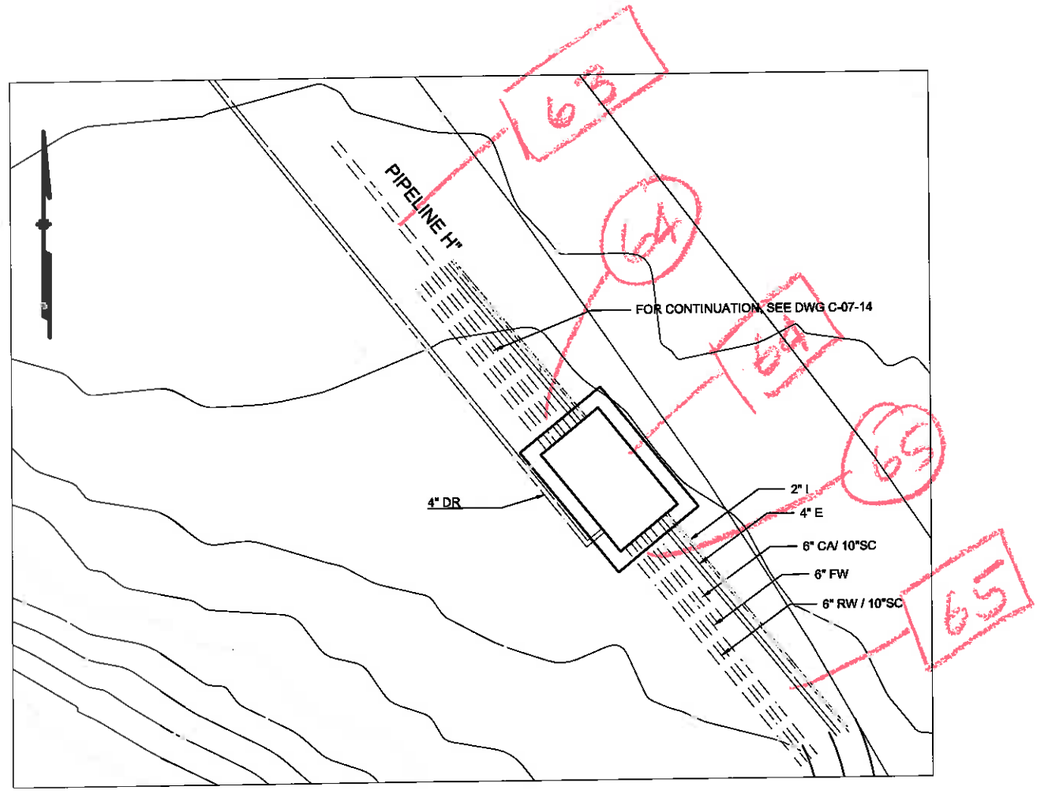
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FILENAME: E2-C-XXX-0714.dwg

NOTES

1. FOR STRUCTURAL DRAWINGS OF WELL AND METER AND VALVE VAULT, SEE DWGS S-05-01 THROUGH S-05-05.
2. FOR MECHANICAL DRAWINGS OF VAULTS, SEE DWGS M-05-05 AND M-06-06.



WELL VAULT SITE PLAN



METER AND VALVE VAULT SITE PLAN

SCALE: 1"=5'-0"

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FRISCH ENGINEERING, INC.
CONSULTING ELECTRICAL ENGINEERS
110 BLUE RAVINE RD, SUITE 101
FOLSOM, CA 95630
PH 916 353 1025 FX 916 353 1028
WWW.FRISCHENGINEERING.COM

CH2MHILL

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

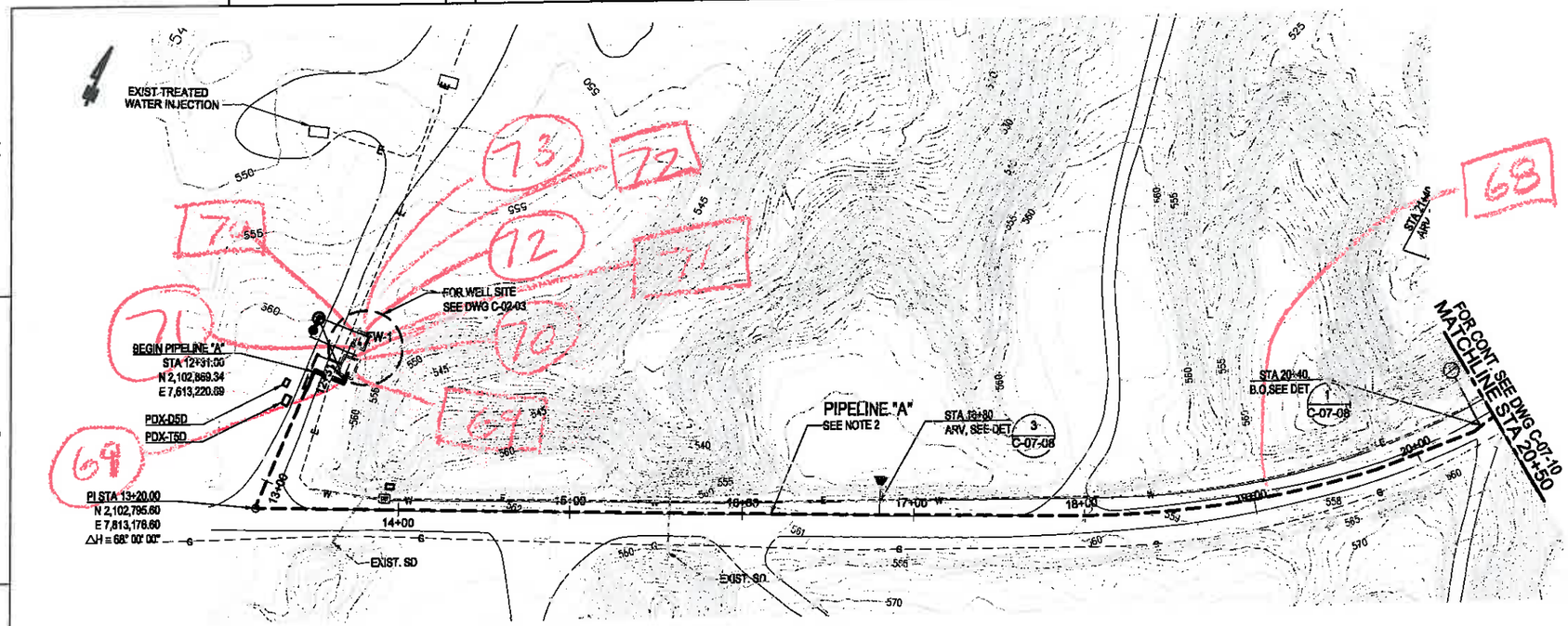
REVISIONS

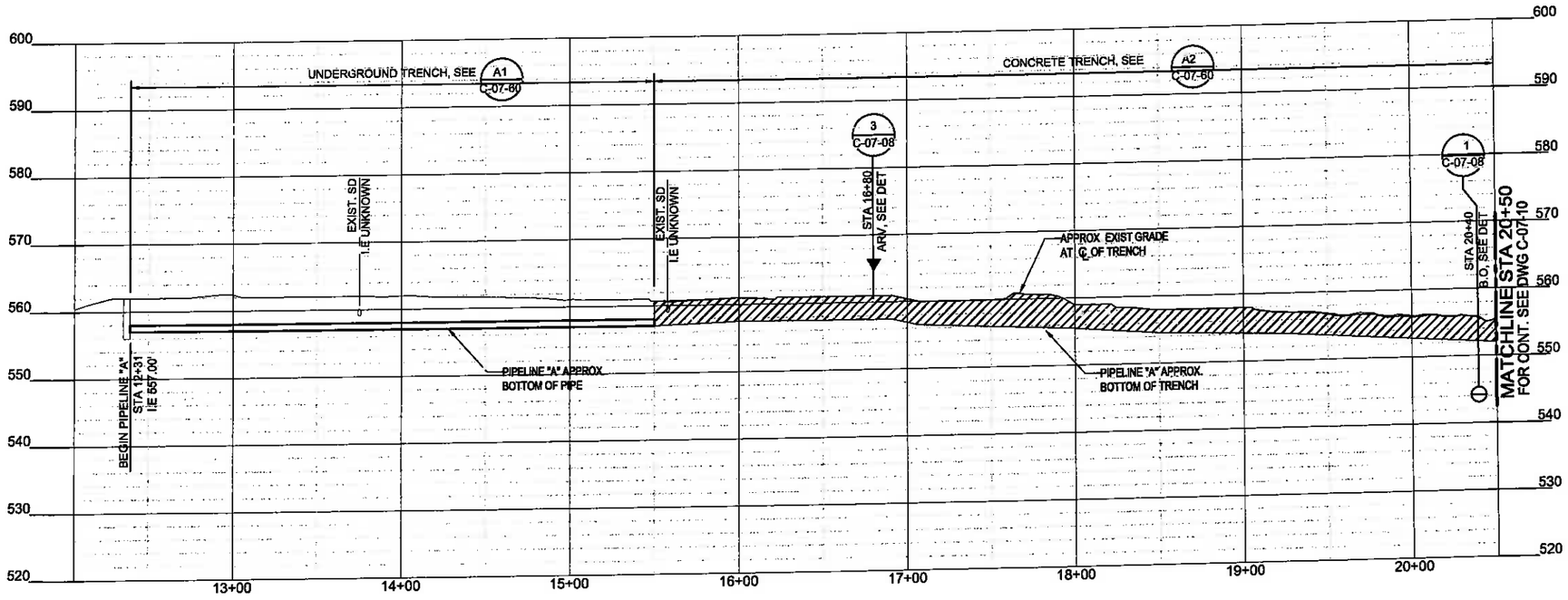
APPROVED BY
SO
SUPV
DSGN PT
DWN PC
CHKD PT
QK PT
DATE 9/12/12
SCALES 1" =5'-0"

TOPOCK GROUNDWATER REMEDIATION PROJECT
INNER RECIRCULATION LOOP INJECTION WELL IRL-4
SITE PLAN
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. of SHEETS
C-05-07
REV

PLOT DATE: $PLOTDATE PLOT TIME: $PLOTTIME
FILENAME: E2-C-XXX-0507AD.DWG





NOTES

1. DEPTHS OF EXISTING UTILITIES ARE UNKNOWN. ALL POTENTIAL CONFLICTS BETWEEN NEW PIPE CONSTRUCTION AND EXISTING UTILITIES WILL BE POTHOLED PRIOR TO 100% DESIGN. A DETERMINATION WILL BE MADE WHETHER TO RELOCATE EXISTING UTILITIES OR RE-ROUTE NEW PIPE TRENCHES AROUND EXISTING UTILITIES. THIS WILL BE INCORPORATED INTO 100% DESIGN.
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40' 0 40' 80'
HORZ: SCALE: 1"=40'-0"
10' 0 10' 20'
VERT: SCALE: 1"=10'-0"

PRELIMINARY NOT FOR CONSTRUCTION

E2 Consulting Engineers, Inc.

CH2MHILL.

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

APPROVED BY	
SO	
SUPV	
DSGN	PT
DWN	PC/EE
CHKD	PT
QK	
DATE	
SCALES	

TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE
PIPELINE "A"
STA 12+31 TO STA 20+50
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

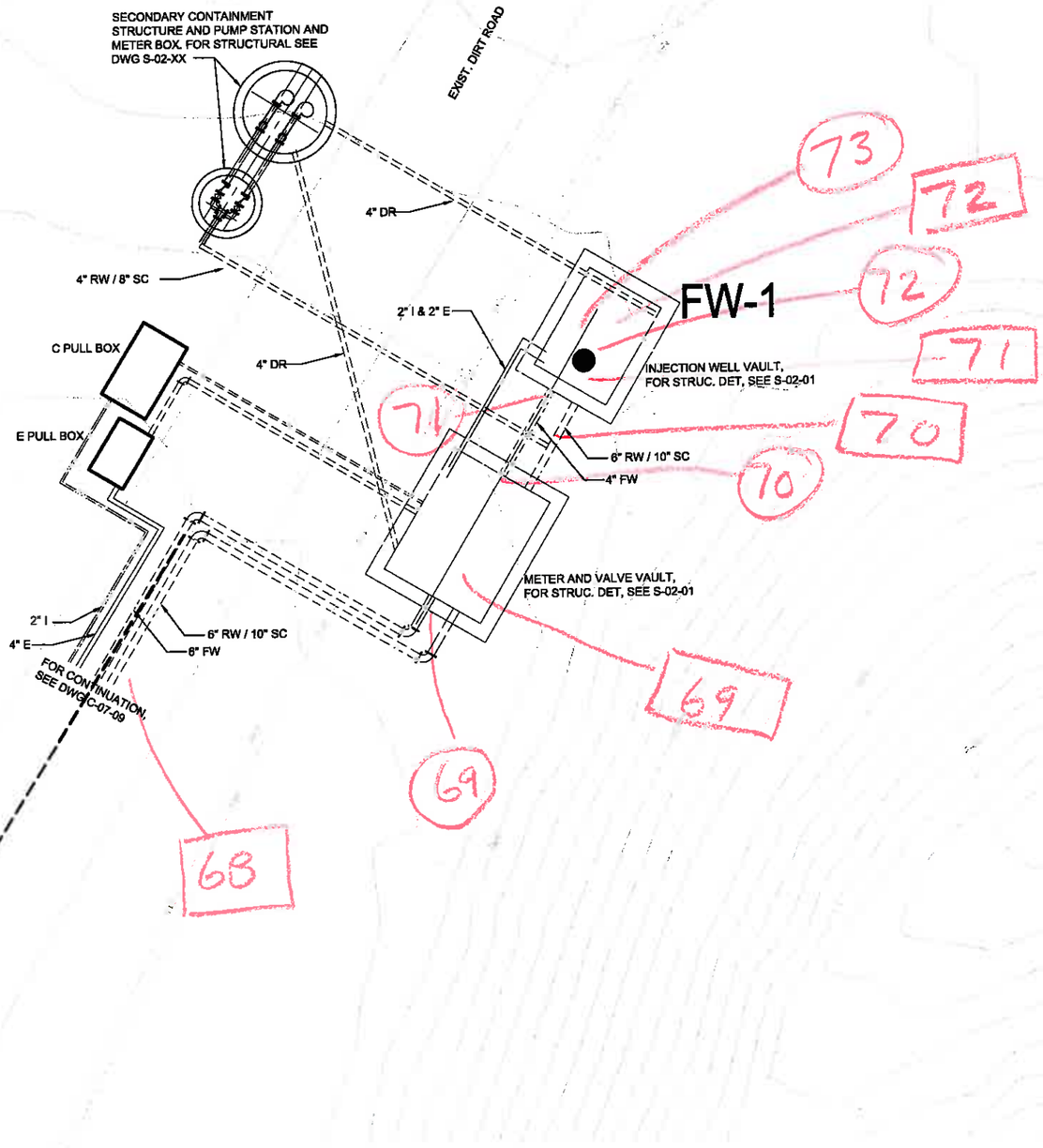
MICROFILM	
BILL OF MATL	
DWG LIST	
SUPSDS	
SUPSD BY	
SHEET NO.	of SHEETS
C-07-09	REV

PLOT DATE: $PLOTDATE PLOT TIME: $PLOTTIME
FILENAME: E2-C-XXX-0709AD.dwg

40/41

NOTES:

1. FOR STANDARD PLANS OF WELL VAULT AND METER VAULT, SEE DWG S-02-01.
2. FOR MECHANICAL PLANS OF WELL VAULT AND METER VAULT, SEE DWG M-02-01.
3. FOR PLC PANEL, SEE DWG E-02-01.
4. FOR STRUCTURAL PLANS OF SECONDARY CONTAINMENT STRUCTURE AND VALVE BOX, SEE DWG S-02-XX.
5. FOR MECHANICAL PLANS OF SECONDARY CONTAINMENT STRUCTURE, SEE DWG M-02-XX.



5' 0 5' 10'
SCALE: 1"=5'-0"

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E2 Consulting Engineers, Inc.

CH2MHILL.

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

REVISIONS

APPROVED BY: SD, SUPV, DSGN PT, DWN PC, CHKD PT, OK PT, DATE 9/12/12, SCALES 1" =5'-0"

TOPOCK GROUNDWATER REMEDIATION PROJECT

FRESHWATER INJECTION WELL
FW-1 - SITE PLAN

GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. of SHEETS
C-02-01
REV

PLOT DATE: $PLOTDATE PLOT TIME: $PLOTTIME
FILENAME: E2-C-XXX-0201AD.DWG

41/41

For continuation see 5/41

Topock 2 & 3, See Detail below

NATIONAL TRAIL HWY

PIPELINE "C"

PIPELINE "G"

COLORADO RIVER

MOHAVE COUNTY HIGHWAY 10

PIPELINE "B"

101

BNSF RAILROAD

PIPELINE "H"

BNSF RAILROAD

40

NATIONAL TRAIL HWY

PG&E TOPOCK COMPRESSOR STATION APPROX. BOUNDARY

PIPELINE "I"

PIPELINE "L"

PIPELINE "M"

PIPELINE "B"

ARCH BRIDGE

COLORADO RIVER

102

101

PIPELINE "J"

PIPE 300 ACCESS ROAD

TCS MAIN ACCESS ROAD

PIPELINE "F"

B&J

LEGEND

- ABOVE GROUND PIPE
- UNDERGROUND PIPE
- BORE AND JACK PIPE
- ON EXISTING BRIDGE

- PIPELINE "A"
- PIPELINE "B"
- PIPELINE "C"
- PIPELINE "E"
- PIPELINE "F"
- PIPELINE "G"
- PIPELINE "H"
- PIPELINE "I"
- PIPELINE "J"
- PIPELINE "L"
- PIPELINE "M"

Pump 202

Topock 2

101

Topock 3

Pump 203

DRAFT NOT FOR CONSTRUCTION

E2 Consulting Engineers, Inc.
1900 Powell Street, Ca. 250
Emeryville, CA 94608
(510) 654-1164

CH2MHILL.

NO.	DATE	DESCRIPTION	CK'D/REC'D	DWN	CHKD	SUPV	APP'D BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

REVISIONS

APPROVED BY: SUPV; DESIGN PT; DWN PC/EE; CHKD PT; QA PT; DATE 9/12/12; SCALES N/A

TOPOCK GROUNDWATER REMEDIATION PROJECT

PIPELINE SEGMENT MAP

GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

BILL OF MATL; DWG LIST; SUPSDS; CHKED BY; SHEET NO. of SHEETS; C-07-02; REV

MICROFILM

PLOT DATE: $PLOTDATE PLOT TIME: $PLOTTIME

FILENAME: E2-C-XXX-0702AD.DWG

Freshwater Injection System - Maximum Demands, High TCS Tank Levels

Network Table - Nodes

Node ID	Elevation ft	Demand GPM	Head ft	Pressure psi
Junc 1	382	0.00	710.04	142.14
Junc 2	466	0.00	709.89	105.68
Junc 3	467	0.00	709.72	105.17
Junc 4	467	0.00	709.65	105.14
Junc 5	504	0.00	704.31	86.79
Junc 6	467	0.00	703.90	102.65
Junc 7	507	0.00	703.84	85.29
Junc 8	511	0.00	701.23	82.42
Junc 9	551	0.00	700.65	64.84
Junc 10	628	0.00	700.36	31.36
Junc 11	632	110.00	700.35	29.61
Junc 12	637	0.00	700.05	27.32
Junc 13	633	0.00	699.82	28.95
Junc 14	610	0.00	699.61	38.83
Junc 15	605	0.00	699.21	40.82
Junc 16	605	0.00	615.75	4.66
Junc 17	595	0.00	615.19	8.75

Freshwater Injection System - Maximum Demands, High TCS Tank Levels

Node ID	Elevation ft	Demand GPM	Head ft	Pressure psi
Junc 18	562	0.00	613.48	22.31
Junc 19	542	0.00	612.19	30.41
Junc 20	542	100.00	612.01	30.33
Junc 21	625	0.00	699.67	32.36
Junc 22	622	0.00	698.95	33.34
Junc 23	620	0.00	698.89	34.18
Junc 24	620	20.00	631.52	4.99
Junc 25	584	0.00	697.71	49.27
Junc 26	584	20.00	595.18	4.85
Junc 27	517	0.00	698.96	78.84
Junc 28	532	0.00	698.96	72.35
Junc 29	535	0.00	698.96	71.05
Junc 30	505	0.00	698.28	83.75
Junc 31	482	0.00	697.49	93.37
Junc 32	457	0.00	694.90	103.08
Junc 33	459	0.00	694.19	101.91
Junc 34	468	0.00	693.00	97.49
Junc 35	494	0.00	692.38	85.96

Freshwater Injection System - Maximum Demands, High TCS Tank Levels

Node ID	Elevation ft	Demand GPM	Head ft	Pressure psi
Junc 36	494	0.00	692.21	85.88
Junc 37	493	0.00	692.10	86.27
Junc 38	492	0.00	691.74	86.55
Junc 39	476	0.00	691.20	93.24
Junc 40	476	0.00	690.95	93.14
Junc 41	476	0.00	690.78	93.07
Junc 42	527	0.00	690.48	70.84
Junc 43	478	0.00	668.63	82.60
Junc 44	476	0.00	665.68	82.19
Junc 45	496	0.00	662.38	72.09
Junc 46	497	0.00	662.38	71.66
Junc 47	497	0.00	508.54	5.00
Junc 48	497	0.00	508.54	5.00
Junc 49	497	0.00	508.54	5.00
Junc 50	384	0.00	508.54	53.96
Junc 51	548	0.00	656.71	47.10
Junc 52	552	0.00	656.46	45.26
Junc 53	552	0.00	563.40	4.94

Freshwater Injection System - Maximum Demands, High TCS Tank Levels

Node ID	Elevation ft	Demand GPM	Head ft	Pressure psi
Junc 54	552	0.00	563.38	4.93
Junc 55	552	0.00	563.31	4.90
Junc 56	395	200.00	562.78	72.70
Junc 57	552	0.00	655.84	44.99
Junc 58	546	0.00	655.67	47.52
Junc 59	546	0.00	557.40	4.94
Junc 60	546	0.00	557.38	4.93
Junc 61	546	0.00	557.31	4.90
Junc 62	389	200.00	556.77	72.70
Junc 63	554	0.00	655.40	43.94
Junc 64	567	0.00	655.04	38.15
Junc 65	567	0.00	578.40	4.94
Junc 66	557	0.00	577.12	8.72
Junc 67	557	0.00	577.05	8.69
Junc 68	557	200.00	576.52	8.46
Junc 69	559	0.00	652.64	40.58
Junc 70	559	0.00	570.14	4.82
Junc 71	559	0.00	570.12	4.82

Freshwater Injection System - Maximum Demands, High TCS Tank Levels

Node ID	Elevation ft	Demand GPM	Head ft	Pressure psi
Junc 72	559	0.00	570.01	4.77
Junc 73	391	200.00	569.54	77.36
Junc 101	520	0.00	794.90	119.11
Junc 102	506	0.00	744.48	103.33
Junc 103	502	5.00	744.41	105.03
Junc 104	502	0.00	743.42	104.61
Junc 105	502	0.00	707.84	89.19
Junc 106	507	0.00	704.71	85.67
Junc 15A	605	0.00	616.54	5.00
Junc 23A	620	0.00	631.54	5.00
Junc 25A	584	0.00	595.54	5.00
Junc 52A	552	0.00	563.54	5.00
Junc 58A	546	0.00	557.54	5.00
Junc 64A	567	0.00	578.54	5.00
Junc 69A	559	0.00	570.54	5.00
Junc 46A	497	0.00	508.54	5.00
Junc 100A	672	0.00	700.04	12.15
Resvr HNWR	400	-763.45	400.00	0.00

Freshwater Injection System - Maximum Demands, High TCS Tank Levels

Node ID	Elevation ft	Demand GPM	Head ft	Pressure psi
Resvr Topock2&3	410	-461.91	410.00	0.00
Tank 100B	672	85.18	700.00	12.13
Tank 100C	672	85.18	700.00	12.13

Freshwater Injection System - Maximum Demands, High TCS Tank Levels

Network Table - Links

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Friction Factor	Status
Pipe 1	763.45	2.17	1.54	0.021	Open
Pipe 2	763.45	1.59	0.73	0.022	Open
Pipe 3	763.45	2.17	1.54	0.021	Open
Pipe 4	763.45	2.17	1.54	0.021	Open
Pipe 5	763.45	1.59	0.56	0.017	Open
Pipe 6	763.45	1.59	0.73	0.022	Open
Pipe 7	1220.36	2.54	1.73	0.020	Open
Pipe 8	1220.36	2.54	1.33	0.015	Open
Pipe 9	420.36	0.88	0.18	0.018	Open
Pipe 10	420.36	0.88	0.24	0.024	Open
Pipe 11	140.00	1.59	1.95	0.025	Open
Pipe 12	140.00	1.59	1.49	0.019	Open
Pipe 13	100.00	1.13	0.80	0.020	Open
Pipe 14	100.00	2.55	5.77	0.019	Open
Pipe 15	100.00	2.55	5.77	0.019	Open
Pipe 16	100.00	2.55	5.77	0.019	Open
Pipe 17	100.00	2.55	7.52	0.025	Open

Freshwater Injection System - Maximum Demands, High TCS Tank Levels

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Friction Factor	Status
Pipe 18	100.00	2.55	5.77	0.019	Open
Pipe 19	100.00	1.13	0.90	0.022	Open
Pipe 20	40.00	1.02	1.06	0.022	Open
Pipe 21	40.00	1.02	1.06	0.022	Open
Pipe 22	20.00	0.51	0.29	0.024	Open
Pipe 23	20.00	0.51	0.37	0.030	Open
Pipe 24	20.00	2.04	8.56	0.022	Open
Pipe 25	20.00	2.04	10.47	0.027	Open
Pipe 26A	400.00	2.55	2.57	0.017	Open
Pipe 26B	400.00	2.55	2.57	0.017	Open
Pipe 27	0.00	0.00	0.00	0.000	Open
Pipe 28	0.00	0.00	0.00	0.000	Open
Pipe 29A	400.00	2.55	2.57	0.017	Open
Pipe 29B	400.00	2.55	2.57	0.017	Open
Pipe 30A	400.00	2.55	2.57	0.017	Open
Pipe 30B	400.00	2.55	2.57	0.017	Open
Pipe 31A	400.00	2.55	2.57	0.017	Open
Pipe 31B	400.00	2.55	2.57	0.017	Open

Freshwater Injection System - Maximum Demands, High TCS Tank Levels

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Friction Factor	Status
Pipe 32A	400.00	2.55	2.57	0.017	Open
Pipe 32B	400.00	2.55	2.57	0.017	Open
Pipe 33A	400.00	2.55	2.57	0.017	Open
Pipe 33B	400.00	2.55	2.57	0.017	Open
Pipe 34A	400.00	2.55	2.57	0.017	Open
Pipe 34B	400.00	2.55	2.57	0.017	Open
Pipe 35A	400.00	2.55	2.57	0.017	Open
Pipe 35B	400.00	2.55	2.57	0.017	Open
Pipe 36A	400.00	2.55	2.57	0.017	Open
Pipe 36B	400.00	2.55	2.57	0.017	Open
Pipe 37A	400.00	2.55	2.57	0.017	Open
Pipe 37B	400.00	2.55	2.57	0.017	Open
Pipe 38A	400.00	2.55	2.57	0.017	Open
Pipe 38B	400.00	2.55	2.57	0.017	Open
Pipe 39A	400.00	2.55	2.57	0.017	Open
Pipe 39B	400.00	2.55	2.57	0.017	Open
Pipe 40A	400.00	2.55	2.57	0.017	Open
Pipe 40B	400.00	2.55	2.57	0.017	Open

Freshwater Injection System - Maximum Demands, High TCS Tank Levels

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Friction Factor	Status
Pipe 41A	400.00	2.55	2.57	0.017	Open
Pipe 41B	400.00	2.55	2.57	0.017	Open
Pipe 42A	400.00	4.54	10.43	0.016	Open
Pipe 42B	400.00	4.54	10.43	0.016	Open
Pipe 43A	400.00	4.54	10.43	0.016	Open
Pipe 43B	400.00	4.54	10.43	0.016	Open
Pipe 44A	400.00	4.54	10.43	0.016	Open
Pipe 44B	400.00	4.54	10.43	0.016	Open
Pipe 45	0.00	0.00	0.00	0.000	Open
Pipe 46	0.00	0.00	0.00	0.000	Open
Pipe 47	0.00	0.00	0.00	0.000	Open
Pipe 48	0.00	0.00	0.00	0.000	Open
Pipe 49	0.00	0.00	0.00	0.000	Open
Pipe 50A	400.00	4.54	10.43	0.016	Open
Pipe 50B	400.00	4.54	10.43	0.016	Open
Pipe 51	200.00	2.27	2.89	0.018	Open
Pipe 52	200.00	2.27	2.89	0.018	Open
Pipe 53	200.00	2.27	2.89	0.018	Open

Freshwater Injection System - Maximum Demands, High TCS Tank Levels

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Friction Factor	Status
Pipe 54	200.00	2.27	2.89	0.018	Open
Pipe 55	200.00	2.27	3.40	0.021	Open
Pipe 56A	300.00	3.40	6.12	0.017	Open
Pipe 56B	300.00	3.40	6.12	0.017	Open
Pipe 57	200.00	2.27	2.89	0.018	Open
Pipe 58	200.00	2.27	2.89	0.018	Open
Pipe 59	200.00	2.27	2.89	0.018	Open
Pipe 60	200.00	2.27	2.89	0.018	Open
Pipe 61	200.00	2.27	3.39	0.021	Open
Pipe 62	400.00	4.54	10.43	0.016	Open
Pipe 63	200.00	2.27	2.89	0.018	Open
Pipe 64	200.00	2.27	2.89	0.018	Open
Pipe 65	200.00	2.27	2.89	0.018	Open
Pipe 66	200.00	2.27	2.89	0.018	Open
Pipe 67	200.00	2.27	3.40	0.021	Open
Pipe 68	200.00	2.27	2.89	0.018	Open
Pipe 69	200.00	2.27	2.89	0.018	Open
Pipe 70	200.00	2.27	2.89	0.018	Open

Freshwater Injection System - Maximum Demands, High TCS Tank Levels

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Friction Factor	Status
Pipe 71	200.00	2.27	2.89	0.018	Open
Pipe 72	200.00	2.27	3.48	0.022	Open
Pipe 101	461.91	5.24	17.74	0.021	Open
Pipe 102	461.91	2.95	4.37	0.022	Open
Pipe 103	456.91	2.92	4.28	0.022	Open
Pipe 104	456.91	11.67	125.31	0.020	Open
Pipe 105	456.91	5.18	17.39	0.021	Open
Pipe 106	456.91	5.18	17.39	0.021	Open
Pipe 107	170.36	1.93	2.80	0.024	Open
Pipe 108	85.18	0.97	0.77	0.027	Open
Pipe 109	85.18	0.97	0.77	0.027	Open
Pump 201	763.45	0.00	-310.04	0.000	Open
Pump 202	230.96	0.00	-384.90	0.000	Open
Pump 203	230.96	0.00	-384.90	0.000	Open
Valve 301	100.00	2.55	82.67	0.000	Active
Valve 302	20.00	0.51	67.35	0.000	Active
Valve 303	20.00	2.04	102.17	0.000	Active
Valve 304	0.00	0.00	153.84	0.000	Active

Freshwater Injection System - Maximum Demands, High TCS Tank Levels

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Friction Factor	Status
Valve 305	200.00	5.11	92.92	0.000	Active
Valve 306	200.00	5.11	98.13	0.000	Active
Valve 307	200.00	5.11	76.50	0.000	Active
Valve 308	200.00	5.11	82.11	0.000	Active

Freshwater Injection System - Maximum Demands, Low TCS Tank Levels

Network Table - Nodes

Node ID	Elevation ft	Demand GPM	Head ft	Pressure psi
Junc 1	382	0.00	687.01	132.16
Junc 2	466	0.00	686.81	95.68
Junc 3	467	0.00	686.61	95.16
Junc 4	467	0.00	686.52	95.12
Junc 5	504	0.00	679.83	76.19
Junc 6	467	0.00	679.31	91.99
Junc 7	507	0.00	679.23	74.63
Junc 8	511	0.00	676.11	71.54
Junc 9	551	0.00	675.42	53.91
Junc 10	628	0.00	674.97	20.35
Junc 11	632	110.00	674.94	18.61
Junc 12	637	0.00	674.65	16.31
Junc 13	633	0.00	674.42	17.95
Junc 14	610	0.00	674.21	27.82
Junc 15	605	0.00	673.80	29.81
Junc 16	605	0.00	615.75	4.66
Junc 17	595	0.00	615.19	8.75

Freshwater Injection System - Maximum Demands, Low TCS Tank Levels

Node ID	Elevation ft	Demand GPM	Head ft	Pressure psi
Junc 18	562	0.00	613.48	22.31
Junc 19	542	0.00	612.19	30.41
Junc 20	542	100.00	612.01	30.33
Junc 21	625	0.00	674.27	21.35
Junc 22	622	0.00	673.54	22.33
Junc 23	620	0.00	673.48	23.17
Junc 24	620	20.00	631.52	4.99
Junc 25	584	0.00	672.30	38.26
Junc 26	584	20.00	595.18	4.85
Junc 27	517	0.00	673.74	67.92
Junc 28	532	0.00	673.74	61.42
Junc 29	535	0.00	673.74	60.12
Junc 30	505	0.00	673.05	72.82
Junc 31	482	0.00	672.27	82.44
Junc 32	457	0.00	669.68	92.15
Junc 33	459	0.00	668.96	90.98
Junc 34	468	0.00	667.78	86.56
Junc 35	494	0.00	667.16	75.03

Freshwater Injection System - Maximum Demands, Low TCS Tank Levels

Node ID	Elevation ft	Demand GPM	Head ft	Pressure psi
Junc 36	494	0.00	666.98	74.95
Junc 37	493	0.00	666.87	75.34
Junc 38	492	0.00	666.51	75.62
Junc 39	476	0.00	665.97	82.32
Junc 40	476	0.00	665.73	82.21
Junc 41	476	0.00	665.56	82.14
Junc 42	527	0.00	665.26	59.91
Junc 43	478	0.00	643.40	71.67
Junc 44	476	0.00	640.45	71.26
Junc 45	496	0.00	637.16	61.16
Junc 46	497	0.00	637.16	60.73
Junc 47	497	0.00	508.54	5.00
Junc 48	497	0.00	508.54	5.00
Junc 49	497	0.00	508.54	5.00
Junc 50	384	0.00	508.54	53.96
Junc 51	548	0.00	631.49	36.17
Junc 52	552	0.00	631.24	34.33
Junc 53	552	0.00	563.40	4.94

Freshwater Injection System - Maximum Demands, Low TCS Tank Levels

Node ID	Elevation ft	Demand GPM	Head ft	Pressure psi
Junc 54	552	0.00	563.38	4.93
Junc 55	552	0.00	563.31	4.90
Junc 56	395	200.00	562.78	72.70
Junc 57	552	0.00	630.61	34.06
Junc 58	546	0.00	630.44	36.59
Junc 59	546	0.00	557.40	4.94
Junc 60	546	0.00	557.38	4.93
Junc 61	546	0.00	557.31	4.90
Junc 62	389	200.00	556.77	72.70
Junc 63	554	0.00	630.17	33.01
Junc 64	567	0.00	629.82	27.22
Junc 65	567	0.00	578.40	4.94
Junc 66	557	0.00	577.12	8.72
Junc 67	557	0.00	577.05	8.69
Junc 68	557	200.00	576.52	8.46
Junc 69	559	0.00	627.42	29.65
Junc 70	559	0.00	570.14	4.82
Junc 71	559	0.00	570.12	4.82

Freshwater Injection System - Maximum Demands, Low TCS Tank Levels

Node ID	Elevation ft	Demand GPM	Head ft	Pressure psi
Junc 72	559	0.00	570.01	4.77
Junc 73	391	200.00	569.54	77.36
Junc 101	520	0.00	779.04	112.24
Junc 102	506	0.00	723.80	94.37
Junc 103	502	5.00	723.72	96.07
Junc 104	502	0.00	722.64	95.60
Junc 105	502	0.00	683.62	78.70
Junc 106	507	0.00	680.19	75.04
Junc 15A	605	0.00	616.54	5.00
Junc 23A	620	0.00	631.54	5.00
Junc 25A	584	0.00	595.54	5.00
Junc 52A	552	0.00	563.54	5.00
Junc 58A	546	0.00	557.54	5.00
Junc 64A	567	0.00	578.54	5.00
Junc 69A	559	0.00	570.54	5.00
Junc 46A	497	0.00	508.54	5.00
Junc 100A	672	0.00	674.11	0.91
Resvr HNWR	400	-862.47	400.00	0.00

Freshwater Injection System - Maximum Demands, Low TCS Tank Levels

Node ID	Elevation ft	Demand GPM	Head ft	Pressure psi
Resvr Topock2&3	410	-485.24	410.00	0.00
Tank 100B	672	146.35	674.00	0.87
Tank 100C	672	146.35	674.00	0.87

Freshwater Injection System - Maximum Demands, Low TCS Tank Levels

Network Table - Links

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Friction Factor	Status
Pipe 1	862.47	2.45	1.93	0.021	Open
Pipe 2	862.47	1.80	0.91	0.021	Open
Pipe 3	862.47	2.45	1.93	0.021	Open
Pipe 4	862.47	2.45	1.93	0.021	Open
Pipe 5	862.47	1.80	0.70	0.016	Open
Pipe 6	862.47	1.80	0.91	0.021	Open
Pipe 7	1342.71	2.80	2.06	0.020	Open
Pipe 8	1342.71	2.80	1.58	0.015	Open
Pipe 9	542.71	1.13	0.30	0.017	Open
Pipe 10	542.71	1.13	0.39	0.023	Open
Pipe 11	140.00	1.59	1.94	0.025	Open
Pipe 12	140.00	1.59	1.49	0.019	Open
Pipe 13	100.00	1.13	0.80	0.020	Open
Pipe 14	100.00	2.55	5.77	0.019	Open
Pipe 15	100.00	2.55	5.77	0.019	Open
Pipe 16	100.00	2.55	5.77	0.019	Open
Pipe 17	100.00	2.55	7.52	0.025	Open

Freshwater Injection System - Maximum Demands, Low TCS Tank Levels

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Friction Factor	Status
Pipe 18	100.00	2.55	5.77	0.019	Open
Pipe 19	100.00	1.13	0.90	0.022	Open
Pipe 20	40.00	1.02	1.06	0.022	Open
Pipe 21	40.00	1.02	1.06	0.022	Open
Pipe 22	20.00	0.51	0.29	0.024	Open
Pipe 23	20.00	0.51	0.37	0.030	Open
Pipe 24	20.00	2.04	8.56	0.022	Open
Pipe 25	20.00	2.04	10.47	0.027	Open
Pipe 26A	400.00	2.55	2.57	0.017	Open
Pipe 26B	400.00	2.55	2.57	0.017	Open
Pipe 27	0.00	0.00	0.00	0.000	Open
Pipe 28	0.00	0.00	0.00	0.000	Open
Pipe 29A	400.00	2.55	2.57	0.017	Open
Pipe 29B	400.00	2.55	2.57	0.017	Open
Pipe 30A	400.00	2.55	2.57	0.017	Open
Pipe 30B	400.00	2.55	2.57	0.017	Open
Pipe 31A	400.00	2.55	2.57	0.017	Open
Pipe 31B	400.00	2.55	2.57	0.017	Open

Freshwater Injection System - Maximum Demands, Low TCS Tank Levels

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Friction Factor	Status
Pipe 32A	400.00	2.55	2.57	0.017	Open
Pipe 32B	400.00	2.55	2.57	0.017	Open
Pipe 33A	400.00	2.55	2.57	0.017	Open
Pipe 33B	400.00	2.55	2.57	0.017	Open
Pipe 34A	400.00	2.55	2.57	0.017	Open
Pipe 34B	400.00	2.55	2.57	0.017	Open
Pipe 35A	400.00	2.55	2.57	0.017	Open
Pipe 35B	400.00	2.55	2.57	0.017	Open
Pipe 36A	400.00	2.55	2.57	0.017	Open
Pipe 36B	400.00	2.55	2.57	0.017	Open
Pipe 37A	400.00	2.55	2.57	0.017	Open
Pipe 37B	400.00	2.55	2.57	0.017	Open
Pipe 38A	400.00	2.55	2.57	0.017	Open
Pipe 38B	400.00	2.55	2.57	0.017	Open
Pipe 39A	400.00	2.55	2.57	0.017	Open
Pipe 39B	400.00	2.55	2.57	0.017	Open
Pipe 40A	400.00	2.55	2.57	0.017	Open
Pipe 40B	400.00	2.55	2.57	0.017	Open

Freshwater Injection System - Maximum Demands, Low TCS Tank Levels

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Friction Factor	Status
Pipe 41A	400.00	2.55	2.57	0.017	Open
Pipe 41B	400.00	2.55	2.57	0.017	Open
Pipe 42A	400.00	4.54	10.43	0.016	Open
Pipe 42B	400.00	4.54	10.43	0.016	Open
Pipe 43A	400.00	4.54	10.43	0.016	Open
Pipe 43B	400.00	4.54	10.43	0.016	Open
Pipe 44A	400.00	4.54	10.43	0.016	Open
Pipe 44B	400.00	4.54	10.43	0.016	Open
Pipe 45	0.00	0.00	0.00	0.000	Open
Pipe 46	0.00	0.00	0.00	0.000	Open
Pipe 47	0.00	0.00	0.00	0.000	Open
Pipe 48	0.00	0.00	0.00	0.000	Open
Pipe 49	0.00	0.00	0.00	0.000	Open
Pipe 50A	400.00	4.54	10.43	0.016	Open
Pipe 50B	400.00	4.54	10.43	0.016	Open
Pipe 51	200.00	2.27	2.89	0.018	Open
Pipe 52	200.00	2.27	2.89	0.018	Open
Pipe 53	200.00	2.27	2.89	0.018	Open

Freshwater Injection System - Maximum Demands, Low TCS Tank Levels

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Friction Factor	Status
Pipe 54	200.00	2.27	2.89	0.018	Open
Pipe 55	200.00	2.27	3.40	0.021	Open
Pipe 56A	300.00	3.40	6.12	0.017	Open
Pipe 56B	300.00	3.40	6.12	0.017	Open
Pipe 57	200.00	2.27	2.89	0.018	Open
Pipe 58	200.00	2.27	2.89	0.018	Open
Pipe 59	200.00	2.27	2.89	0.018	Open
Pipe 60	200.00	2.27	2.89	0.018	Open
Pipe 61	200.00	2.27	3.39	0.021	Open
Pipe 62	400.00	4.54	10.43	0.016	Open
Pipe 63	200.00	2.27	2.89	0.018	Open
Pipe 64	200.00	2.27	2.89	0.018	Open
Pipe 65	200.00	2.27	2.89	0.018	Open
Pipe 66	200.00	2.27	2.89	0.018	Open
Pipe 67	200.00	2.27	3.40	0.021	Open
Pipe 68	200.00	2.27	2.89	0.018	Open
Pipe 69	200.00	2.27	2.89	0.018	Open
Pipe 70	200.00	2.27	2.89	0.018	Open

Freshwater Injection System - Maximum Demands, Low TCS Tank Levels

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Friction Factor	Status
Pipe 71	200.00	2.27	2.89	0.018	Open
Pipe 72	200.00	2.27	3.48	0.022	Open
Pipe 101	485.24	5.51	19.44	0.021	Open
Pipe 102	485.24	3.10	4.79	0.021	Open
Pipe 103	480.24	3.07	4.70	0.021	Open
Pipe 104	480.24	12.26	137.41	0.020	Open
Pipe 105	480.24	5.45	19.07	0.021	Open
Pipe 106	480.24	5.45	19.07	0.021	Open
Pipe 107	292.71	3.32	7.62	0.022	Open
Pipe 108	146.35	1.66	2.11	0.025	Open
Pipe 109	146.35	1.66	2.11	0.025	Open
Pump 201	862.47	0.00	-287.01	0.000	Open
Pump 202	242.62	0.00	-369.04	0.000	Open
Pump 203	242.62	0.00	-369.04	0.000	Open
Valve 301	100.00	2.55	57.26	0.000	Active
Valve 302	20.00	0.51	41.94	0.000	Active
Valve 303	20.00	2.04	76.76	0.000	Active
Valve 304	0.00	0.00	128.62	0.000	Active

Freshwater Injection System - Maximum Demands, Low TCS Tank Levels

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Friction Factor	Status
Valve 305	200.00	5.11	67.70	0.000	Active
Valve 306	200.00	5.11	72.90	0.000	Active
Valve 307	200.00	5.11	51.28	0.000	Active
Valve 308	200.00	5.11	56.88	0.000	Active

Topock Remediation Design

Hydraulic analysis of Remedy Wastewater System

The piping and the pumps for the remedy wastewater system on the Topock Remediation project were sized from simulations of a hydraulic network model of the system. The hydraulic network model of the remedy wastewater system proposed for Topock remediation was constructed using EPANET. EPANET is software that models water distribution piping systems. EPANET tracks the flow of water at each pipe, the pressure at each node, pumping heads and levels of water in tanks and reservoirs. Chemical species can be tracked, although that was not needed for the remedy wastewater system at Topock.

Pipe junctions, reservoirs and tanks are represented as nodes. A listing of nodes is contained on the following pages. Pipes, pumps and valves are represented as links. A listing of links is contained on the pages following the node listing. A map showing the location of all nodes and links is attached.

The piping routes and corridors have been approved by the client, Pacific Gas & Electric; however, they are subject to change pending stakeholder and regulatory review. The following summary describes the development of the hydraulic model:

Junction nodes, tanks and wells (modeled as pumps attached to an underground reservoir) have been located by coordinates from an aerial survey conducted by Toponex, a subcontractor to PG & E. The aerial survey was verified with a ground survey by PG & E staff. A summary of the model development is as follows:

Ground elevations for pipe junctions, reservoirs, wells and tanks are taken from the 60% plan drawings and the Toponex aerial survey.

Pipe lengths have been taken off from plan and profile drawings.

Maximum wastewater flows are generated during rehabilitation of injection wells. It is estimated that rehabilitation flows will be twice the amount of injection flows. It is assumed that only one well will be rehabilitated at a time. The following flow rates are used:

- Freshwater Injection Well no. 1 (FW-1, link PMP001) = 400 gpm
- Freshwater Injection Well no. 2 (FW-2, link PMP002) = 200 gpm
- Inner Recirculation Loop Well no. 1 (IRL-1, PMP641) =400 gpm
- Inner Recirculation Loop Well no. 2 (IRL-2, PMP642) =400 gpm
- Inner Recirculation Loop Well no. 3 (IRL-3, PMP643) = 400 gpm
- Inner Recirculation Loop Well no. 4 (IRL-4, PMP644) = 400 gpm
- TCS Loop Injection Well no. 1 (TCS-1, link PMP443) = 75 gpm
- TCS Loop Injection Well no. 2 (TCS-2, link PMP442) = 75 gpm

A pumping level elevation of 405 feet above sea level is assumed for all wells, except FW-2. A pumping level elevation of 420 feet is assumed at FW-2.

Wastewater will be pumped to influent storage tanks for the proposed wastewater treatment plant at Topock Compressor Station. Influent storage tanks are designed to be portable. The elevation of the tanks at the highest potential location (628 feet above sea level for base of the tank) was assumed for this analysis.

Hazen-Williams C value of 130 was assumed for all steel pipes. Hazen Williams C value of 150 was assumed for PVC and HDPE pipes.

Pipe sizing is an iterative process. After the initial simulation, pipe diameters for various segments of pipes are increased or decreased for subsequent simulations until an optimum size is selected for each segment. The criteria used for determining optimum size were unit head losses and minimum velocities. Usually, unit head losses of between 1 to 10 feet per 1,000 foot of pipe length yield the optimal combination of pipe capital cost and pumping energy costs. However, minimum velocities preclude the lower end of this range. It is desired to have at least three feet per second minimum velocity and preferably higher to flush sediments through the pipe. It was desired to keep head losses less than 35 feet per 1,000 foot of pipe length. Above this number, pumping costs become prohibitive. These criteria were used to size most of the pipes. The only exceptions to this were for short segments of pipes, such as pumping manifolds, bridge crossings and for lower flow scenarios where minimum flow velocities are not achieved. Model simulations were run separately for each individual pump since only one well will be rehabilitated at a time. For a certain sections of pipe, the flow velocities are more than adequate to flush sediment for most of the well pumps discharging to that section of pipe. However, minimum velocities might not be achieved for smaller well rehabilitation pumps. This was deemed acceptable because the larger well rehabilitation flows would be able to flush out sediments deposited by lower well rehabilitation flows.

Pump sizing is also an iterative process in conjunction with pipe sizing. A horsepower is selected for each simulation. The horsepower is increased or decreased until the optimum pipe size and desired flow rate are achieved.

Remedy Wastewater Node Tabulation

Node	Type	Ground Elev	Invert Elev/Min Elev	Initial Elev	Max Elev/Total Head
FW-1	Reservoir				405
FW-2	Reservoir				420
IRL-1	Reservoir				405
IRL-2	Reservoir				405
IRL-3	Reservoir				405
IRL-4	Reservoir				405
TCS-1	Reservoir				405
TCS-2	Reservoir				405
T-721	Tank	498	500	508	508.5
T201	Tank	626	628	636	636.5
T202	Tank	626	628	636	636.5
T203	Tank	626	628	636	636.5
T204	Tank	626	628	636	636.5
100	Junction	393			
101	Junction	558			
102	Junction	555			
103	Junction	555			
104	Junction	550			
105	Junction	498			
106	Junction	478			
107	Junction	480			
108	Junction	530			
109	Junction	478			
110	Junction	478			
111	Junction	493			
112	Junction	494			
113	Junction	495			
114	Junction	495			
115	Junction	500			
116	Junction	405			
117	Junction	557			
118	Junction	397			
119	Junction	552			
120	Junction	390			
121	Junction	551			
122	Junction	387			
123	Junction	499			
124	Junction	497			
125	Junction	497			
126	Junction	497			
127	Junction	497			
128	Junction	497			
129	Junction	497			
130	Junction	627			

Remedy Wastewater Node Tabulation

Node	Type	Ground Elev	Invert Elev/Min Elev	Initial Elev	Max Elev/Total Head
131	Junction	627			
132	Junction	627			
133	Junction	627			
200	Junction	390			
201	Junction	616			
202	Junction	616			
203	Junction	618			
204	Junction	625			
205	Junction	623			
206	Junction	623			
207	Junction	628			
208	Junction	628			
209	Junction	628			
210	Junction	628			
211	Junction	390			
212	Junction	584			
213	Junction	584			
300	Junction	410			
301	Junction	543			
302	Junction	563			
303	Junction	606			
304	Junction	606			
305	Junction	606			
306	Junction	625			

Remedy Wastewater Link/Conduit Tabulation

Link	Type	Upstr Node	Downstr Node	Dia (in)	Material	C value	Straight Length	Fitting Length	Equivalent Length	$V^2/2g$
PMP001	Pump	FW-1	100							
PMP002	Pump	Fw-2	300							
PMP442	Pump	TCS-2	211							
PMP443	Pump	TCS-1	200							
PMP641	Pump	IRL-1	122							
PMP642	Pump	IRL-2	120							
PMP643	Pump	IRL-3	118							
PMP644	Pump	IRL-4	116							
PMP745	Pump	127	128							
101	Pipe	100	101	5.761	CPVC	150	175	45	220	
102	Pipe	101	102	5.761	CPVC	150	937	119	1056	
103	Pipe	102	103	5.421	HDPE	150	25	11	36	
104	Pipe	103	104	5.421	HDPE	150	132	11	143	
105	Pipe	104	105	5.421	HDPE	150	533	11	544	
106	Pipe	105	106	7.057	HDPE	150	300	0	300	
107	Pipe	106	107	7.48	Steel	130	220	88	308	
108	Pipe	107	108	7.057	HDPE	150	2165	77	2242	
109	Pipe	108	109	7.057	HDPE	150	43	11	54	
110	Pipe	109	110	7.057	HDPE	150	79	11	90	
111	Pipe	110	111	7.057	HDPE	150	175	11	186	
112	Pipe	111	112	7.057	HDPE	150	103	11	114	
113	Pipe	112	113	7.057	HDPE	150	27	11	38	
114	Pipe	113	114	7.057	HDPE	150	60	11	71	
115	Pipe	114	115	7.057	HDPE	150	100	44	144	
116	Pipe	115	T721	7.48	Steel	130	10	70	80	
117	Pipe	116	117	5.761	CPVC	150	156	56	212	
118	Pipe	117	102	5.421	HDPE	150	533	558	1091	
119	Pipe	118	119	5.761	CPVC	150	175	625	800	
120	Pipe	119	103	5.421	HDPE	150	10	22	32	
121	Pipe	120	121	5.761	CPVC	150	175	625	800	
122	Pipe	121	104	5.421	HDPE	150	72	33	105	
123	Pipe	122	123	5.761	CPVC	150	130	625	755	
124	Pipe	123	105	5.421	HDPE	150	10	22	32	
125	Pipe	T721	124	3.53	Steel	130	10	30	40	
126	Pipe	124	125	3.53	Steel	130	16	25	41	
127	Pipe	125	126	2.07	Steel	130	10	5	15	
128	Pipe	126	127	2.07	Steel	130	3	5	8	
129	Pipe	128	129	1.61	Steel	130	10	25	35	
130	Pipe	129	130	3.682	HDPE	150	3700	405	4105	
131	Pipe	130	131	3.682	HDPE	150	11	18	29	
132	Pipe	131	132	3.682	HDPE	150	11	18	29	
133	Pipe	132	133	3.682	HDPE	150	11	18	29	
134	Pipe	130	T204	2.07	Steel	130	5	12	17	0.5
135	Pipe	131	T203	2.07	Steel	130	5	12	17	0.5
136	Pipe	132	T202	2.07	Steel	130	5	12	17	0.5

Remedy Wastewater Link/Conduit Tabulation

Link	Type	Upstr Node	Downstr Node	Dia (in)	Material	C value	Straight Length	Fitting Length	Equivalent Length	$V^2/2g$
137	Pipe	133	T201	2.07	Steel	130	5	12	17	0.5
201	Pipe	200	201	2.9	CPVC	150	226	20	246	
202	Pipe	201	202	2.839	HDPE	150	20	389	409	
203	Pipe	202	203	2.839	HDPE	150	83	19	102	
204	Pipe	203	204	2.839	HDPE	150	692	35	727	
205	Pipe	204	205	7.057	HDPE	150	142	0	142	
206	Pipe	205	206	7.057	HDPE	150	11	42	53	
207	Pipe	206	207	7.057	HDPE	150	11	40	51	
208	Pipe	207	208	7.48	Steel	130	11	18	29	
209	Pipe	208	209	7.48	Steel	130	11	18	29	
210	Pipe	209	210	7.48	Steel	130	11	18	29	
211	Pipe	207	T201	2.568	Steel	130	5	12	17	0.5
212	Pipe	208	T202	2.568	Steel	130	5	12	17	0.5
213	Pipe	209	T203	2.568	Steel	130	5	12	17	0.5
214	Pipe	210	T204	2.568	Steel	130	5	12	17	0.5
215	Pipe	211	212	2.9	CPVC	150	204	0	204	
216	Pipe	212	213	2.839	HDPE	150	25	203	228	
217	Pipe	213	203	2.839	HDPE	150	138	17	155	
301	Pipe	300	301	3.826	CPVC	150	147	17	164	
302	Pipe	301	302	3.682	HDPE	150	200	12	212	
303	Pipe	302	303	3.53	Steel	130	200	48	248	
304	Pipe	303	304	3.682	HDPE	150	185	24	209	
305	Pipe	304	305	3.826	CPVC	150	13	44	57	
306	Pipe	305	306	3.682	HDPE	150	305	41	346	
307	Pipe	306	307	3.682	HDPE	150	104	52	156	

Remedy Wastewater System - Junction, Well and Tank Data

Network Table - Nodes

Node ID	Elevation ft	Base Demand GPM	Initial Quality
Junc 100	393	0	0
Junc 101	558	0	0
Junc 102	555	0	0
Junc 103	555	0	0
Junc 104	550	0	0
Junc 105	498	0	0
Junc 106	478	0	0
Junc 107	480	0	0
Junc 108	530	0	0
Junc 109	478	0	0
Junc 110	478	0	0
Junc 111	493	0	0
Junc 112	494	0	0
Junc 113	495	0	0
Junc 114	495	0	0
Junc 115	500	0	0
Junc 116	405	0	0
Junc 117	557	0	0
Junc 118	397	0	0
Junc 119	552	0	0
Junc 120	390	0	0
Junc 121	551	0	0
Junc 122	387	0	0
Junc 123	499	0	0
Junc 124	497	0	0

Remedy Wastewater System - Junction, Well and Tank Data

Node ID	Elevation ft	Base Demand GPM	Initial Quality
Junc 125	497	0	0
Junc 126	497	0	0
Junc 127	497	0	0
Junc 128	497	0	0
Junc 129	497	0	0
Junc 130	627	0	0
Junc 131	627	0	0
Junc 132	627	0	0
Junc 133	627	0	0
Junc 200	390	0	0
Junc 201	616	0	0
Junc 202	616	0	0
Junc 203	618	0	0
Junc 204	625	0	0
Junc 205	623	0	0
Junc 206	623	0	0
Junc 207	628	0	0
Junc 208	628	0	0
Junc 209	628	0	0
Junc 210	628	0	0
Junc 211	390	0	0
Junc 212	584	0	0
Junc 213	584	0	0
Junc 300	410	0	0
Junc 301	543	0	0
Junc 302	563	0	0

Remedy Wastewater System - Junction, Well and Tank Data

Node ID	Elevation ft	Base Demand GPM	Initial Quality
Junc 303	606	0	0
Junc 304	606	0	0
Junc 305	606	0	0
Junc 306	625	0	0
Resvr FW-1	405	#N/A	0
Resvr FW-2	420	#N/A	0
Resvr IRL-1	405	#N/A	0
Resvr IRL-2	405	#N/A	0
Resvr IRL-3	405	#N/A	0
Resvr IRL-4	405	#N/A	0
Resvr TCS-1	405	#N/A	0
Resvr TCS-2	405	#N/A	0
Tank T721	498	#N/A	0
Tank T201	628	#N/A	0
Tank T202	628	#N/A	0
Tank T203	628	#N/A	0
Tank T204	628	#N/A	0

Remedy Wastewater System - Pipe and Pump Data

Network Table - Links

Link ID	Length ft	Diameter in	Roughness
Pipe 101	220	5.761	150
Pipe 102	1056	5.761	150
Pipe 103	36	5.421	150
Pipe 104	143	5.421	150
Pipe 105	544	5.421	150
Pipe 106	300	7.057	150
Pipe 107	308	7.48	130
Pipe 108	2242	7.057	150
Pipe 109	54	7.057	150
Pipe 110	90	7.057	150
Pipe 111	186	7.057	150
Pipe 112	114	7.057	150
Pipe 113	38	7.057	150
Pipe 114	71	7.057	150
Pipe 115	144	7.057	150
Pipe 116	80	7.48	130
Pipe 117	212	5.761	150
Pipe 118	1091	5.421	150
Pipe 119	800	5.761	150
Pipe 120	32	5.421	150
Pipe 121	800	5.761	150
Pipe 122	105	5.421	150
Pipe 123	755	5.761	150
Pipe 124	32	5.421	150
Pipe 125	40	3.53	130

Remedy Wastewater System - Pipe and Pump Data

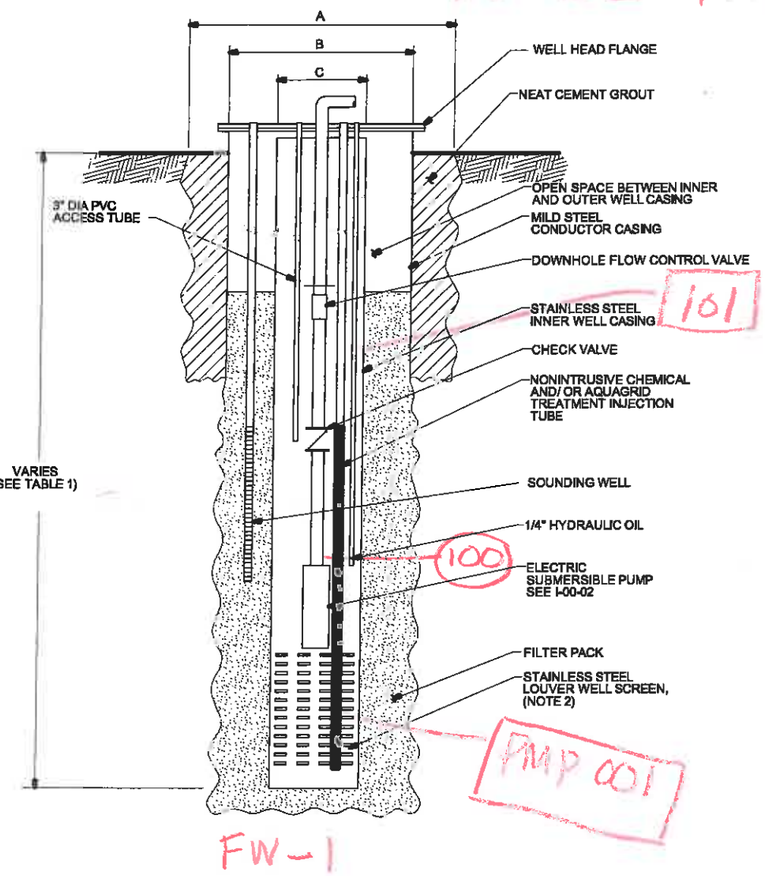
Link ID	Length ft	Diameter in	Roughness
Pipe 126	41	3.53	150
Pipe 127	15	2.07	130
Pipe 128	8	2.07	130
Pipe 129	35	1.61	130
Pipe 130	4105	3.682	150
Pipe 131	29	3.682	150
Pipe 132	29	3.682	150
Pipe 133	29	3.682	150
Pipe 134	17	2.07	130
Pipe 135	17	2.07	130
Pipe 136	17	2.07	130
Pipe 137	17	2.07	130
Pipe 201	246	2.900	150
Pipe 202	409	2.839	150
Pipe 203	102	2.839	150
Pipe 204	727	2.839	150
Pipe 205	142	7.057	150
Pipe 206	53	7.057	150
Pipe 207	51	7.057	150
Pipe 208	29	7.48	130
Pipe 209	29	7.48	130
Pipe 210	29	7.48	130
Pipe 211	17	2.568	130
Pipe 212	17	2.568	130
Pipe 213	17	2.568	130
Pipe 214	17	2.568	130

Remedy Wastewater System - Pipe and Pump Data

Link ID	Length ft	Diameter in	Roughness
Pipe 215	204	2.90	150
Pipe 216	228	2.839	150
Pipe 217	155	2.839	150
Pipe 301	164	3.826	150
Pipe 302	212	3.682	150
Pipe 303	248	3.53	130
Pipe 304	209	3.682	150
Pipe 305	57	3.826	150
Pipe 306	346	3.826	150
Pipe 307	156	3.682	150
Pump PMP001	#N/A	#N/A	#N/A
Pump PMP002	#N/A	#N/A	#N/A
Pump PMP442	#N/A	#N/A	#N/A
Pump PMP443	#N/A	#N/A	#N/A
Pump PMP641	#N/A	#N/A	#N/A
Pump PMP642	#N/A	#N/A	#N/A
Pump PMP643	#N/A	#N/A	#N/A
Pump PMP644	#N/A	#N/A	#N/A
Pump PMP745	#N/A	#N/A	#N/A

REMEDY WASTEWATER COLLECTION SYSTEM NODE AND LINK MAP

1/38



NOTE:

1. WELL DEPTH AND WELL CASING DIMENSIONS (A,B & C) SHOWN IN TABLE 1 ON THIS SHEET
2. ENGINEER WILL DESIGN LOUVER SLOT SIZE AND FILTER PACK GRADE BASED ON GRAIN SIZE DISTRIBUTION ANALYSIS OF FORMATION SAMPLES

FRESH WATER INJECTION WELL WITH BACKWASH PUMP

NTS

TABLE 1

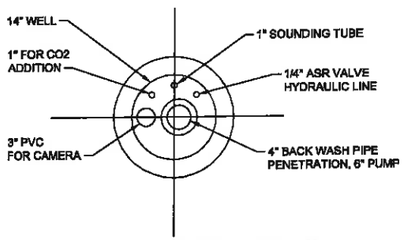
			A		B	C						
Well ID	Depth of Conductor Casing (ft)	Surface Elevation (ft , msl)	Diameter of Conductor Borehole (inches)	Depth of Borehole (ft)	Borehole Diameter (in)	Well Casing Diameter (inches)	Model Saturated Thickness (ft)	Depth to Water (ft)	Depth to Pump (ft)	Well Depth (ft)	Well Screen Length (ft)	Pump Submergence (ft)
FW-001	50	561	32	376	24	14	250	106	168.5	356	187.5	62.5
FW-002 *Note 1*	50	546	32	171	24	14	60	91	136	151	45	45
IRL-001	50	501	32	336	24	14	270	46	113.5	316	202.5	67.5
IRL-002	50	547	32	372	24	14	260	92	157	352	195	65
IRL-003	50	555	32	350	24	14	230	100	157.5	330	172.5	57.5
IRL-004	50	561	32	326	24	14	200	106	156	306	150	50

Note 1. It is assumed that pump in FW-002 will be equipped with a cooling shroud so that pump can be installed deeper in the well to increase pump submergence.

TABLE 2

	Pipe Sizes/MOC/Civil Drawing Reference							
	FW Into Meter Vault	FW Inside Meter Vault	FW Out of Meter Vault/Into Well Vault	FW Inside Well Vault	RW Out of Well Vault/Into Meter Vault	RW In Meter Vault	RW Out of Meter Vault	*Reference to Civil Site Plan*
MOC	*HPDE*	*CPVC*	*HDPE*	*CPVC*	*Double Contained HDPE*	*CPVC*	*Double Contained HDPE*	
FW-001	4"	4"	4"	4"	6" in 10"	6"	6" in 10"	C-02-03
FW-002	2"	3"	2"	3"	4" in 8"	4"	4" in 8"	C-02-04
IRL-001	4"	4"	4"	4"	6" in 10"	6"	6" in 10"	C-05-04
IRL-002	4"	4"	4"	4"	6" in 10"	6"	6" in 10"	C-05-05
IRL-003	4"	4"	4"	4"	6" in 10"	6"	6" in 10"	C-05-06
IRL-004	4"	4"	4"	4"	6" in 10"	6"	6" in 10"	C-05-07

NOTE: Six Vaults are represented by this drawing.
RW (remedy water) pipe is double contained leaving the vaults.
All HDPE piping is Standard Dimension Ratio - SDR-11
All CPVC piping is Schedule 80



WELL FLANGE DETAIL

NTS

NOTES:

1. FOR DISTANCE BETWEEN VAULTS, SEE TABLE 2 FOR CIVIL DRAWING REFERENCE.

PRELIMINARY PLANS-NOT FOR CONSTRUCTION

DRAFT NOT FOR CONSTRUCTION

CH2MHILL.

NO.	DATE	DESCRIPTION	CM/SPEC	DWN	CHKD	SUPV	APVD BY
D	2012/09/12	INTERMEDIATE (60%) DESIGN SUBMITTAL		GJ			JP

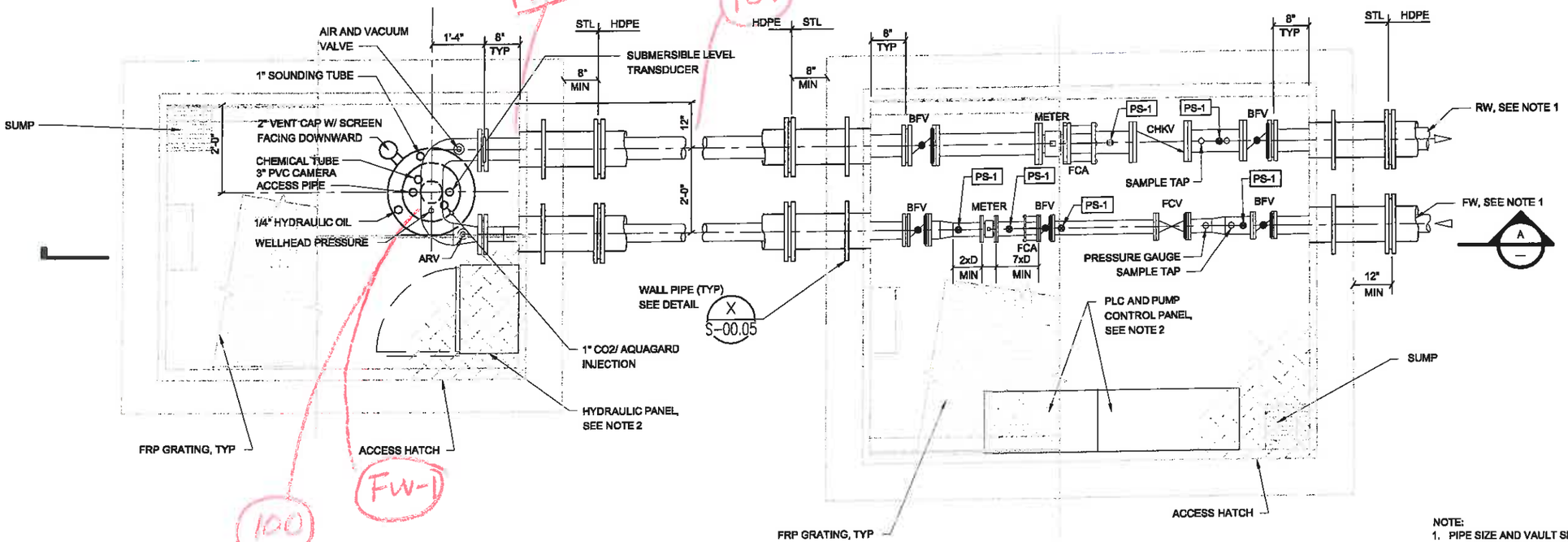
REVISIONS

APPROVED BY: SO, SUPV, DSGN GJ, DWN GJ, CHKD EL, QK JP, DATE 9/12/12, SCALES

TOPOCK GROUNDWATER REMEDIATION PROJECT
FRESHWATER INJECTION WELL CONSTRUCTION DETAILS
PACIFIC GAS AND ELECTRIC COMPANY (GAS TRANSMISSION & DISTRIBUTION)
SAN FRANCISCO, CALIFORNIA

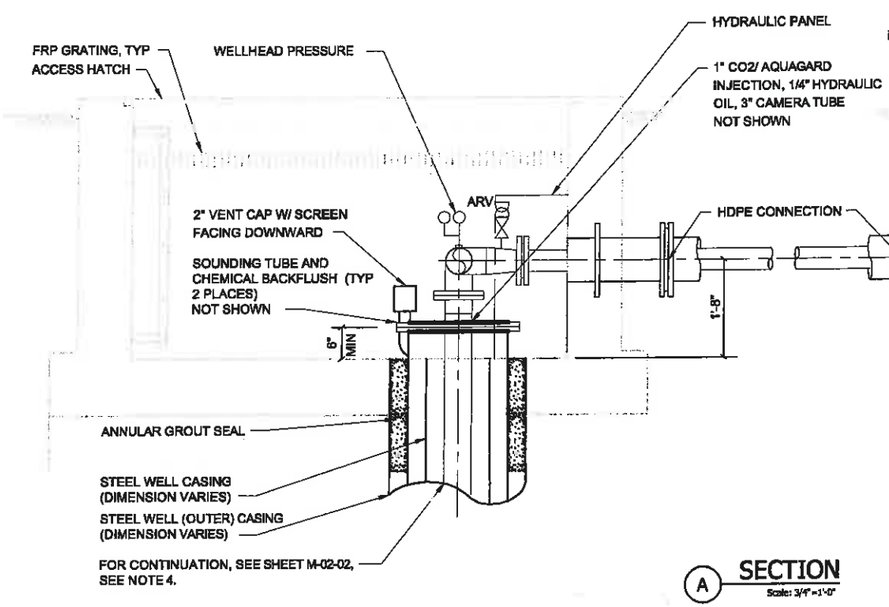
MICROFILM | BILL OF MATL | DWG LIST | SUPSDS | SUPSD BY | SHEET NO. of SHEETS | M-02-02 | REV

PLOT DATE: $PLOTDATE PLOT TIME: $PLOTTIME FILENAME: CH-M-XXX-0202AD.dwg



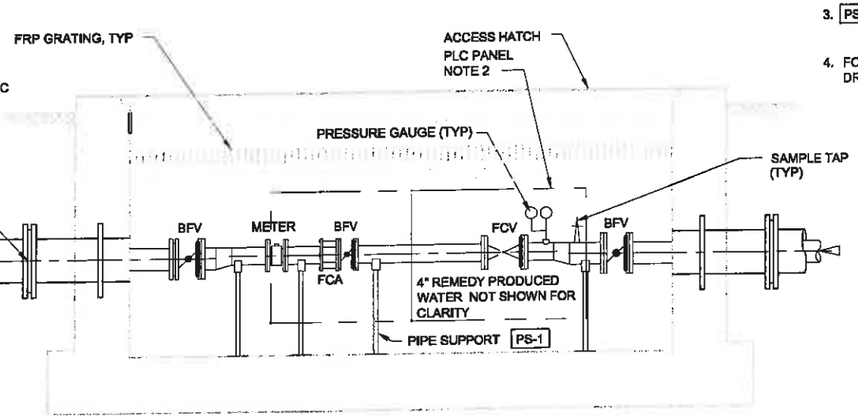
WELL VAULT PLAN

NOTE 1



METER VAULT PLAN

NOTE 1



A SECTION

Scale: 3/4" = 1'-0"

NOTE:
1. PIPE SIZE AND VAULT SIZES VARY ACCORDING TO LOCATION, SEE TABLE 2 ON DWG M-02-02, TYP OF 6 SETS OF VAULTS
2. FOR CONTROL PANEL PLACEMENT SEE ELECTRICAL DRAWING E-02-01-A
3. PS-1 PIPE SUPPORT, SEE DETAIL 2 S-00.05
4. FOR STRUCTURAL VAULT DIMENSIONS SEE DRAWINGS S-02-01 AND S-02-02.

DRAFT NOT FOR CONSTRUCTION

CH2MHILL.

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0	2012/09/12	INTERMEDIATE (90%) DESIGN SUBMITTAL	GJ			JP	

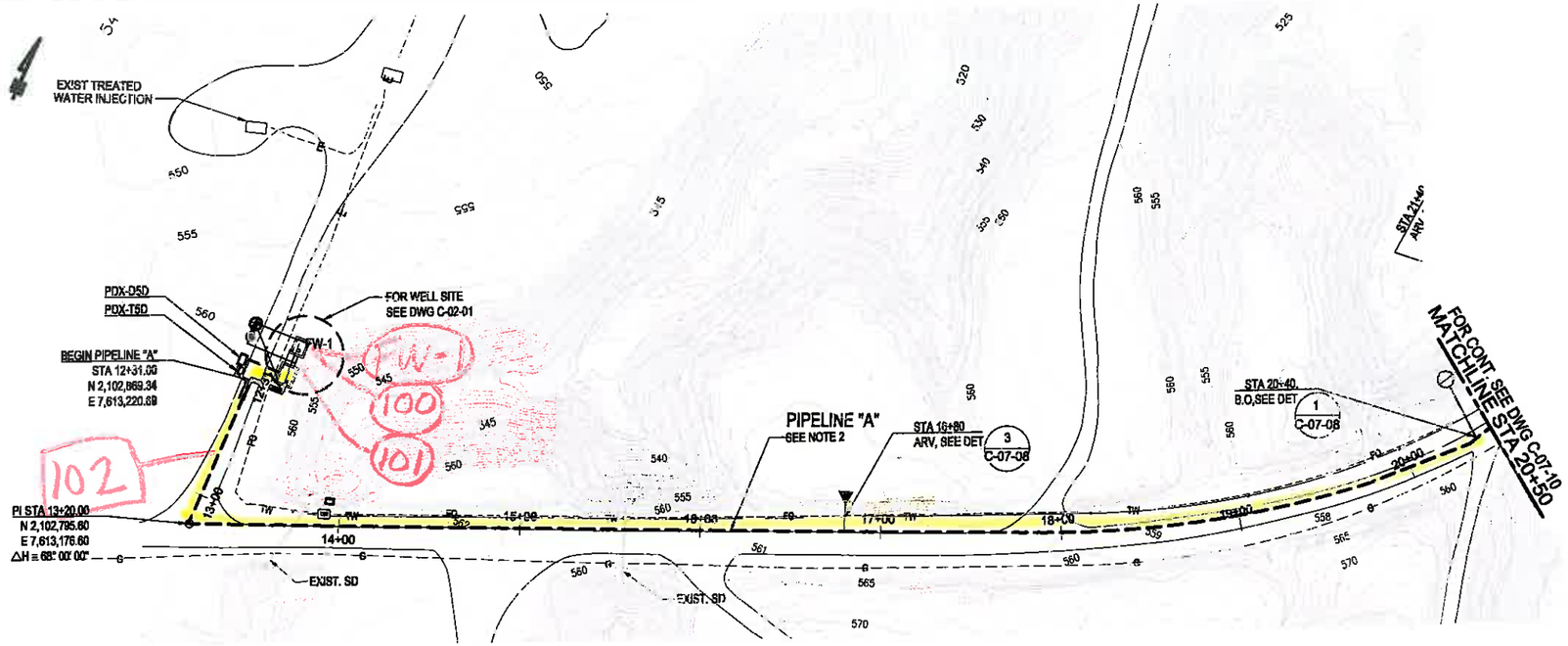
REVISIONS

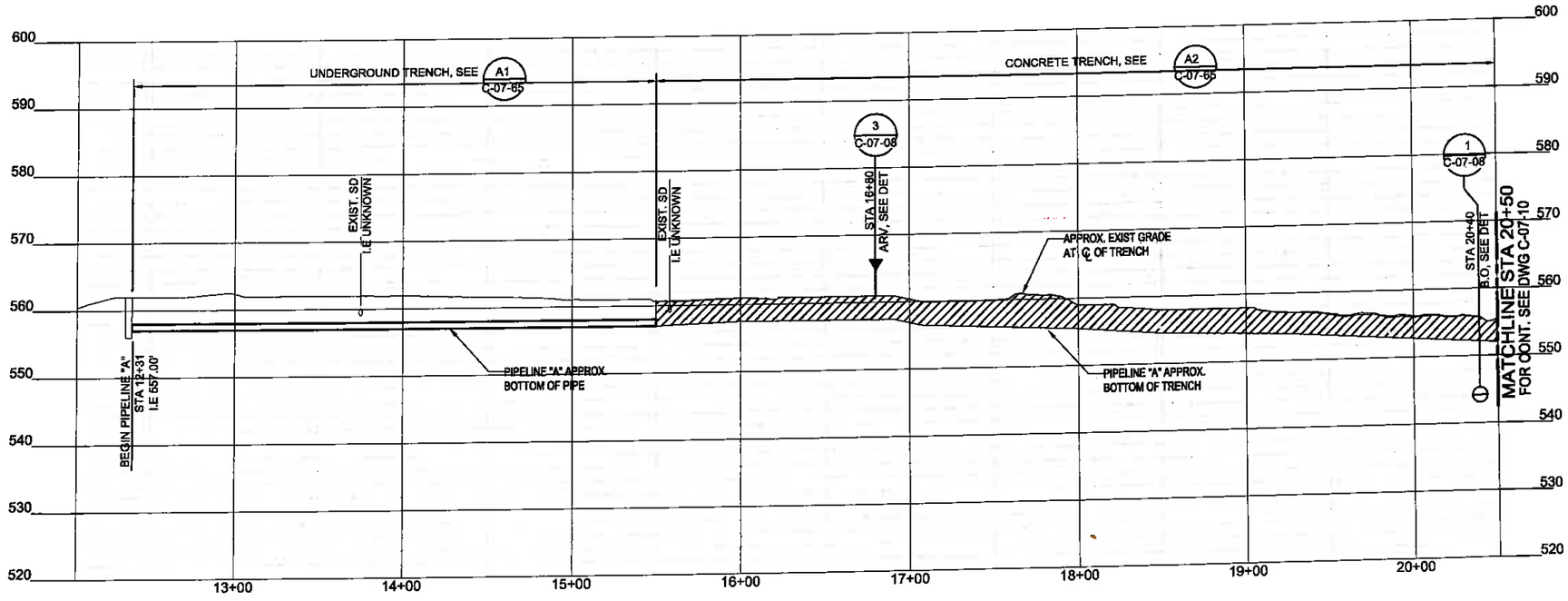
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SUPV
DSGN RH
DWN GJ
CHKD ML
QK JP
DATE 9/12/12
SCALES

TOPOCK GROUNDWATER REMEDIATION PROJECT
FRESHWATER INJECTION WELL AND METER VAULT PLAN AND SECTIONS
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. of SHEETS
M-02-01
REV

PLOT DATE: $PLOTDATE PLOT TIME: $PLOTTIME
FILENAME: CH-M-XXX-02D1AD.dwg





3/38

NOTES

1. DEPTHS OF EXISTING UTILITIES ARE UNKNOWN. ALL POTENTIAL CONFLICTS BETWEEN NEW PIPE CONSTRUCTION AND EXISTING UTILITIES WILL BE POTHOLED PRIOR TO THE 100% DESIGN. A DETERMINATION WILL BE MADE WHETHER TO RELOCATE EXISTING UTILITIES OR RE-ROUTE NEW PIPE TRENCHES AROUND EXISTING UTILITIES. THIS WILL BE INCORPORATED INTO THE 100% DESIGN.
2. THE NEW PIPELINE ALIGNMENT SHOWS CENTER OF TRENCH. THE NUMBER AND SIZES OF PIPE IN EACH TRENCH VARIES. REFER TO PIPE SECTION NUMBER ON EACH PLAN AND PROFILE SHEET AND PIPE SCHEDULE ON DRAWING C-07-03 FOR NUMBER AND SIZE OF EACH PIPE. REFER TO TRENCH DETAILS ON DRAWINGS C-07-65, C-07-66 AND C-07-67 FOR ARRANGEMENT OF PIPING IN EACH TRENCH SECTION.

HORZ: SCALE: 1"=40'-0"
VERT: SCALE: 1"=10'-0"

DRAFT NOT FOR CONSTRUCTION

E2 Consulting Engineers, Inc.

CH2MHILL.

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

REVISIONS

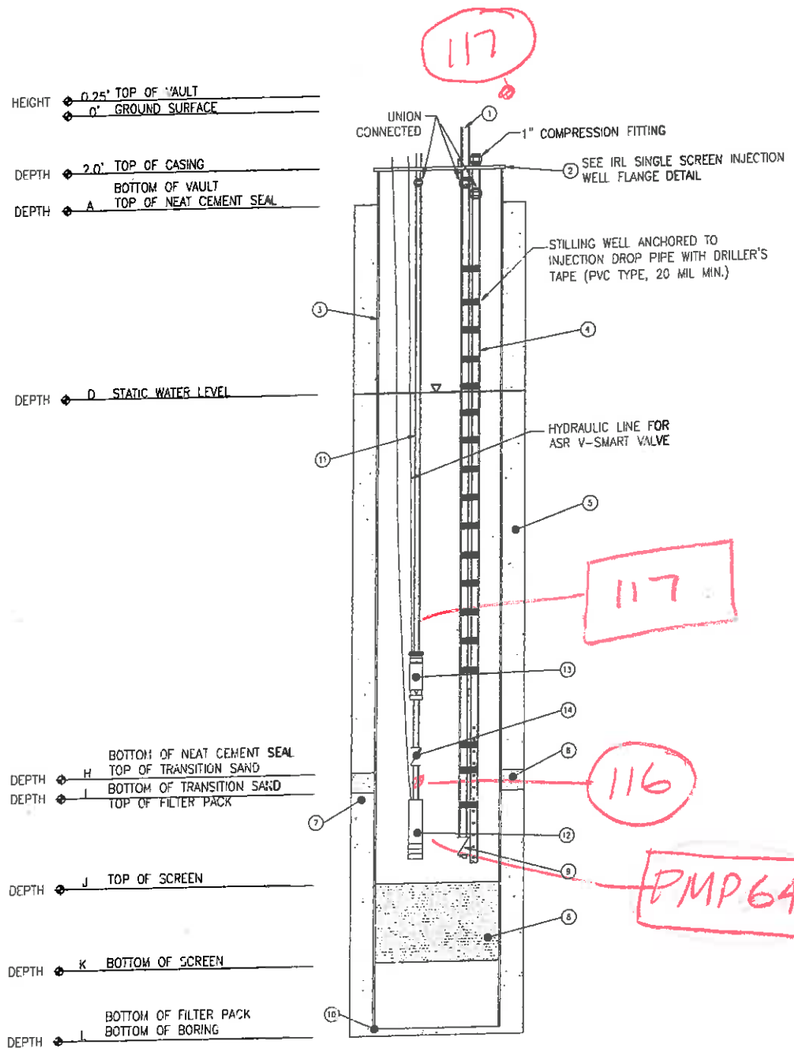
APPROVED BY	
SO	
SUPV	
DSGN	PT
DWN	PC/EE
CHKD	PT
QK	PT
DATE	9/12/12
SCALES	

TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE
PIPELINE "A"
STA 12+31 TO STA 20+50
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM	
BILL OF MATL	
DWG LIST	
SUPSDS	
SUPSD BY	
SHEET NO.	of SHEETS
C-07-09	REV

PLOT DATE: $PLOTDATE PLOT TIME: $PLOTTIME
FILENAME: E2-C-XXX-0709AD.dwg

4/38



IRL SINGLE SCREEN INJECTION WELL WITH BACKWASH PUMP DETAIL

A ~

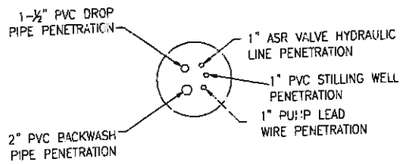
NOT TO SCALE. SEE WELL CONSTRUCTION SCHEDULE SHEET M-X-01 FOR REPRESENTATIVE DEPTHS. WELL DIAMETER EXAGGERATED TO SHOW DETAIL.

IRL-4

KEY

1	1-½" PVC DROP PIPE (MATERIALS TBD)
2	CUSTOM TAPPED WELL FLANGE
3	WELL CASING (MATERIALS TBD)
4	1" PVC TUBING (STILLING WELL WITH PRESSURE TRANSDUCER)
5	ANNULAR SPACE, 100% NEAT CEMENT GROUT
6	ANNULAR SPACE, TRANSITION SAND (SIZE TBD)
7	ANNULAR SPACE, FILTER PACK (TYPE TBD)
8	WELL SCREEN (MATERIALS TBD)
9	SPRING CHECK VALVE (TYPE AND MATERIALS TBD)
10	SUMP
11	3" BACKWASH PIPING
12	BACKWASH PUMP
13	3" ASR V-SMART VALVE
14	3" CHECK VALVE

NOTES:
1. ALL DEPTH INTERVALS 'A' THRU 'K' ARE IN FEET BELOW GROUND SURFACE.
2. ALL COORDINATES BASED ON NAD83, CA ZONE V.
3. ALL WELL SEALS ARE 100% NEAT CEMENT.
4. ALL ABOVE-GRADE PIPING AND INSTRUMENTATION INSTALLED IN ACCORDANCE WITH THE P&ID AND THE WELLHEAD MECHANICAL LAYOUT



IRL SINGLE SCREEN WELL FLANGE DETAIL

B ~

NOT TO SCALE

ETIC ENGINEERING

ARCADIS

NO.	DATE	DESCRIPTION	SM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL	AJW	JPB	JPB	JEF	

REVISIONS

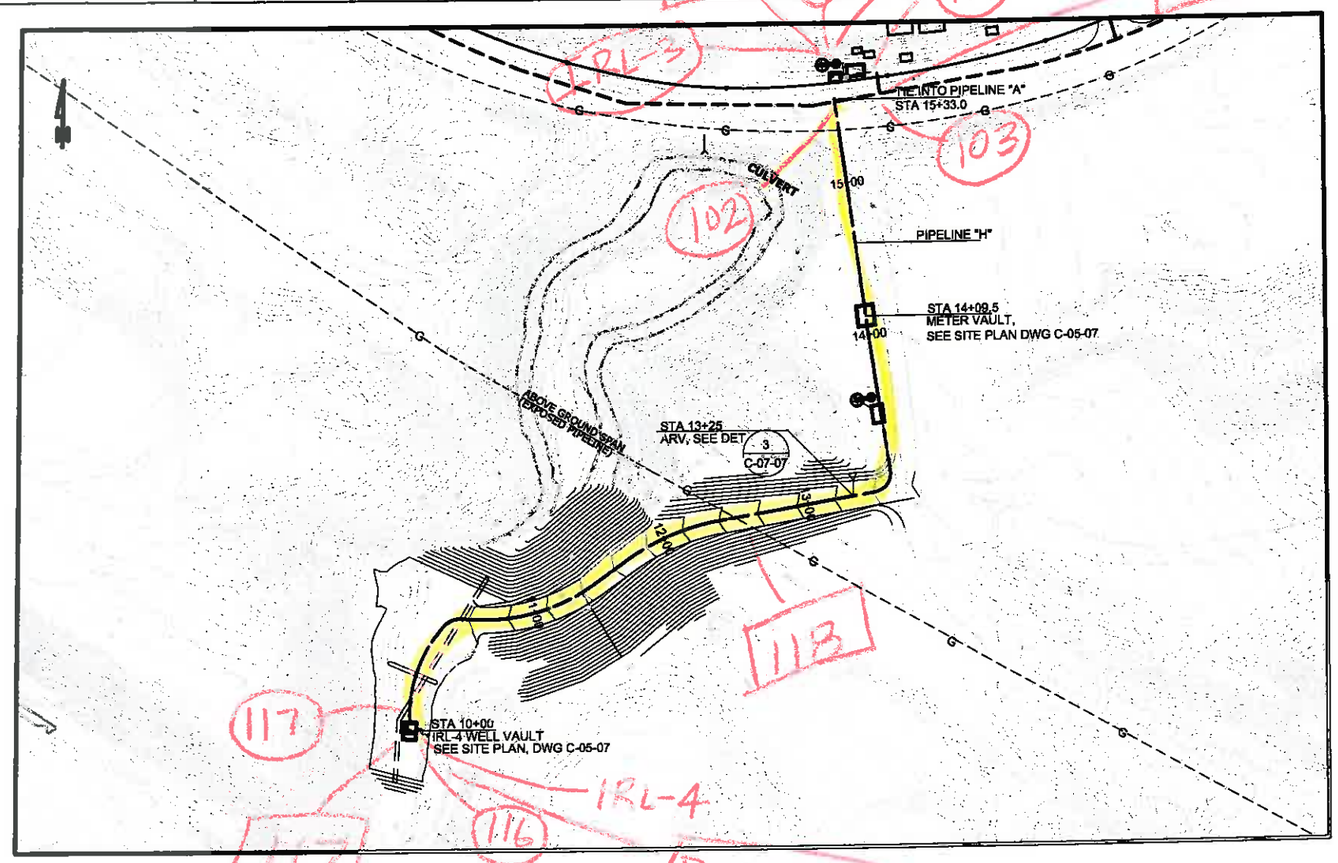
APPROVED BY		
JEF	SD	
	SUPV	JPB
	DSGN	JPB
	DWN	AJW
	CHKD	JPB
	OK	JEF
	DATE	9/12/12
	SCALES	AS NOTED

TOPOCK GROUNDWATER REMEDIATION PROJECT
INNER RECIRCULATION LOOP INJECTION WELL CONSTRUCTION DETAILS
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

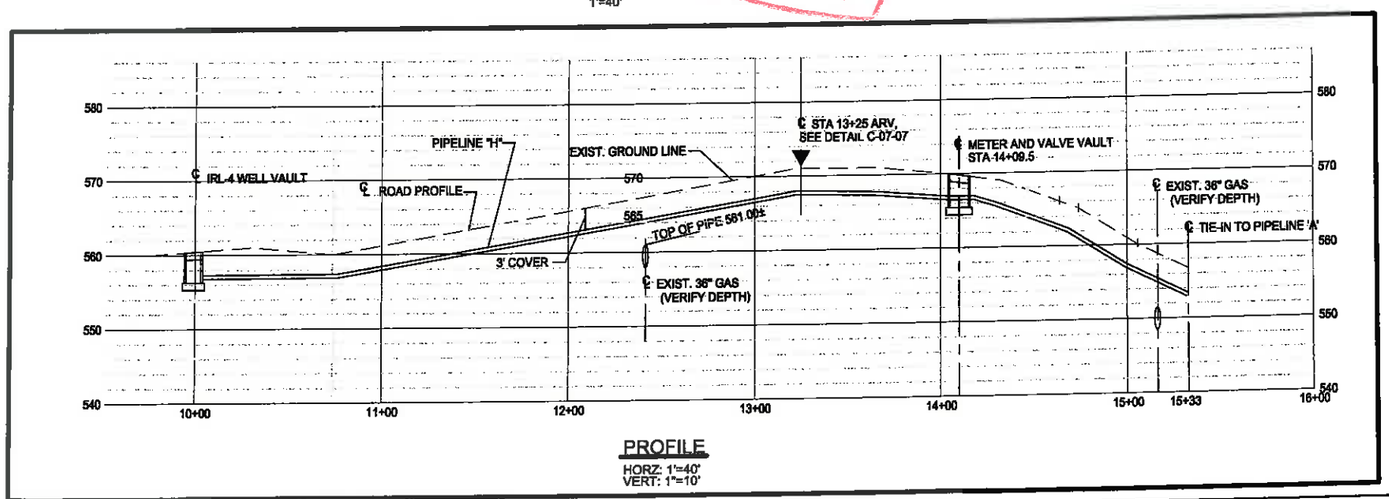
- DRAFT - NOT FOR CONSTRUCTION

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. M-05-02 of SHEETS
REV

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PLAN
1'=40'



PROFILE
HORZ: 1'=40'
VERT: 1"=10'

NOTES

1. DEPTHS OF EXISTING UTILITIES ARE UNKNOWN. ALL POTENTIAL CONFLICTS BETWEEN NEW PIPE CONSTRUCTION AND EXISTING UTILITIES WILL BE POTHOLED PRIOR TO THE 100% DESIGN. A DETERMINATION WILL BE MADE WHETHER TO RELOCATE EXISTING UTILITIES OR RE-ROUTE NEW PIPE TRENCHES AROUND EXISTING UTILITIES. THIS WILL BE INCORPORATED INTO THE 100% DESIGN.
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HORZ: SCALE: 1"=40'-0"
VERT: SCALE: 1"=10'-0"

DRAFT
NOT FOR
CONSTRUCTION

E2 Consulting Engineers, Inc.

CH2MHILL.

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

REVISIONS

APPROVED BY
SO
SUPV
DSGN PT
DWN PC
CHKD PT
QK PT
DATE 9/12/12
SCALES

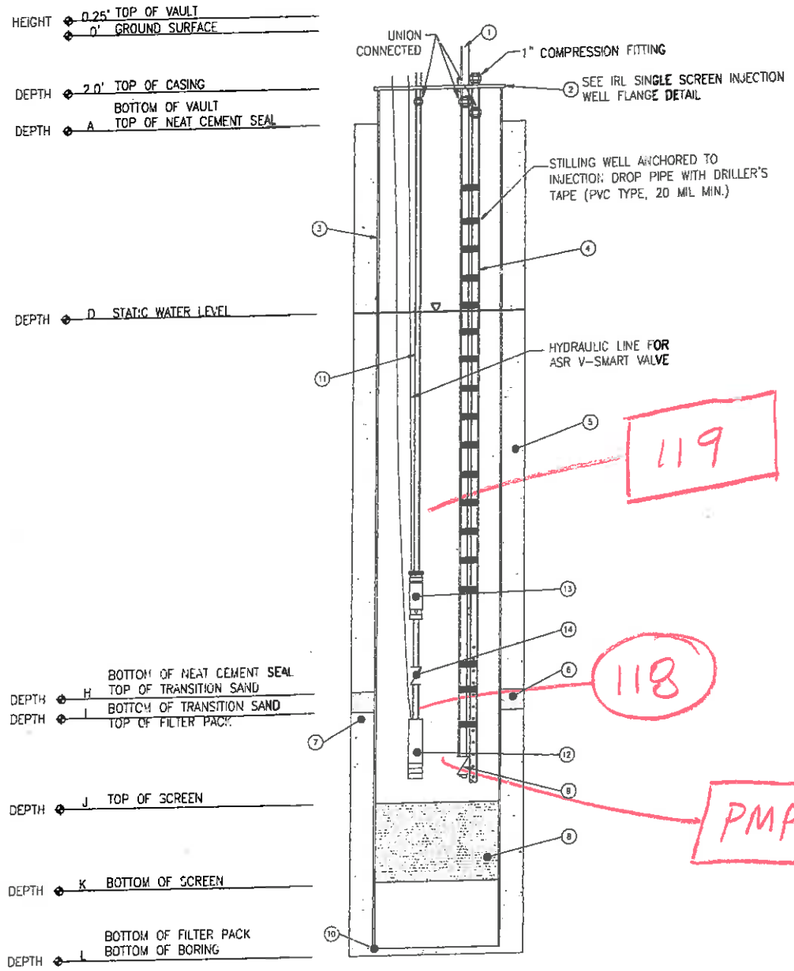
TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE PIPELINE "H"
STA 10+00 TO STA 15+33
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. C-07-14 of SHEETS REV

PLOT DATE: $PLOTDATE PLOT TIME: $PLOTTIME
FILENAME: E2-C-XXX-0714.dwg

6/38

119



IRL SINGLE SCREEN INJECTION WELL WITH BACKWASH PUMP DETAIL

A

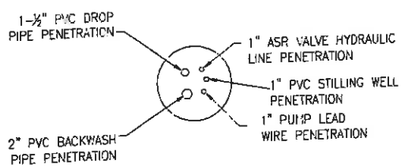
NOT TO SCALE. SEE WELL CONSTRUCTION SCHEDULE SHEET M-X-01 FOR REPRESENTATIVE DEPTHS. WELL DIAMETER EXAGGERATED TO SHOW DETAIL.

IRL-3

KEY

1	1-½" PVC DROP PIPE (MATERIALS TBD)
2	CUSTOM TAPPED WELL FLANGE
3	WELL CASING (MATERIALS TBD)
4	1" PVC TUBING (STILLING WELL WITH PRESSURE TRANSDUCER)
5	ANNULAR SPACE, 100% NEAT CEMENT GROUT
6	ANNULAR SPACE, TRANSITION SAND (SIZE TBD)
7	ANNULAR SPACE, FILTER PACK (TYPE TBD)
8	WELL SCREEN (MATERIALS TBD)
9	SPRING CHECK VALVE (TYPE AND MATERIALS TBD)
10	SUMP
11	3" BACKWASH PIPING
12	BACKWASH PUMP
13	3" ASR V-SMART VALVE
14	3" CHECK VALVE

NOTES:
1. ALL DEPTH INTERVALS 'A' THRU 'K' ARE IN FEET BELOW GROUND SURFACE.
2. ALL COORDINATES BASED ON NAD83, CA ZONE V.
3. ALL WELL SEALS ARE 100% NEAT CEMENT.
4. ALL ABOVE-GRADE PIPING AND INSTRUMENTATION INSTALLED IN ACCORDANCE WITH THE P&ID AND THE WELLHEAD MECHANICAL LAYOUT



IRL SINGLE SCREEN WELL FLANGE DETAIL

B

NOT TO SCALE

ETIC ENGINEERING

ARCADIS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL	AJW	JPB	JPB	JEF	

REVISIONS

APPROVED BY		
JEF	SO	
	SUPV	JPB
	DSGN	JPB
	DWN	AJW
	CHKD	JPB
	QK	JEF
	DATE	9/12/12
	SCALES	AS NOTED

TOPOCK GROUNDWATER REMEDIATION PROJECT
INNER RECIRCULATION LOOP INJECTION WELL CONSTRUCTION DETAILS
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

- DRAFT - NOT FOR CONSTRUCTION

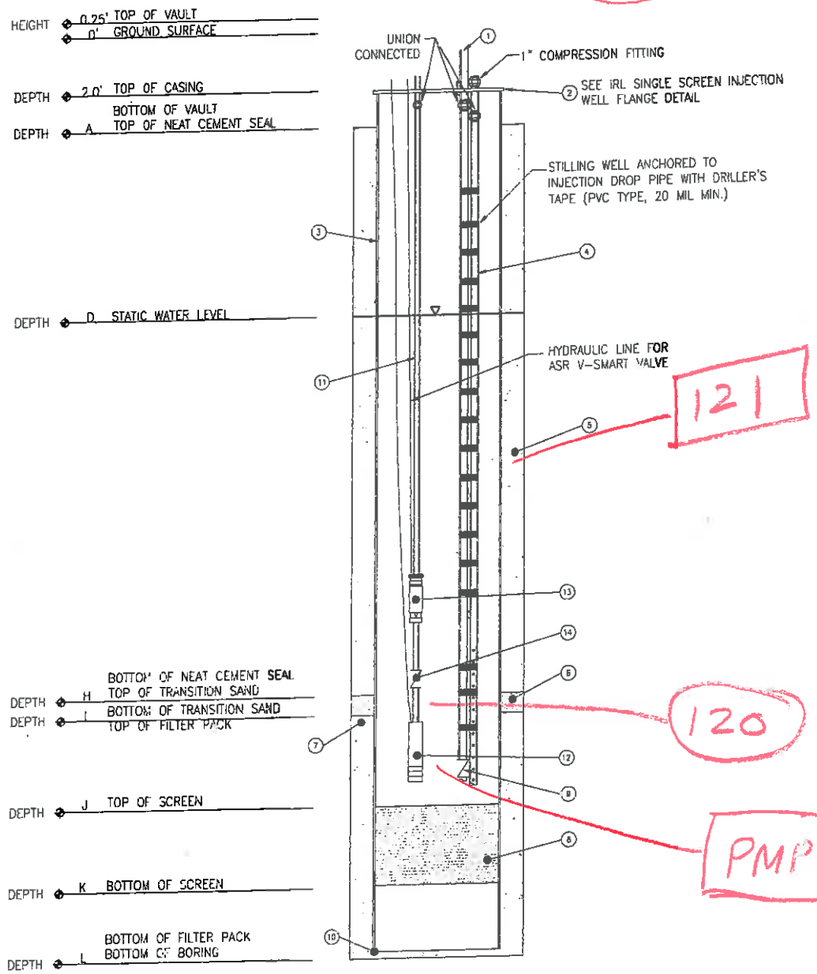
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BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. M-05-02 of SHEETS REV

FIELD

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7/38

121



IRL SINGLE SCREEN INJECTION WELL WITH BACKWASH PUMP DETAIL

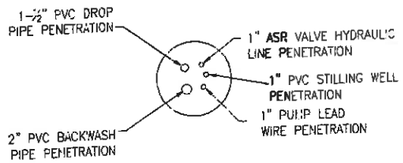
NOT TO SCALE. SEE WELL CONSTRUCTION SCHEDULE SHEET M-X-01 FOR REPRESENTATIVE DEPTHS. WELL DIAMETER EXAGGERATED TO SHOW DETAIL.

IRL-2

KEY

1	1-½" PVC DROP PIPE (MATERIALS TBD)
2	CUSTOM TAPPED WELL FLANGE
3	WELL CASING (MATERIALS TBD)
4	1" PVC TUBING (STILLING WELL WITH PRESSURE TRANSDUCER)
5	ANNULAR SPACE, 100% NEAT CEMENT GROUT
6	ANNULAR SPACE, TRANSITION SAND (SIZE TBD)
7	ANNULAR SPACE, FILTER PACK (TYPE TBD)
8	WELL SCREEN (MATERIALS TBD)
9	SPRING CHECK VALVE (TYPE AND MATERIALS TBD)
10	SUMP
11	3" BACKWASH PIPING
12	BACKWASH PUMP
13	3" ASR V-SMART VALVE
14	3" CHECK VALVE

NOTES:
1. ALL DEPTH INTERVALS 'A' THPU 'K' ARE IN FEET BELOW GROUND SURFACE.
2. ALL COORDINATES BASED ON NAD83, CA ZONE V.
3. ALL WELL SEALS ARE 100% NEAT CEMENT.
4. ALL ABOVE-GRADE PIPING AND INSTRUMENTATION INSTALLED IN ACCORDANCE WITH THE P&ID AND THE WELLHEAD MECHANICAL LAYOUT



IRL SINGLE SCREEN WELL FLANGE DETAIL

NOT TO SCALE

- DRAFT - NOT FOR CONSTRUCTION

ETIC ENGINEERING

ARCADIS

NO.	DATE	DESCRIPTION	BM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL	AJW	JPB	JPB	JEF	

REVISIONS

APPROVED BY: JEF

SO	
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DSGN	JPB
DWN	AJW
CHKD	JPB
QK	JEF
DATE	9/12/12
SCALES	AS NOTED

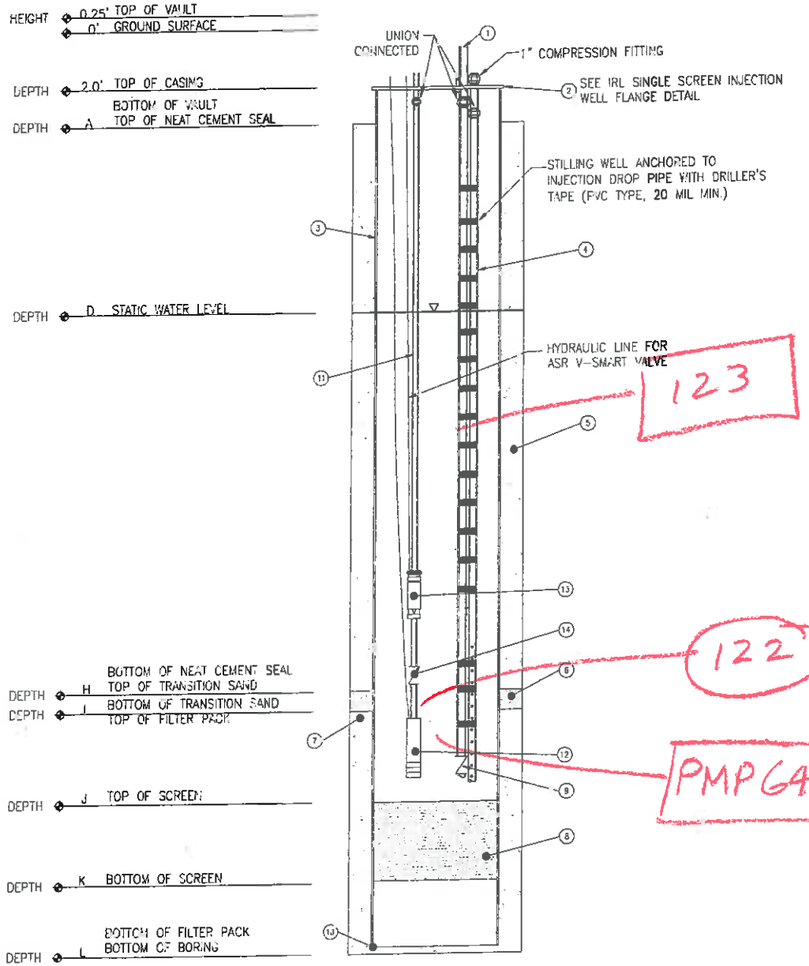
TOPOCK GROUNDWATER REMEDIATION PROJECT
INNER RECIRCULATION LOOP INJECTION WELL CONSTRUCTION DETAILS
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM	
BILL OF MATL	
DWG LIST	
SUPSDS	
SUPSD BY	
SHEET NO.	of SHEETS
M-05-02	REV

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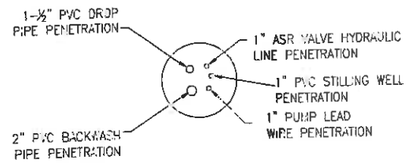
A IRL SINGLE SCREEN INJECTION WELL WITH BACKWASH PUMP DETAIL
NOT TO SCALE. SEE WELL CONSTRUCTION SCHEDULE SHEET M-X-01 FOR REPRESENTATIVE DEPTHS. WELL DIAMETER EXAGGERATED TO SHOW DETAIL.

IRL-1

KEY

1	1-½" PVC DROP PIPE (MATERIALS TBD)
2	CUSTOM TAPPED WELL FLANGE
3	WELL CASING (MATERIALS TBD)
4	1" PVC TUBING (STILLING WELL WITH PRESSURE TRANSDUCER)
5	ANNULAR SPACE, 100% NEAT CEMENT GROUT
6	ANNULAR SPACE, TRANSITION SAND (SIZE TBD)
7	ANNULAR SPACE, FILTER PACK (TYPE TBD)
8	WELL SCREEN (MATERIALS TBD)
9	SPRING CHECK VALVE (TYPE AND MATERIALS TBD)
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NOTES:
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B IRL SINGLE SCREEN WELL FLANGE DETAIL
NOT TO SCALE

- DRAFT - NOT FOR CONSTRUCTION

ETIC ENGINEERING

ARCADIS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITAL	A/W	JPB	JPB	JEF	

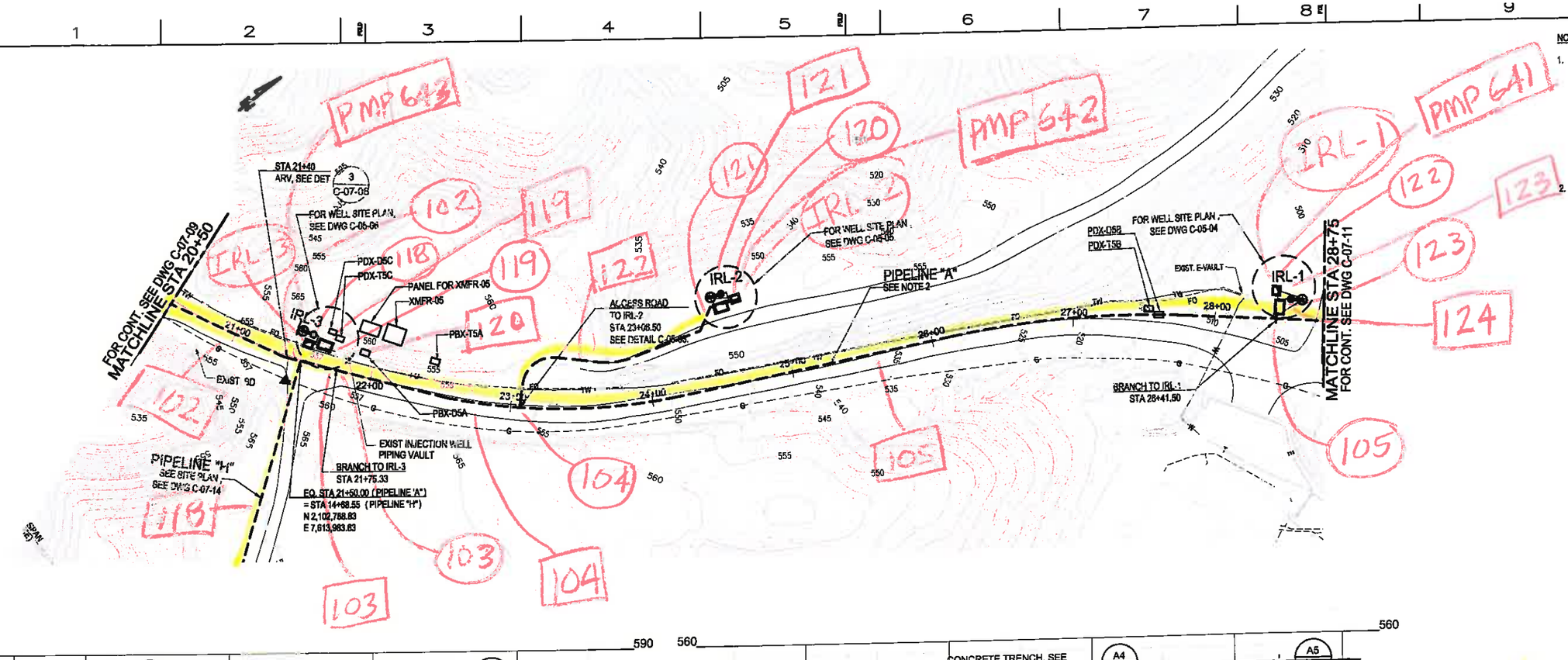
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APPROVED BY		
JEF	SO	
	SUPV	JPB
	DSGN	JPB
	DWN	AJW
	CHKD	JPB
	OK	JEF
	DATE	9/12/12
	SCALES	AS NOTED

TOPOCK GROUNDWATER REMEDIATION PROJECT
INNER RECIRCULATION LOOP INJECTION WELL CONSTRUCTION DETAILS
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. M-05-02 of SHEETS REV

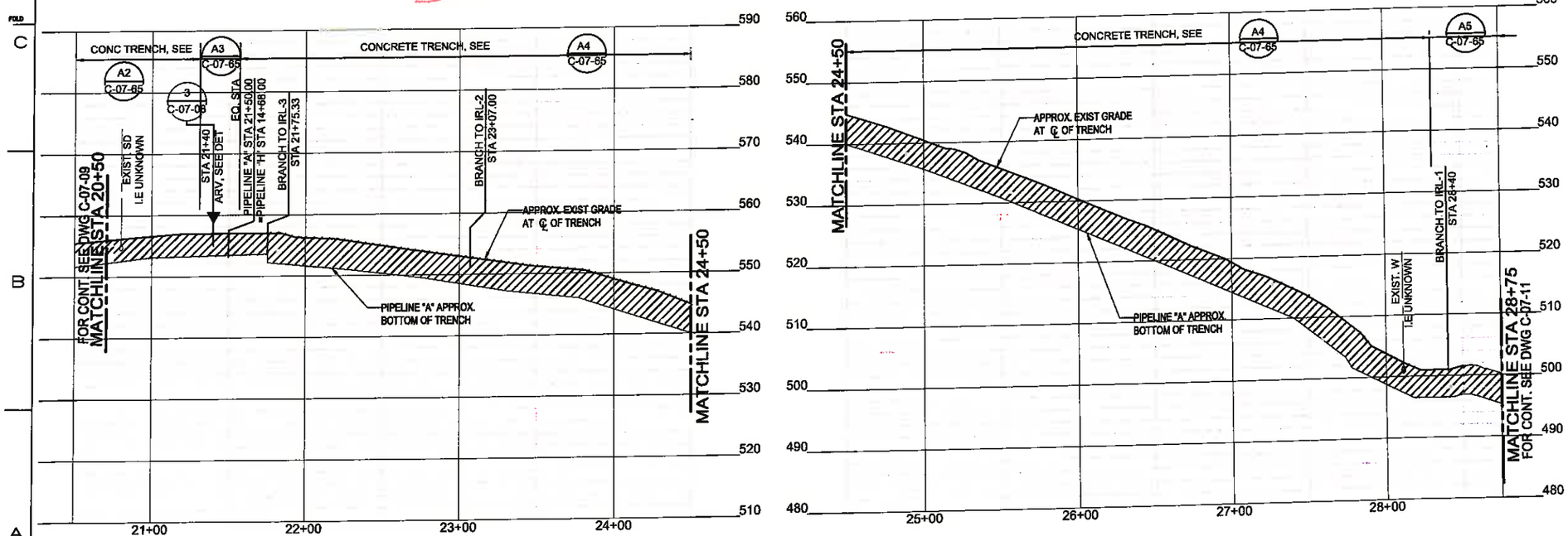
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NOTES

1. DEPTHS OF EXISTING UTILITIES ARE UNKNOWN. ALL POTENTIAL CONFLICTS BETWEEN NEW PIPE CONSTRUCTION AND EXISTING UTILITIES WILL BE POTHOLED PRIOR TO THE 100% DESIGN. A DETERMINATION WILL BE MADE WHETHER TO RELOCATE EXISTING UTILITIES OR RE-ROUTE NEW PIPE TRENCHES AROUND EXISTING UTILITIES. THIS WILL BE INCORPORATED INTO THE 100% DESIGN.
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9/38



HORZ: SCALE: 1"=40'-0"
VERT: SCALE: 1"=10'-0"

DRAFT
NOT FOR
CONSTRUCTION

E2 Consulting Engineers, Inc.

CH2MHILL.

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

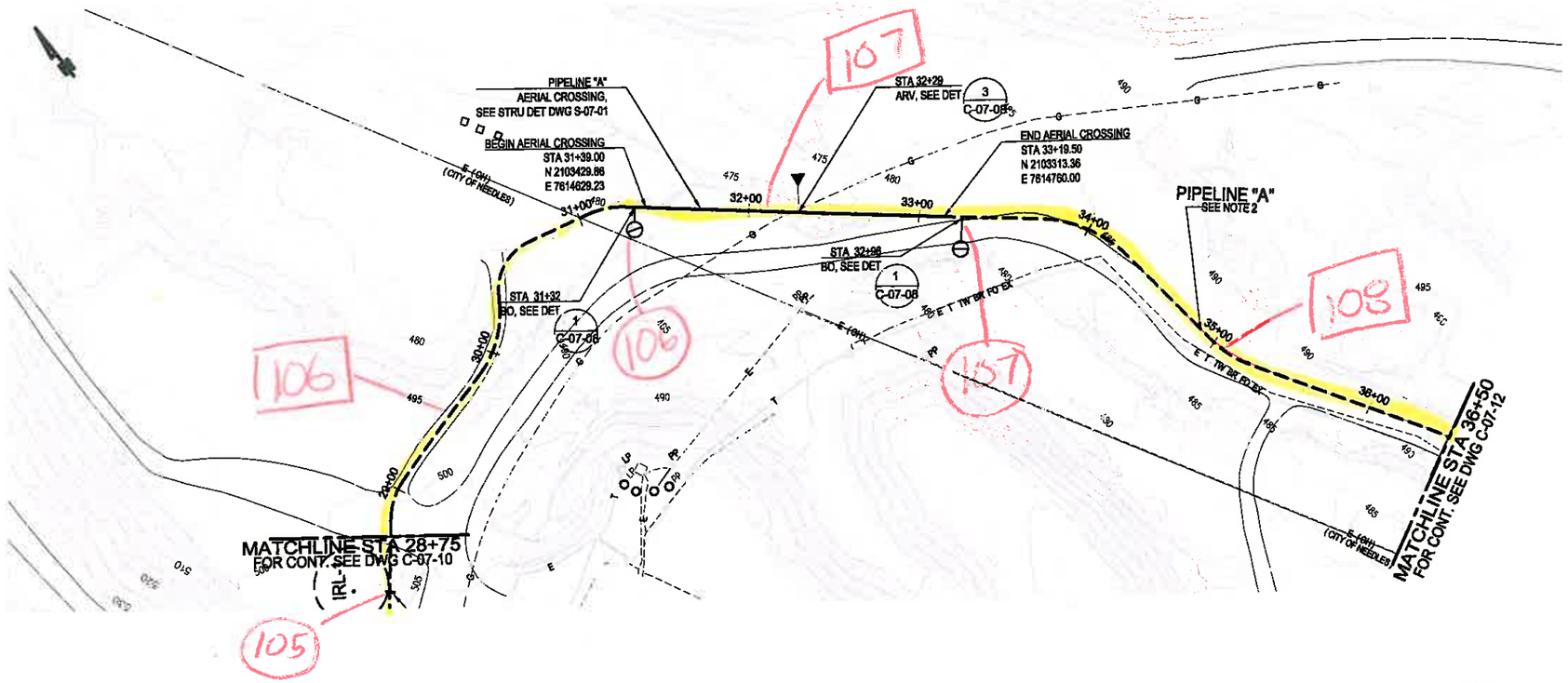
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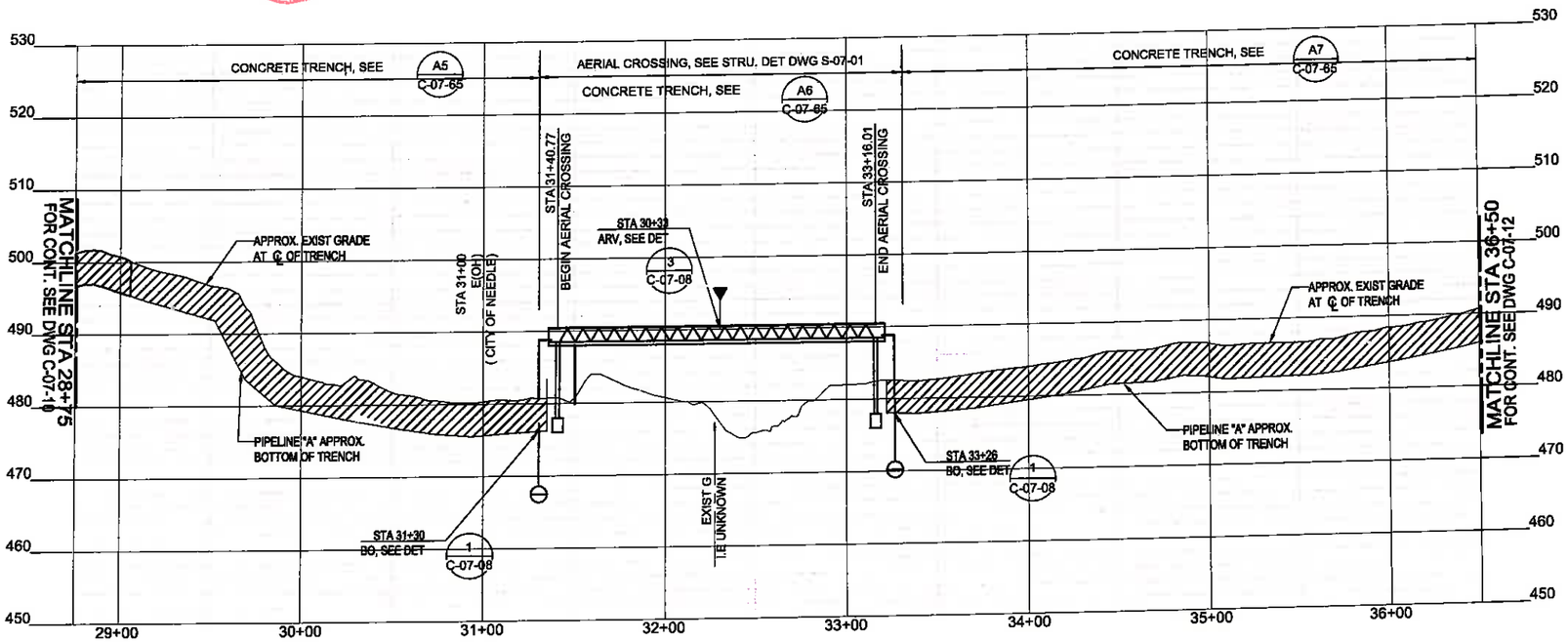
APPROVED BY	
SO	
SUPV	
DSGN	PT
DWN	PC/EE
CHKD	PT
OK	PT
DATE	9/12/12
SCALES	

TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE
PIPELINE "A"
STA 20+50 TO STA 28+75
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM	
BILL OF MATL	
DWG LIST	
SUPSDS	
SUPSD BY	
SHEET NO.	of SHEETS
C-07-10	REV

PLOT DATE: $PLOTDATE PLOT TIME: $PLOTTIME
FILENAME: E2-C-XXX-0710AD.dwg





10/38

NOTES

1. DEPTHS OF EXISTING UTILITIES ARE UNKNOWN. ALL POTENTIAL CONFLICTS BETWEEN NEW PIPE CONSTRUCTION AND EXISTING UTILITIES WILL BE POTHOLED PRIOR TO THE 100% DESIGN. A DETERMINATION WILL BE MADE WHETHER TO RELOCATE EXISTING UTILITIES OR RE-ROUTE NEW PIPE TRENCHES AROUND EXISTING UTILITIES. THIS WILL BE INCORPORATED INTO THE 100% DESIGN.
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HORZ. SCALE: 1"=40'-0"
VERT. SCALE: 1"=10'-0"

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CONSTRUCTION

E2 Consulting Engineers, Inc.

CH2MHILL.

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

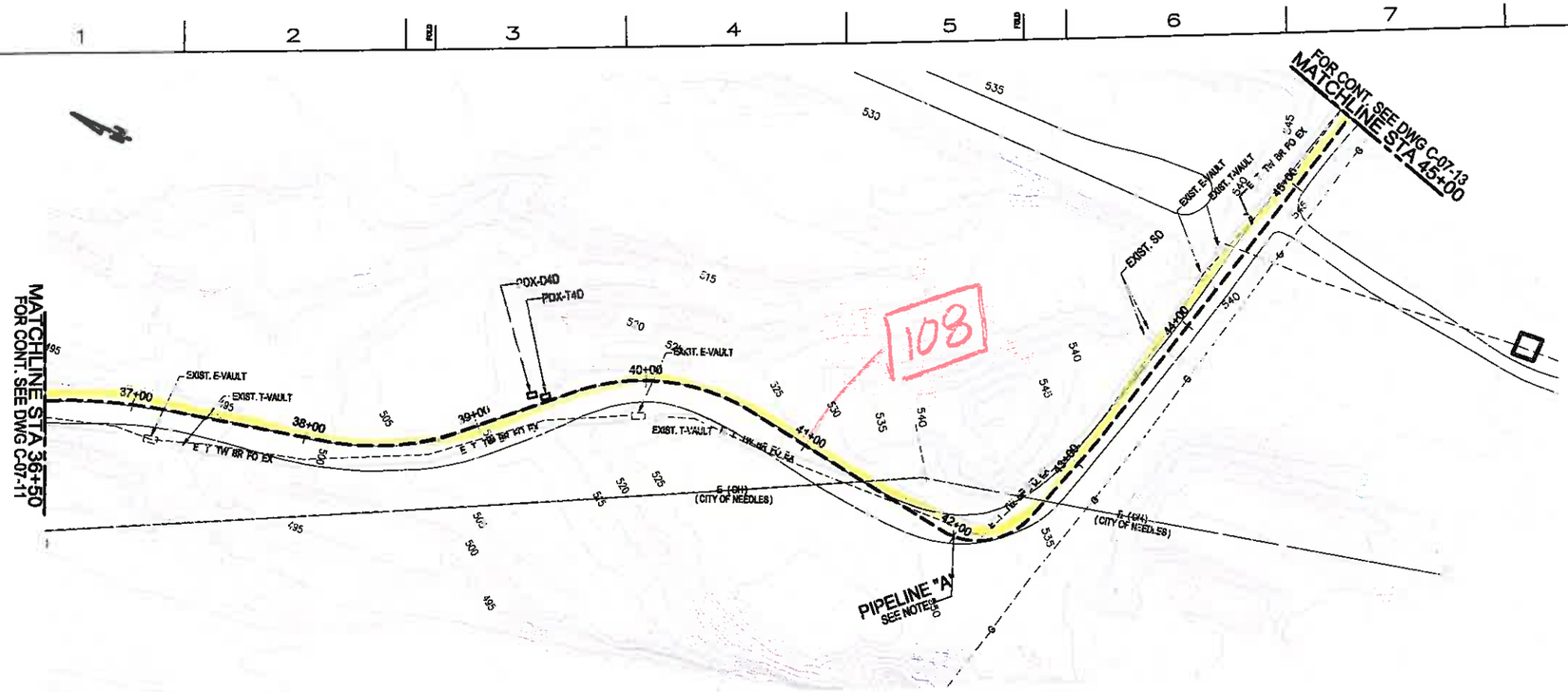
REVISIONS

APPROVED BY	
SO	
SUPV	
DSGN	PT
DWN	PG&E
CHKD	PT
QK	PT
DATE	9/12/12
SCALES	

TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE
PIPELINE "A"
STA 28+75 TO STA 36+50
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM	
BILL OF MATL	
DWG LIST	
SUPSDS	
SUPSD BY	
SHEET NO.	of SHEETS
C-07-11	REV

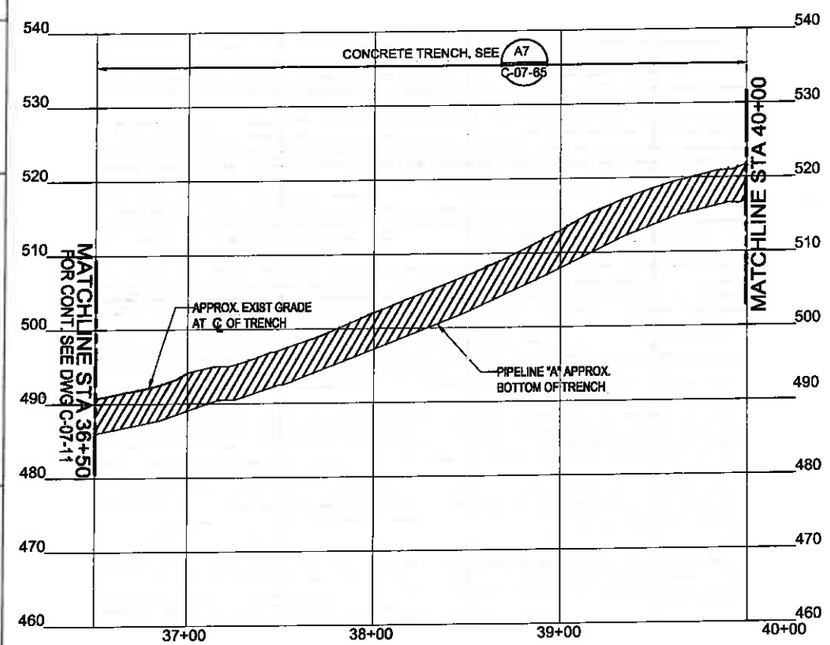
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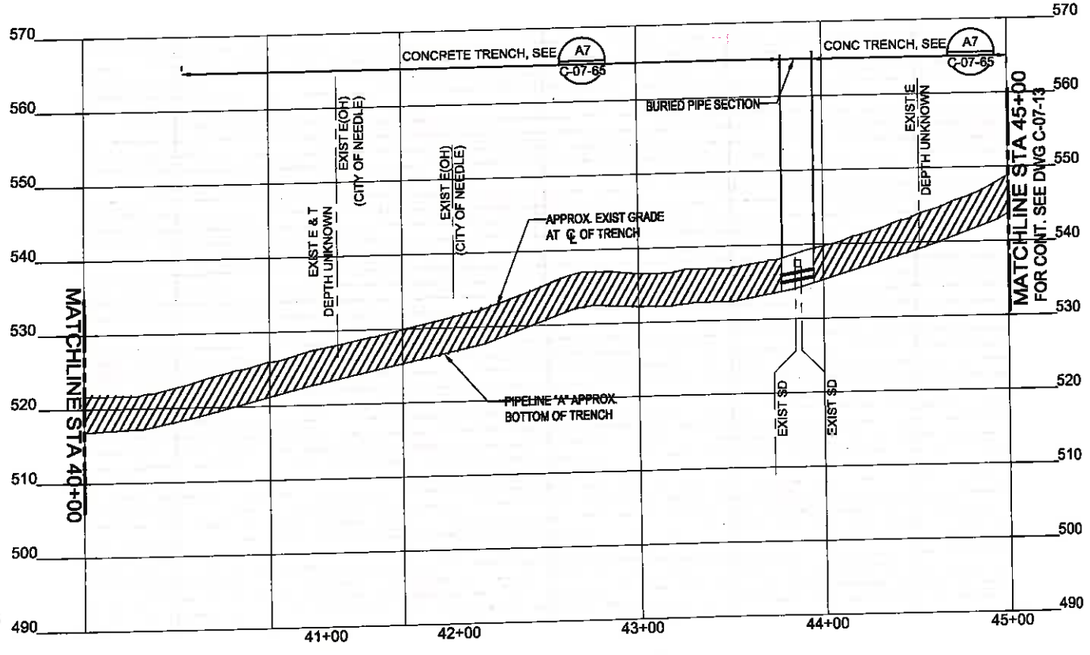


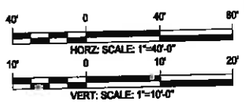
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NOTES

1. DEPTHS OF EXISTING UTILITIES ARE UNKNOWN. ALL POTENTIAL CONFLICTS BETWEEN NEW PIPE CONSTRUCTION AND EXISTING UTILITIES WILL BE POTHOLED PRIOR TO THE 100% DESIGN. A DETERMINATION WILL BE MADE WHETHER TO RELOCATE EXISTING UTILITIES OR RE-ROUTE NEW PIPE TRENCHES AROUND EXISTING UTILITIES. THIS WILL BE INCORPORATED INTO THE 100% DESIGN.
2. THE NEW PIPELINE ALIGNMENT SHOWS CENTER OF TRENCH. THE NUMBER AND SIZES OF PIPE IN EACH TRENCH VARIES. REFER TO PIPE SECTION NUMBER ON EACH PLAN AND PROFILE SHEET AND PIPE SCHEDULE ON DRAWING C-07-03 FOR NUMBER AND SIZE OF EACH PIPE. REFER TO TRENCH DETAILS ON DRAWINGS C-07-65, C-07-66 AND C-07-67 FOR ARRANGEMENT OF PIPING IN EACH TRENCH SECTION.







DRAFT NOT FOR CONSTRUCTION

E2 Consulting Engineers, Inc.

CH2MHILL.

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

REVISIONS

APPROVED BY	
SO	
SUPV	
DSGN	PT
DWN	PC/EE
CHKD	PT
OK	PT
DATE	9/12/12
SCALES	

TOPOCK GROUNDWATER REMEDIATION PROJECT

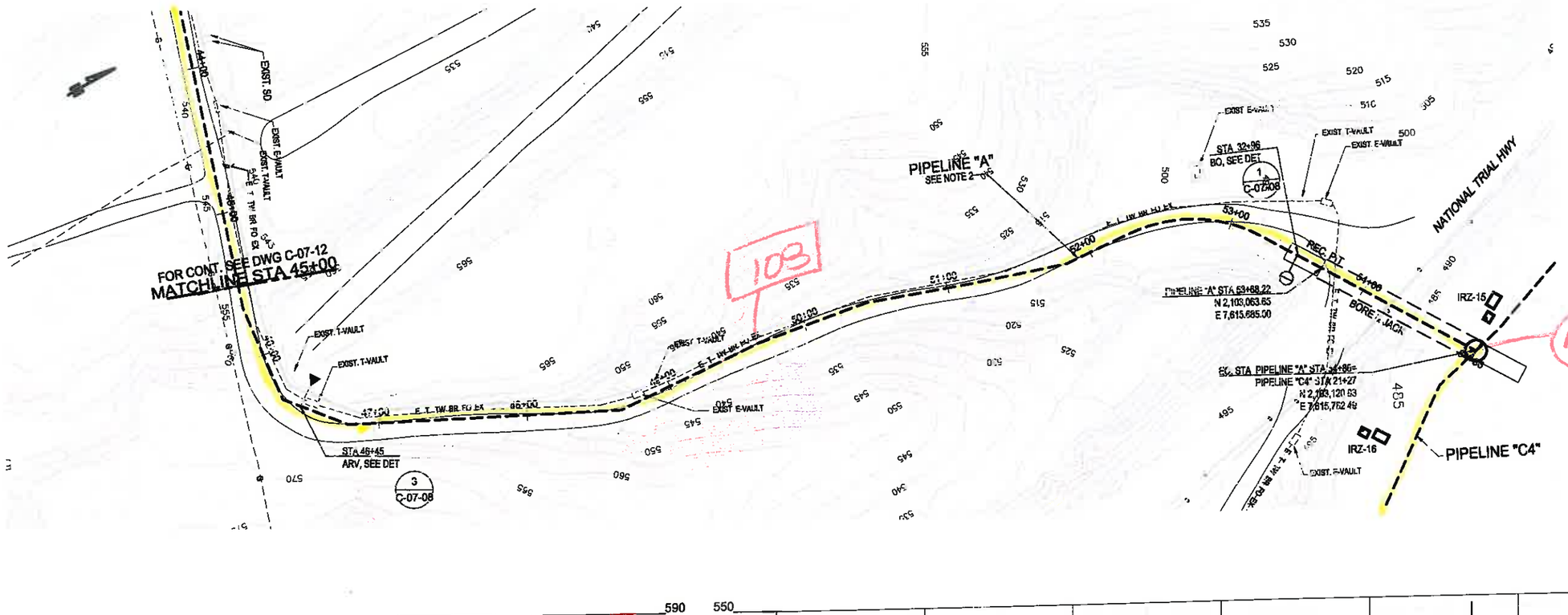
PLAN AND PROFILE
PIPELINE "A"
STA 36+50 TO STA 45+00

GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM	
BILL OF MATL	
DWG LIST	
SUPSDS	
SUPSD BY	
SHEET NO.	of SHEETS
C-07-12	REV

PLOT DATE: $PLOTDATE PLOT TIME: $PLOTTIME

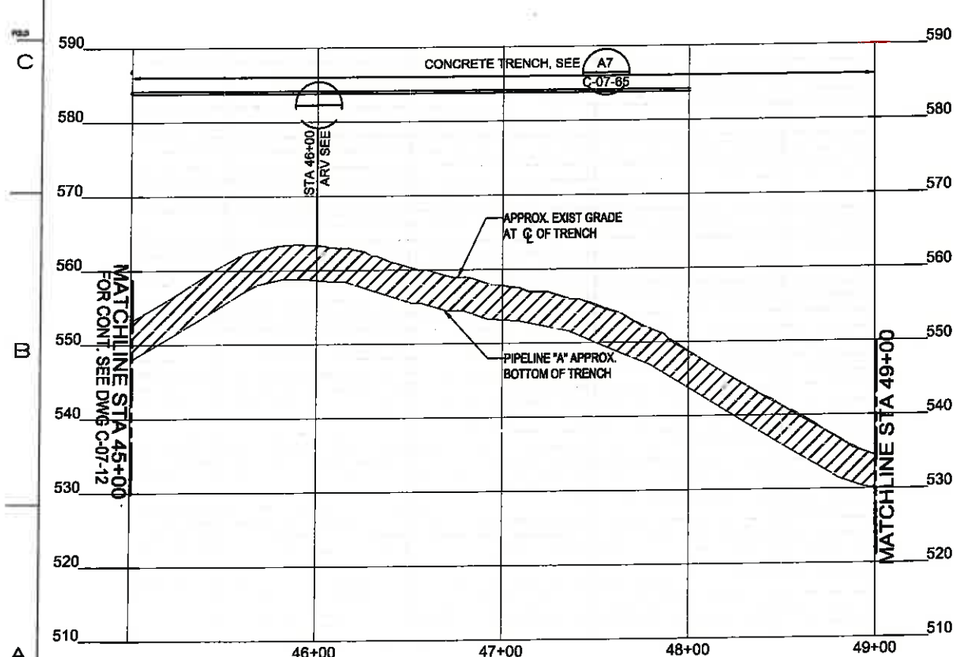
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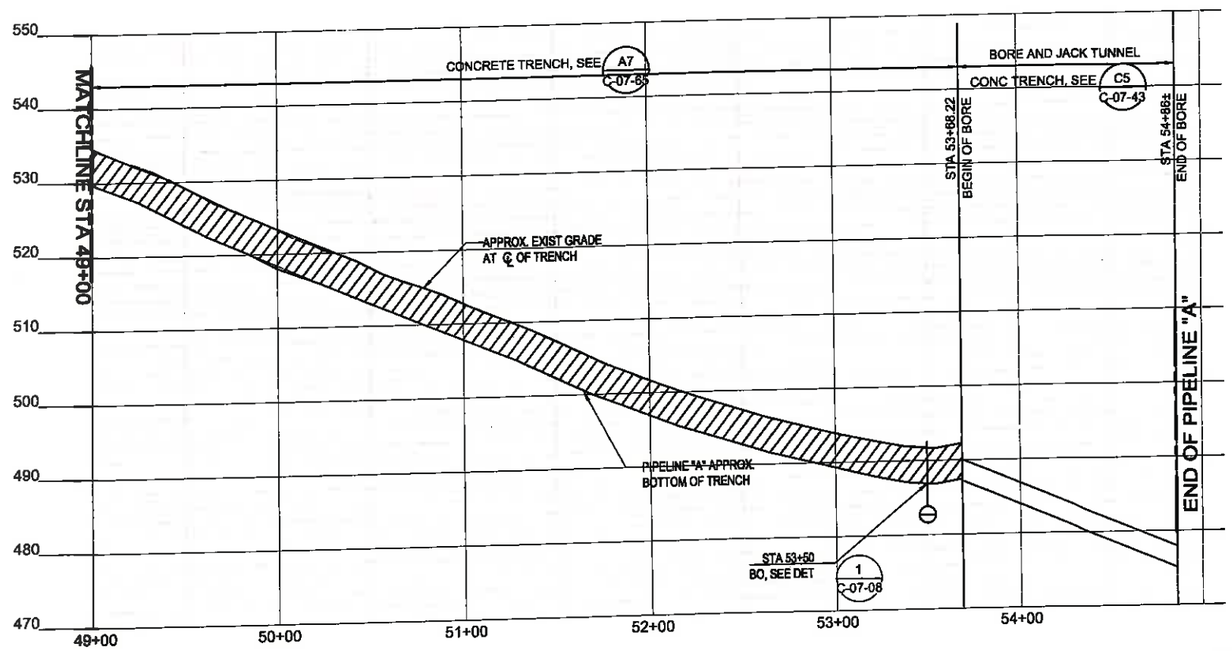


NOTES

1. DEPTHS OF EXISTING UTILITIES ARE UNKNOWN. ALL POTENTIAL CONFLICTS BETWEEN NEW PIPE CONSTRUCTION AND EXISTING UTILITIES WILL BE POTHOLED PRIOR TO THE 100% DESIGN. A DETERMINATION WILL BE MADE WHETHER TO RELOCATE EXISTING UTILITIES OR RE-ROUTE NEW PIPE TRENCHES AROUND EXISTING UTILITIES. THIS WILL BE INCORPORATED INTO THE 100% DESIGN.
2. THE NEW PIPELINE ALIGNMENT SHOWS CENTER OF TRENCH. THE NUMBER AND SIZES OF PIPE IN EACH TRENCH VARIES. REFER TO PIPE SECTION NUMBER ON EACH PLAN AND PROFILE SHEET AND PIPE SCHEDULE ON DRAWING C-07-03 FOR NUMBER AND SIZE OF EACH PIPE. REFER TO TRENCH DETAILS ON DRAWINGS C-07-65, C-07-66 AND C-07-67 FOR ARRANGEMENT OF PIPING IN EACH TRENCH SECTION.

HORZ: SCALE: 1"=40'-0"
VERT: SCALE: 1"=10'-0"





DRAFT
NOT FOR
CONSTRUCTION

E2 Consulting Engineers, Inc.

CH2MHILL®

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

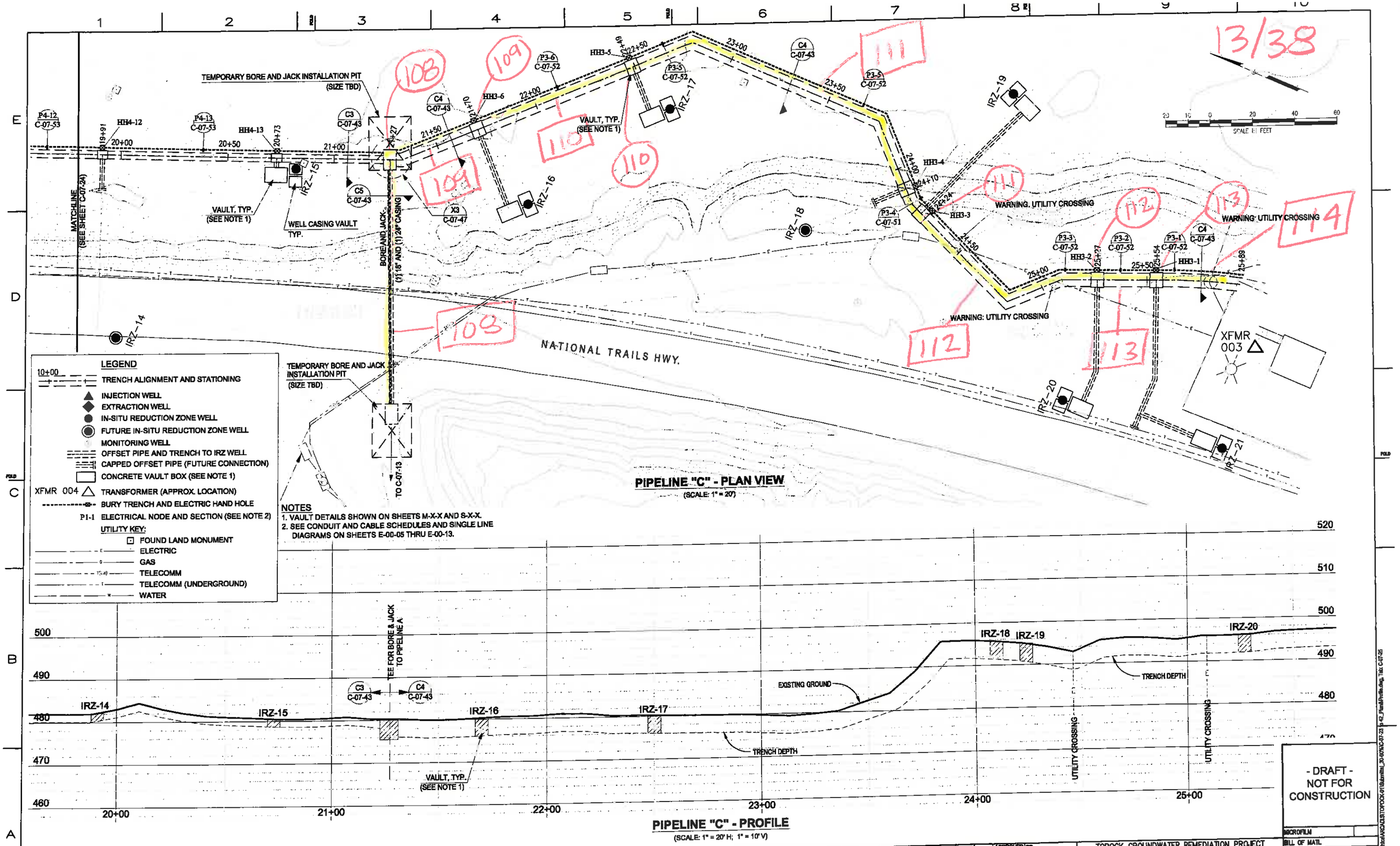
REVISIONS

APPROVED BY	
SO	
SUPV	
DSGN	PT
DWN	PC/EE
CHKD	PT
OK	PT
DATE	9/12/12
SCALES	

TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE
PIPELINE "A"
STA 45+00 TO STA 54+86
G.S. TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM	
BILL OF MATL	
DWG LIST	
SUPSDS	
SUPSD BY	
SHEET NO.	of SHEETS
C-07-13	REV

PLOT DATE: $PLOTDATE PLOT TIME: $PLOTTIME
FILENAME: E2-C-XXX-0713AD.dwg



- DRAFT - NOT FOR CONSTRUCTION

ETIC ENGINEERING

ARCADIS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL	AW	LD	JPB	JEF	

REVISIONS

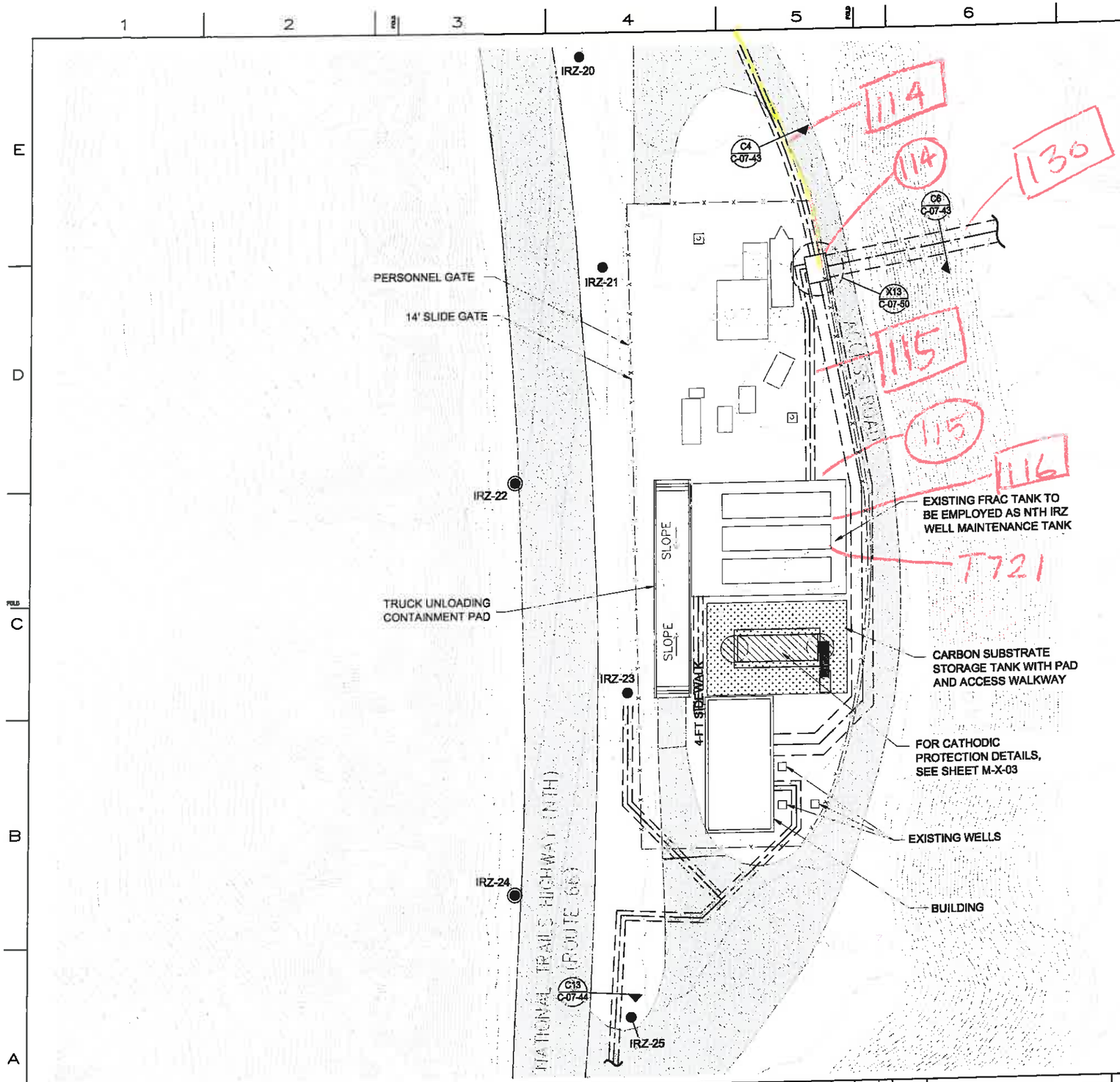
APPROVED BY	
JEF	SD
	SUPV JPB
	DSGN CJD
	DWN AW
	CHKD JPB
	OK JEF
	DATE 9/12/12
	SCALES 1" = 20'

TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE
PIPELINE "C3 & C4"
STA 19+60 TO STA 25+89
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. C-07-25 of SHEETS
REV

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14/38



NOTES:

1. ELECTRICAL HAZARD CLASSIFICATIONS:
   - A. CLASS I, DIV I WITHIN A 5-FT RADIUS OF THE CARBON STORAGE TANK VENTS.
   - B. CLASS I, DIV II WITHIN A 10-FT RADIUS OF THE CARBON STORAGE TANK VENTS (FROM VENT ELEVATION TO GROUND).
   - C. CLASS I, DIV II FROM GROUND SURFACE TO 18-INCHES ABOVE GRADE WITHIN A 10-FT RADIUS OF THE TANK FOOTPRINT.
   - D. CLASS I, DIV II WITHIN THE CARBON AMENDMENT BUILDING WHERE DOSING LINES CONTAIN >10% EtOH, FIRE RATED WALLS MAY BE USED TO MINIMIZE THE FOOTPRINT OF THE CLASSIFIED AREA.
   - E. CLASS I, DIV II WITHIN A 10-FT RADIUS OF THE VENTS OF THE EQUIVALENT HAZ CLASS LOCATIONS WITHIN THE BUILDING.
2. CARBON AMENDMENT AND WELL MAINTENANCE BUILDING FOUNDATIONS INCLUDE A 6" CONCRETE CURB TO PROVIDE SECONDARY CONTAINMENT FOR PROCESSES WITHIN BUILDINGS.
3. ENTIRE NTH IRZ FACILITY WILL BE ENCLOSED WITHIN A SECURITY FENCE TO BE FULLY SHOWN IN LATER DRAWING SET REVISIONS.

LEGEND

- CLASS I, DIV I
- CLASS I, DIV II
- FENCE
- IN-SITU REDUCTION ZONE WELL
- FUTURE IN-SITU REDUCTION ZONE WELL
- NEW PIPE ALIGNMENT

20 10 0 20 40 60
SCALE IN FEET

- DRAFT - NOT FOR CONSTRUCTION

ETIC ENGINEERING

ARCADIS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

APPROVED BY	
JEF	SO
	SUPV JPB
	DSGN KLD
	DWN AJW
	CHKD JPC
	OK JEF
	DATE 9/12/12
	SCALES 1" = 20'

TOPOCK GROUNDWATER REMEDIATION PROJECT

MW-20 BENCH YARD PIPING PLAN

GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM	
BILL OF MATL	
DWG LIST	
SUPSDS	
SUPSD BY	
SHEET NO.	of SHEETS
C-06-03	REV

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15/38

SCADA
PLC NODE 2
LOCAL PANEL
FIELD
SEE NOTE 1

*LAH 75X
*LAL 755
*LAH 755
HOA HS XXX
*LALL 75X
*LAL 75X
*LAH 75X
*LAHH 75X
HOA HS SC XXX 0-100%
*YI 74X
*FIQR 77X
*FIQ 77X
*FIR 77X
*FI 77X
HOA HS XXX
*YI 731
*ZO 731
*ZC 731
*XX XXX
*FAH 781

LIMITS OF SECONDARY CONTAINMENT
LIMITS OF IRZ WELL MAINTENANCE ROOM

WELL MAINT. REAGENT TANKER
VENT TO ATMOSPHERE
REAGENT FILL PIPE LEAK DETECTION
*LS 755
*V720A
*V720B
DRY BREAK QUICK CONNECT
SECONDARY CONTAINMENT
I-02-01 FRESHWATER
*V725A
*V725B
*FV729
*FE 777
*FIT 777
*E722
*V720C
*V720D
*FE 778
*FIT 778
*FV730
*V725C
*V725D
*V725E
*V725F
*FS 781
EYEWASH STATION
*LT 759
*LE 759
*V720E
SEE NOTE 2
*T719
IRZ WELL MAINT. REAGENT DAY TANK
OVERPRESSURE BYPASS
*LS 749
LEAK DETECTION
*V720H
*F722
*V720G
*V720I
*V720F
*V729C
*PS 788
*P743
WELL MAINTENANCE REAGENT HOSE PUMP
0-100 PSI *PI 760D
SAMPLE PORT
*V729B
*V729A
*FIT 779
*FE 779
*FV731
*PIT 761
*PE 761
*V720J
*V720K
I-06-01 WELL MAINTENANCE REAGENT

NOTE:
DO NOT ENERGIZE FLOW METER UNTIL FLOW HAS BEEN ESTABLISHED

NOTES
1. SIMILAR FOR EACH TYPE OF INSTRUMENT.
2. FLOAT VALVE PROVIDES MECHANICAL SHUT-OFF AT 90% OF TANK CAPACITY.
3. TAG NUMBER "**" IS A PLACEHOLDER FOR THE STATION SCADA ID. THE LOCATION ID FOR THE NTH IRZ CARBON AMENDMENT BUILDING IS "IRZ00-". EXCHANGE "IRZ00-" FOR "**" TO COMPLETE TAG OR INSTRUMENT REFERENCE.
4. SEE SHEET I-00-03 FOR INTERLOCK TABLE.

*P747
*V728C
*V728D
*LS 748
TRUCK OFFLOAD SUMP
*V728E
*V728F
CLEAN IN PLACE REAGENT
*V728H
*V728G
I-06-01 CLEAN IN PLACE RETURN
*V728I
*V728J
I-04-03 BACKWASH IRL AND NORTH IRZ LEG IRZ 1-22
*V728K
*V728L
I-04-02 BACKWASH RETURN AND SOUTH IRZ LEG IRZ 24-40
*V728M
*V728N
I-14-02 CONDITIONED WATER
*V728B
*V728A
*LT 758
*LE 758
*T723
CLEAN-IN-PLACE FRAC TANK (EXISTING)
*LT 757
*LE 757
*T721
BACKWASH FRAC TANK (EXISTING)
*LT 756
*LE 756
*T720
CONDITIONED WATER FRAC TANK (EXISTING)
SECONDARY CONTAINMENT (EXISTING)

OVERPRESSURE BYPASS
*FV732
*PS 789A
*V726N
*V726M
*V726G
*V726H
*V726E
*V726F
*P744
CLEAN-IN-PLACE REAGENT PUMP
*PI 760F 0-100 PSI
*PI 760G 0-100 PSI
*FIT 780
*FE 780
SUMP PUMP *P746
*V727F
*V727G
*V726I
*V727E
I-06-01 CLEAN-IN-PLACE
I-11-01 REMEDY PRODUCED WATER CONDITIONING PLANT
*FV733
*V727B
*V727A
*PS 789B
SAMPLE PORT
*V727C
*V727D
*P745
PRODUCED WATER TRANSFER PUMP
*V726D
*V726J
*V726K
*V726L
DRY BREAK QUICK CONNECT
TANKER TRUCK
TANKER TRUCK OFFSITE DISPOSAL
SECONDARY CONTAINMENT

- DRAFT - NOT FOR CONSTRUCTION

ETIC ENGINEERING
ARCADIS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
J	3/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL	AW	MWM	JPJ	JEF	

REVISIONS

APPROVED BY: JEF
SD
SUPV JPJ
DSGN MWM
DWN AW
CHKD JPJ
QC JEF
DATE 3/12/12
SCALES NONE

TOPOCK GROUNDWATER REMEDIATION PROJECT
IRZ CARBON AMENDMENT BUILDING P&ID SHEET 2 OF 2
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. of SHEETS
I-06-02
REV

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16/38

NATIONAL TRAILS HWY.

MATCHLINE (SEE SHEET C-07-25)

C4 C-07-43

25+89

VAULT, TYP. (SEE NOTE 1)

XFMR 003

WELL CASING VAULT TYP.

IRZ-21

IRZ-22

26+00

26+50

27+00

27+50

C6 C-07-43

P3-13 C-07-52

WARNING: UTILITY CROSSING

X13 C-07-50

(FOR CONTINUATION SEE SHEET C-07-03)

G4 C-07-46

10+50

MATCHLINE (SEE SHEET C-07-40)

P3-14 C-07-52

HH3-13

28+00

28+16

130

C7 C-07-43

28+50

X4 C-07-47

29+00

WARNING: UTILITY CROSSING

29+30

MATCHLINE (SEE SHEET C-07-28)

PIPELINE "C" - PLAN VIEW
(SCALE: 1" = 20')

LEGEND

- 10+00 — TRENCH ALIGNMENT AND STATIONING
- INJECTION WELL
- EXTRACTION WELL
- IN-SITU REDUCTION ZONE WELL
- FUTURE IN-SITU REDUCTION ZONE WELL
- MONITORING WELL
- OFFSET PIPE AND TRENCH TO IRZ WELL
- CAPPED OFFSET PIPE (FUTURE CONNECTION)
- CONCRETE VAULT BOX (SEE NOTE 1)
- XFMR 004 — TRANSFORMER (APPROX. LOCATION)
- BURY TRENCH AND ELECTRIC HAND HOLE
- P1-1 — ELECTRICAL NODE AND SECTION (SEE NOTE 2)

UTILITY KEY:

- FOUND LAND MONUMENT
- E — ELECTRIC
- G — GAS
- T(xx) — TELECOMM
- T — TELECOMM (UNDERGROUND)
- W — WATER

NOTES
1. VAULT DETAILS SHOWN ON SHEETS M-X-X AND S-X-X.
2. SEE CONDUIT AND CABLE SCHEDULES AND SINGLE LINE DIAGRAMS ON SHEETS E-00-05 THRU E-00-13.

20 10 0 20 40 60
SCALE IN FEET

520
510
500
490
480
470
460
450
440

ELECTRIC VAULT
UTILITY CROSSING
TEE TO PIPELINE G
C6 C-07-43
C7 C-07-43
ELECTRIC VAULT
UTILITY CROSSING
EXISTING GROUND
TRENCH DEPTH
Vault, Typ. (See Note 1)

26+00 27+00 28+00 29+00

PIPELINE "C" - PROFILE
(SCALE: 1" = 20' H; 1" = 10' V)

- DRAFT - NOT FOR CONSTRUCTION

ETIC ENGINEERING

ARCADIS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL	AJW	KLD	JPB	JEF	

REVISIONS

APPROVED BY	
SO	
SUPV	JPB
DSGN	KLD
DWN	AJW
CHKD	JPB
OK	JEF
DATE	9/12/12
SCALES	1" = 20'

TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE
PIPELINE "C6 & C7"
STA 26+00 TO STA 29+50
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM	
BILL OF MATL	
DWG LIST	
SUPSDS	
SUPSD BY	
SHEET NO.	of SHEETS
C-07-27	REV

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LEGEND

- 10+00 — TRENCH ALIGNMENT AND STATIONING
- INJECTION WELL
- EXTRACTION WELL
- IN-SITU REDUCTION ZONE WELL
- FUTURE IN-SITU REDUCTION ZONE WELL
- MONITORING WELL
- OFFSET PIPE AND TRENCH TO IRZ WELL
- CAPPED OFFSET PIPE (FUTURE CONNECTION)
- CONCRETE VAULT BOX (SEE NOTE 1)
- XFMR 004 — TRANSFORMER (APPROX. LOCATION)
- BURY TRENCH AND ELECTRIC HAND HOLE
- P1-1 — ELECTRICAL NODE AND SECTION (SEE NOTE 2)
- UTILITY KEY:
  - FOUND LAND MONUMENT
  - ELECTRIC
  - GAS
  - TELECOMM
  - TELECOMM (UNDERGROUND)
  - WATER

NOTES

1. VAULT DETAILS SHOWN ON SHEETS M-X-X AND S-X-X.
2. SEE CONDUIT AND CABLE SCHEDULES AND SINGLE LINE DIAGRAMS ON SHEETS E-00-05 THRU E-00-13.

17/38

130

BNSF RAILROAD

SWALE

MATCHLINE (SEE SHEET C-07-27)

MATCHLINE (SEE SHEET C-07-41)

MATCHLINE (SEE SHEET C-07-29)

MATCHLINE (SEE SHEET C-07-32)

VAULT, TYP. (SEE NOTE 1)

HH2-14

HH2-13

HH2-12

P2-14 C-07-51

P2-13 C-07-51

P2-12 C-07-51

G6 C-07-46

X5 C-07-48

X6 C-07-48

C7 C-07-43

C8 C-07-44

C9 C-07-44

C14 C-07-45

SCALE IN FEET

PIPELINE "C" - PLAN VIEW

(SCALE: 1" = 20')

TEE TO PIPELINE G

TEE TO C14

BNSF RAILROAD

EXISTING GROUND

TRENCH DEPTH

VAULT, TYP. (SEE NOTE 1)

PIPELINE "C" - PROFILE

(SCALE: 1" = 20' H; 1" = 10' V)

- DRAFT - NOT FOR CONSTRUCTION

ETIC ENGINEERING

ARCADIS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	6/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL	AW	KLD	JPB	JEF	

REVISIONS

APPROVED BY: JEF

SD	
SUPV	JPB
DSGN	KLD
DWN	AW
CHKD	JPB
OK	JEF
DATE	9/12/12
SCALES	1" = 20'

TOPOCK GROUNDWATER REMEDIATION PROJECT

PLAN AND PROFILE
PIPELINE "C7, C8 & C9"
STA 26+50 TO 35+60

GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

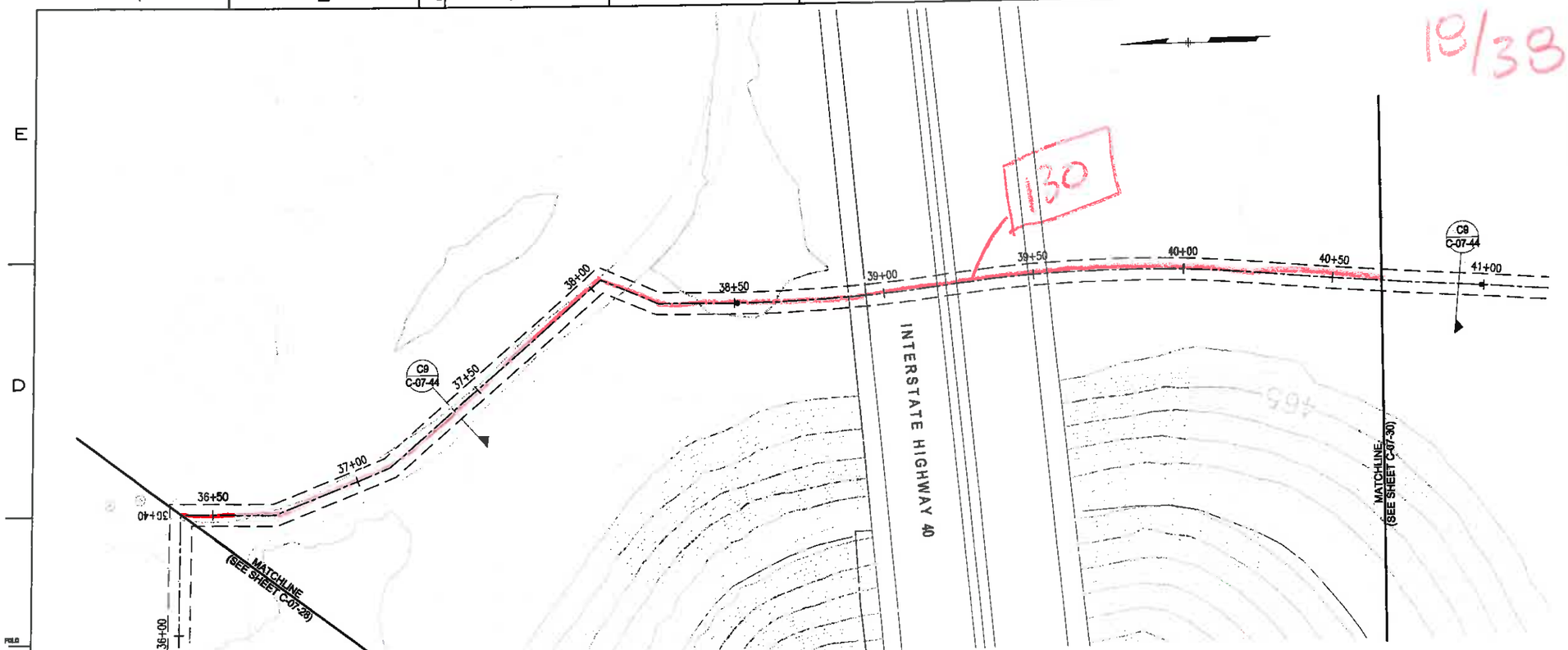
MICROFILM	
BILL OF MATL	
DWG LIST	
SUPSDS	
SUPSD BY	
SHEET NO.	of SHEETS

C-07-28 REV

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19/33

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PIPELINE "C" - PLAN VIEW
(SCALE: 1" = 20')

LEGEND

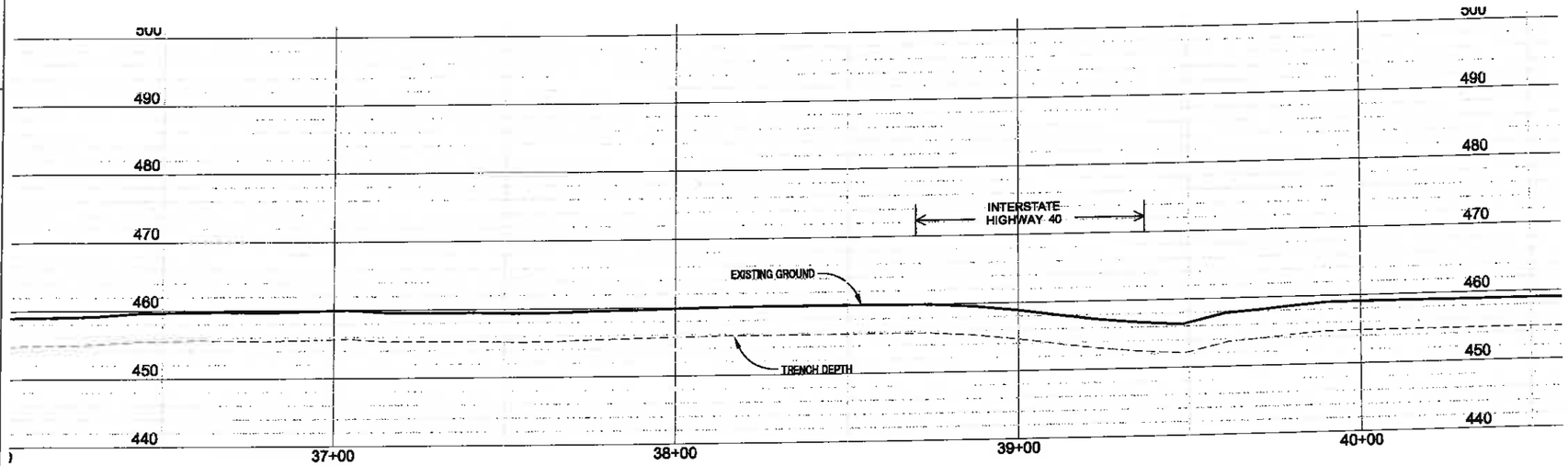
- 10+00 — TRENCH ALIGNMENT AND STATIONING
- INJECTION WELL
- EXTRACTION WELL
- IN-SITU REDUCTION ZONE WELL
- FUTURE IN-SITU REDUCTION ZONE WELL
- MONITORING WELL
- OFFSET PIPE AND TRENCH TO IRZ WELL
- CAPPED OFFSET PIPE (FUTURE CONNECTION)
- CONCRETE VAULT BOX (SEE NOTE 1)
- XFMR 004 — TRANSFORMER (APPROX. LOCATION)
- BURY TRENCH AND ELECTRIC HAND HOLE
- P1-1 — ELECTRICAL NODE AND SECTION (SEE NOTE 2)

UTILITY KEY:

- FOUND LAND MONUMENT
- E — ELECTRIC
- G — GAS
- T(OH) — TELECOMM
- T — TELECOMM (UNDERGROUND)
- W — WATER

NOTES
1. VAULT DETAILS SHOWN ON SHEETS M-X-X AND S-X-X.
2. SEE CONDUIT AND CABLE SCHEDULES AND SINGLE LINE DIAGRAMS ON SHEETS E-00-05 THRU E-00-13.

20 10 0 20 40 60
SCALE IN FEET



PIPELINE "C" - PROFILE
(SCALE: 1" = 20' H; 1" = 10' V)

ETIC ENGINEERING

ARCADIS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL	JW	KLD	JPB	JEF	

REVISIONS

APPROVED BY: JEF

SO	
SUPV	JPB
DSGN	KLD
DWN	AJW
CHKD	JPB
OK	JEF
DATE	9/12/12
SCALES	1" = 20'

TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE
PIPELINE "C9"
STA 36+40 TO STA 40+60
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

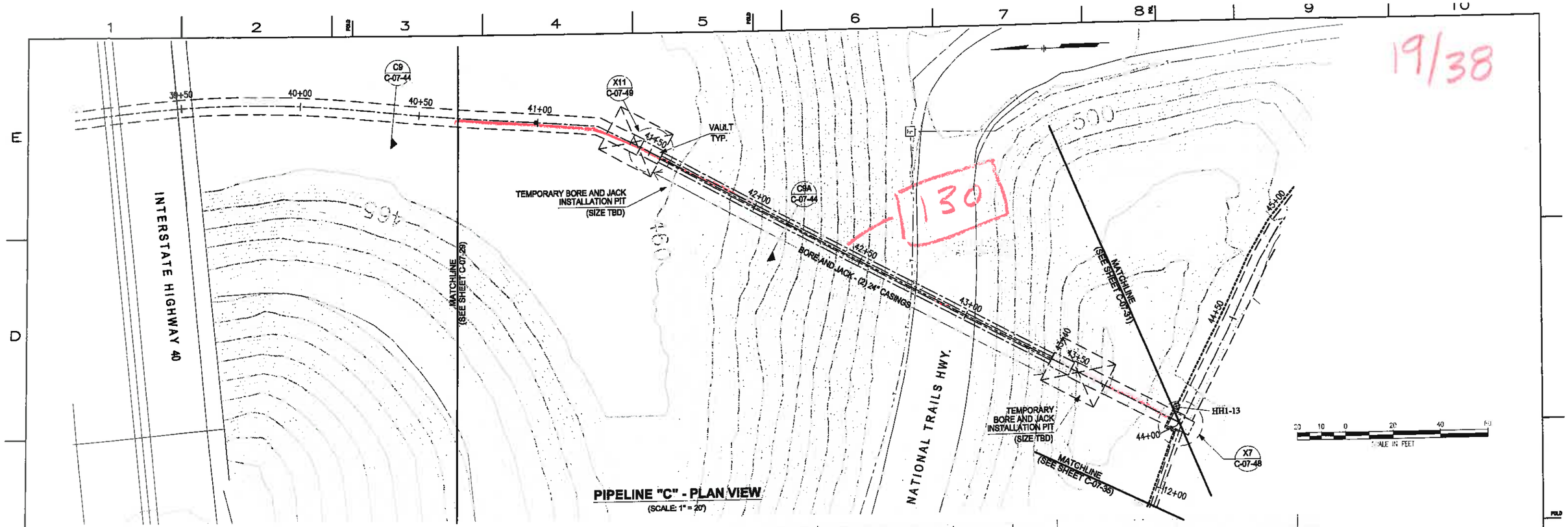
- DRAFT -
NOT FOR CONSTRUCTION

MICROFILM	
BILL OF MATL	
DWG LIST	
SUPSDS	
SUPSD BY	
SHEET NO.	of SHEETS
C-07-29	REV

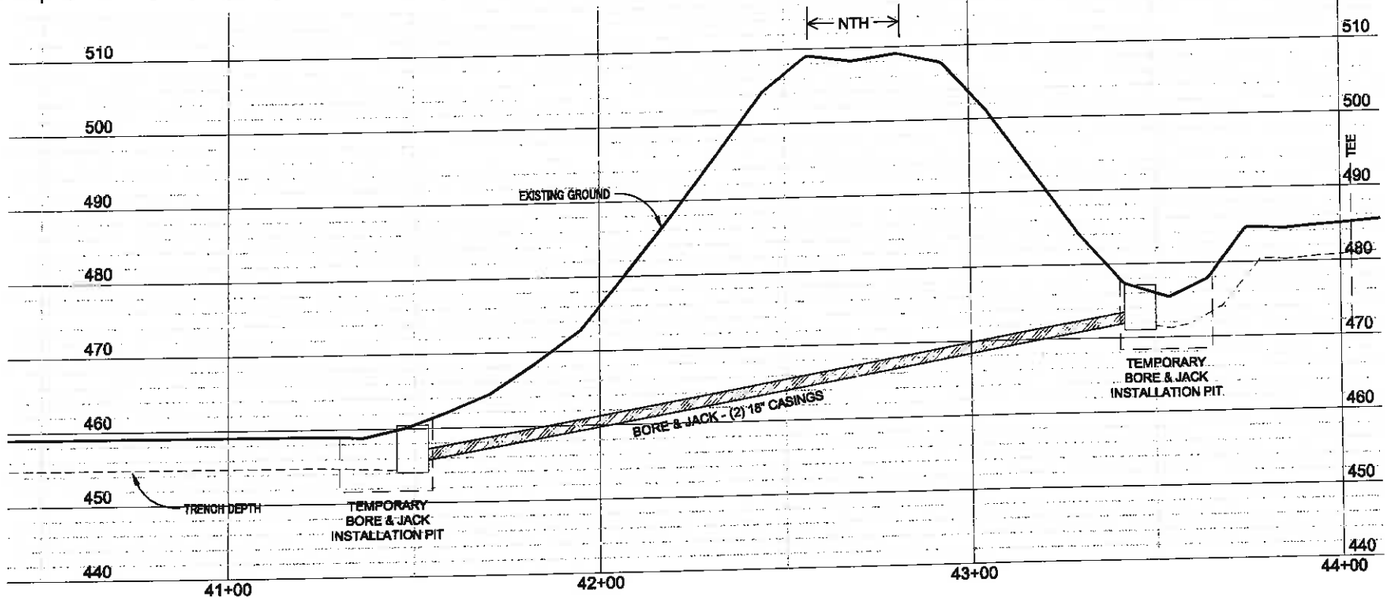
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19/38

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PIPELINE "C" - PLAN VIEW
(SCALE: 1" = 20')



PIPELINE "C" - PROFILE
(SCALE: 1" = 20' H; 1" = 10' V)

LEGEND

- 10+00 — TRENCH ALIGNMENT AND STATIONING
- INJECTION WELL
- EXTRACTION WELL
- IN-SITU REDUCTION ZONE WELL
- FUTURE IN-SITU REDUCTION ZONE WELL
- MONITORING WELL
- OFFSET PIPE AND TRENCH TO IRZ WELL
- CAPPED OFFSET PIPE (FUTURE CONNECTION)
- CONCRETE VAULT BOX (SEE NOTE 1)
- XFMR 004 — TRANSFORMER (APPROX. LOCATION)
- BURY TRENCH AND ELECTRIC HAND HOLE
- P1-1 — ELECTRICAL NODE AND SECTION (SEE NOTE 2)

UTILITY KEY:

- FOUND LAND MONUMENT
- E — ELECTRIC
- G — GAS
- TCOM — TELECOMM
- T — TELECOMM (UNDERGROUND)
- W — WATER

NOTES

1. VAULT DETAILS SHOWN ON SHEETS M-X-X AND S-X-X.
2. SEE CONDUIT AND CABLE SCHEDULES AND SINGLE LINE DIAGRAMS ON SHEETS E-00-05 THRU E-00-13.

ETIC ENGINEERING

ARCADIS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (50%) DESIGN SUBMITTAL	AJW	KLD	JPB	JEF	JEF

REVISIONS

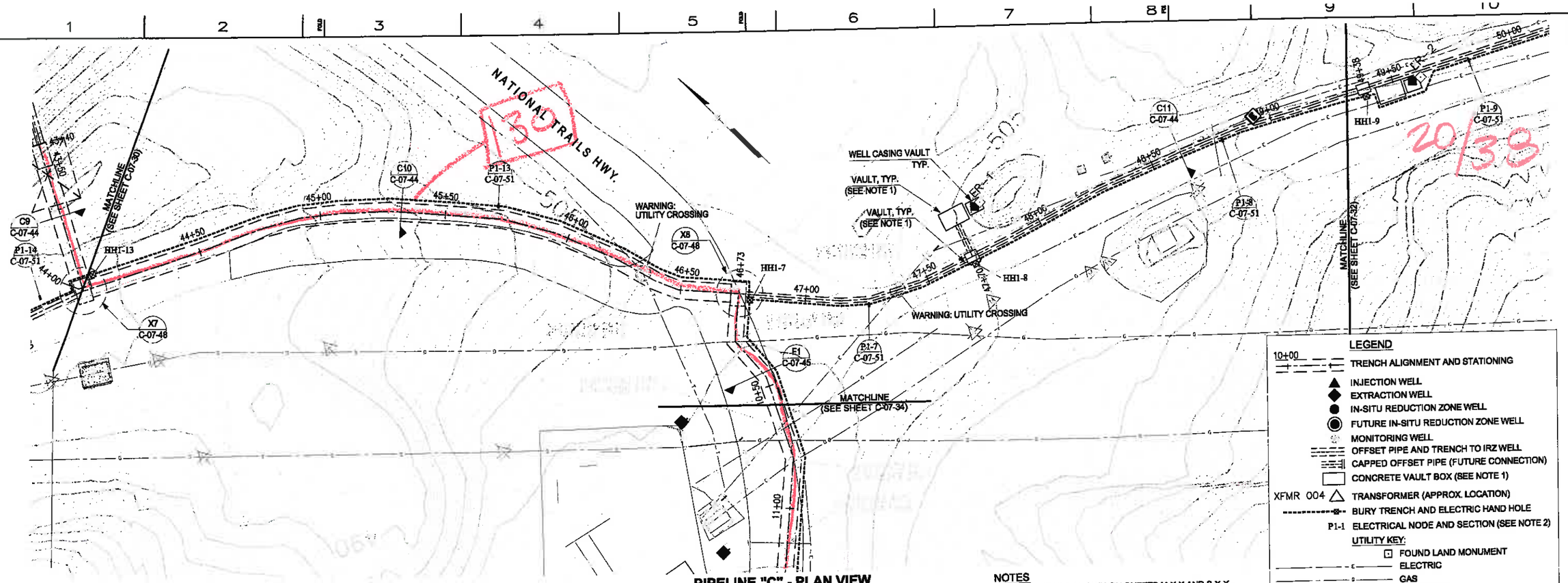
APPROVED BY	
SD	
SUPV	JPB
DSGN	KLD
DWN	AJW
CHKD	JPB
QK	JEF
DATE	9/12/12
SCALES	1" = 20'

TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE
PIPELINE "C9A"
STA 40+60 TO STA 44+00
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

- DRAFT -
NOT FOR
CONSTRUCTION

MICROFILM	
BILL OF MATL	
DWG LIST	
SUPSDS	
SUPSD BY	
SHEET NO.	of SHEETS
C-07-30	REV

05/11/2012, 08:48, d:\Compton\MXD\ESTOPOCK-01\Submittal_50-60%\C-07-30 (E-42, Plan&Profile).dwg, Tab: C-07-30

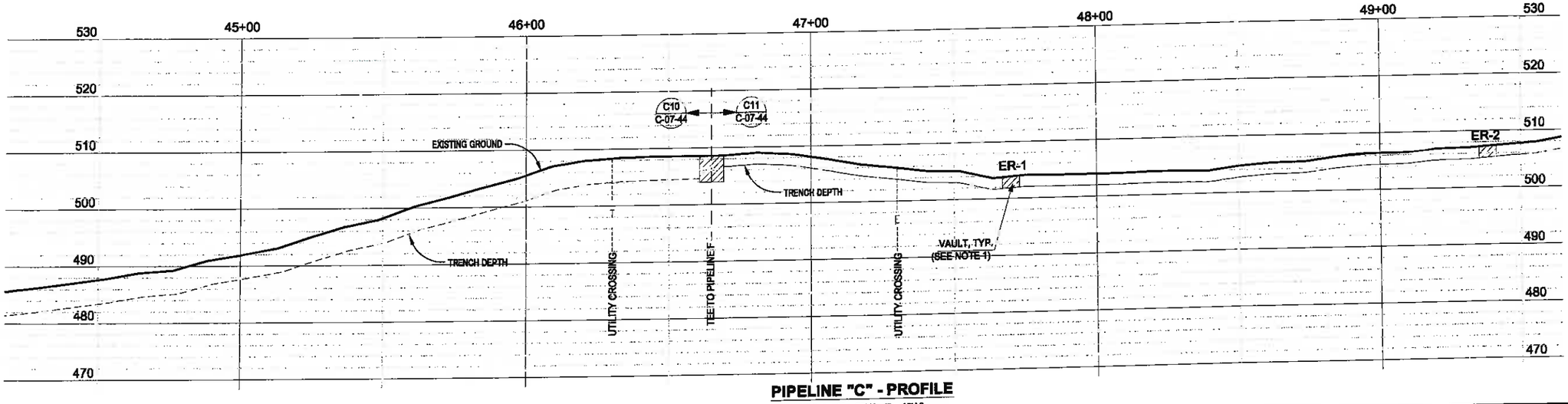


PIPELINE "C" - PLAN VIEW
(SCALE: 1" = 20')

NOTES
1. VAULT DETAILS SHOWN ON SHEETS M-X-X AND S-X-X.
2. SEE CONDUIT AND CABLE SCHEDULES AND SINGLE LINE DIAGRAMS ON SHEETS E-00-05 THRU E-00-13.

LEGEND
- TRENCH ALIGNMENT AND STATIONING (10+00)
- INJECTION WELL
- EXTRACTION WELL
- IN-SITU REDUCTION ZONE WELL
- FUTURE IN-SITU REDUCTION ZONE WELL
- MONITORING WELL
- OFFSET PIPE AND TRENCH TO IRZ WELL
- CAPPED OFFSET PIPE (FUTURE CONNECTION)
- CONCRETE VAULT BOX (SEE NOTE 1)
- XFMR 004 TRANSFORMER (APPROX. LOCATION)
- BURY TRENCH AND ELECTRIC HAND HOLE
- P1-1 ELECTRICAL NODE AND SECTION (SEE NOTE 2)

UTILITY KEY:
- FOUND LAND MONUMENT
- ELECTRIC
- GAS
- TELECOMM
- TELECOMM (UNDERGROUND)
- WATER



PIPELINE "C" - PROFILE
(SCALE: 1" = 20' H; 1" = 10' V)

- DRAFT - NOT FOR CONSTRUCTION

ETIC ENGINEERING | ARCADIS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	7/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL	AJW	MLD	JPB	JEF	

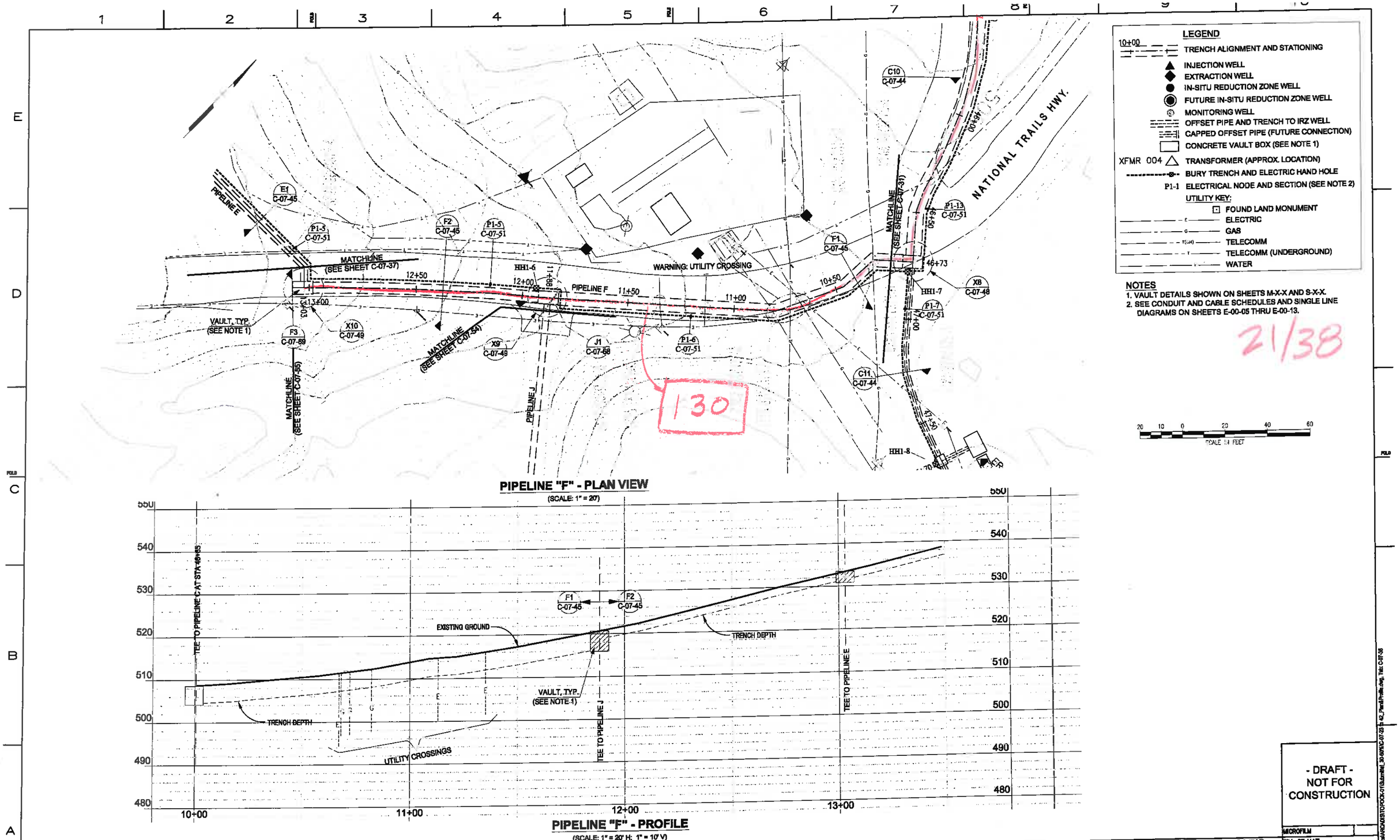
REVISIONS

APPROVED BY	
JEF	SD
	SUPV JPB
	DSGN MLD
	DWN AJW
	CHKD JPB
	OK JEF
	DATE 7/12/12
	SCALES 1" = 20'

TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE
PIPELINE "C10 & C11"
STA 44+00 TO STA 49+20
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM	
BILL OF MATL	
DWG LIST	
SUPSDS	
SUPSD BY	
SHEET NO.	of SHEETS
C-07-31	REV

09/17/2012, 10:46, C:\Engineer\ARCADIS\TOPOCK-01\Submittal_09-60%\C-07-31 p-42_PlanProfile.dwg, Tab: C-07-31



PIPELINE "F" - PLAN VIEW

(SCALE: 1" = 20')

PIPELINE "F" - PROFILE

(SCALE: 1" = 20' H; 1" = 10' V)

- DRAFT - NOT FOR CONSTRUCTION

ETIC ENGINEERING

ARCADIS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL	AJW	KLD	JPB	JEF	

REVISIONS

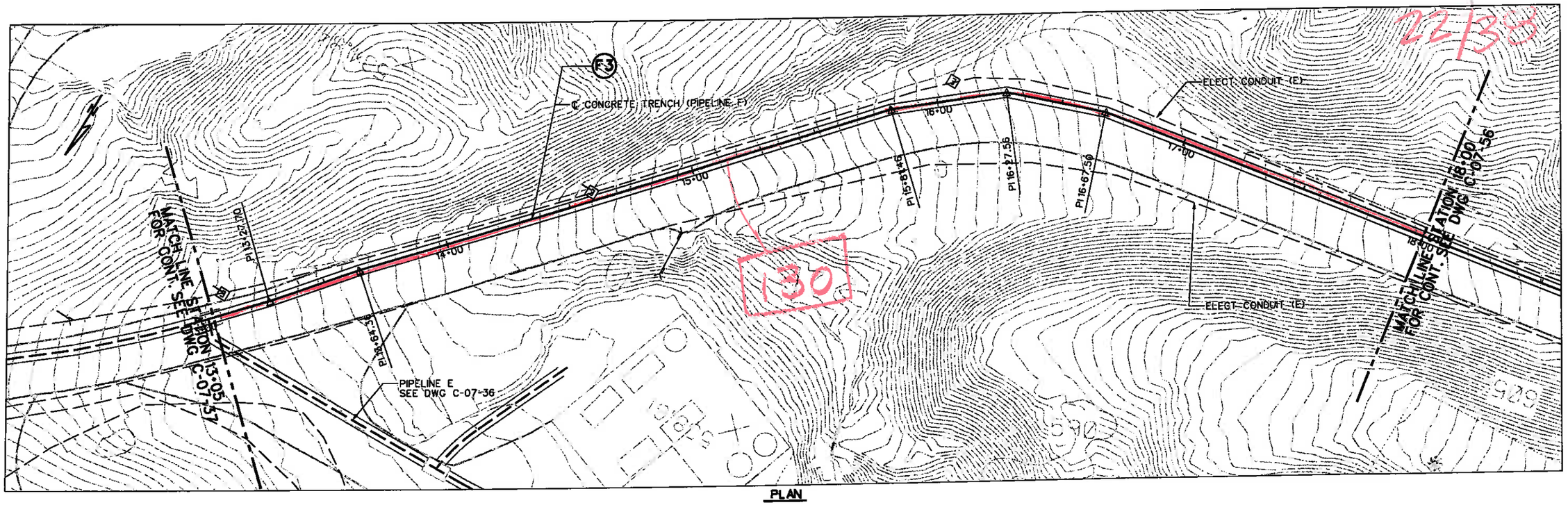
APPROVED BY	
	SD
JEF	SUPV JPB
	DSGN KLD
	DWN AJW
	CHKD JPB
	QK JEF
	DATE 9/12/12
	SCALES 1" = 20'

TOPOCK GROUNDWATER REMEDIATION PROJECT
PLAN AND PROFILE
PIPELINE "F"
STA 10+00 TO STA 13+50
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

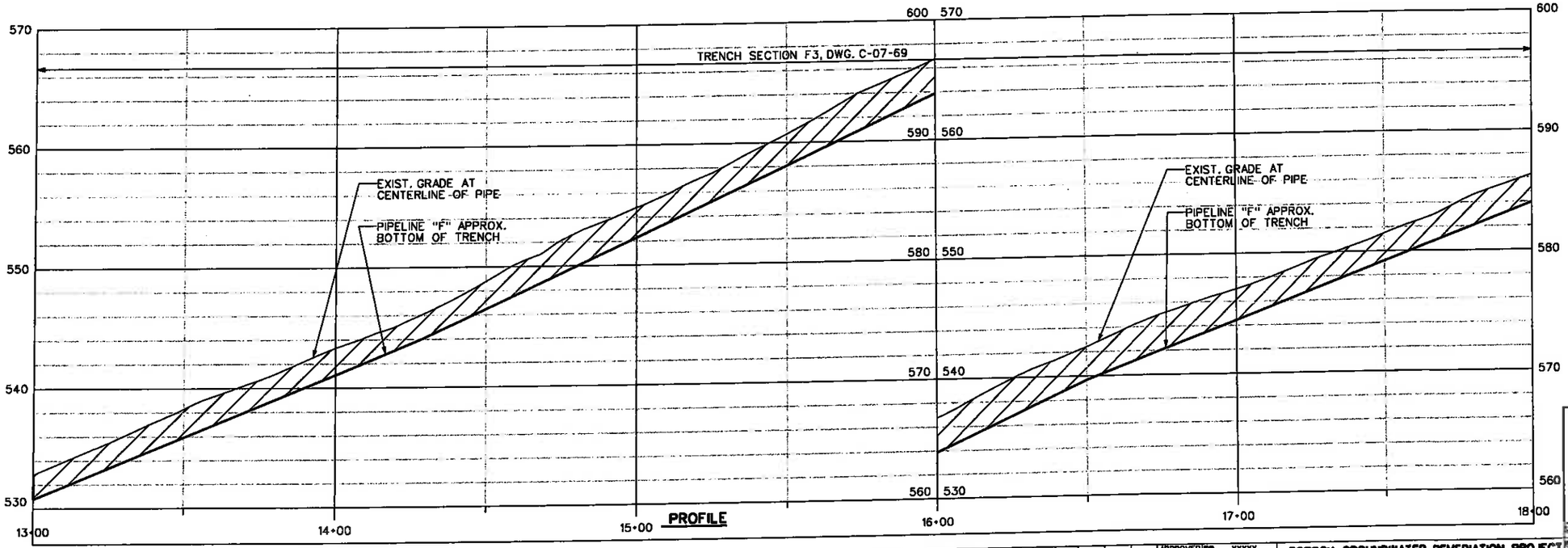
MICROFILM	
BILL OF MATL	
DWG LIST	
SUPSDS	
SUPSD BY	
SHEET NO.	of SHEETS
C-07-36	REV

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22/33



PLAN



PROFILE

0 5 10 20 40
GRAPHIC SCALE: 1"-20' HORIZ

0 5 10
GRAPHIC SCALE: 1"-5' VERT

AECOM
2101 WEBSTER STREET SUITE 1000
OAKLAND, CA 94612-3000
PROJECT NO. 60272335

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

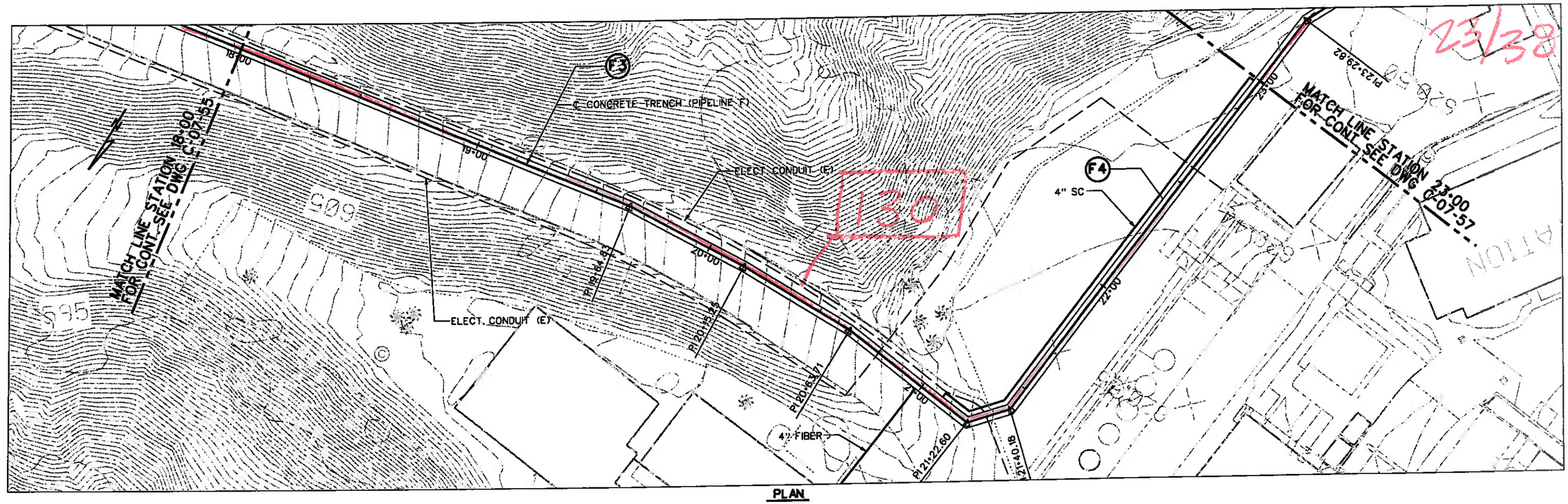
REVISIONS

APPROVED BY		
GM	XXXXX	
SUPV	PD	
DSGN	TL	
DWN	TL	
CHKD	JM	
QA	PD	
DATE	9/12/12	
SCALES	1" - 20'-0"	

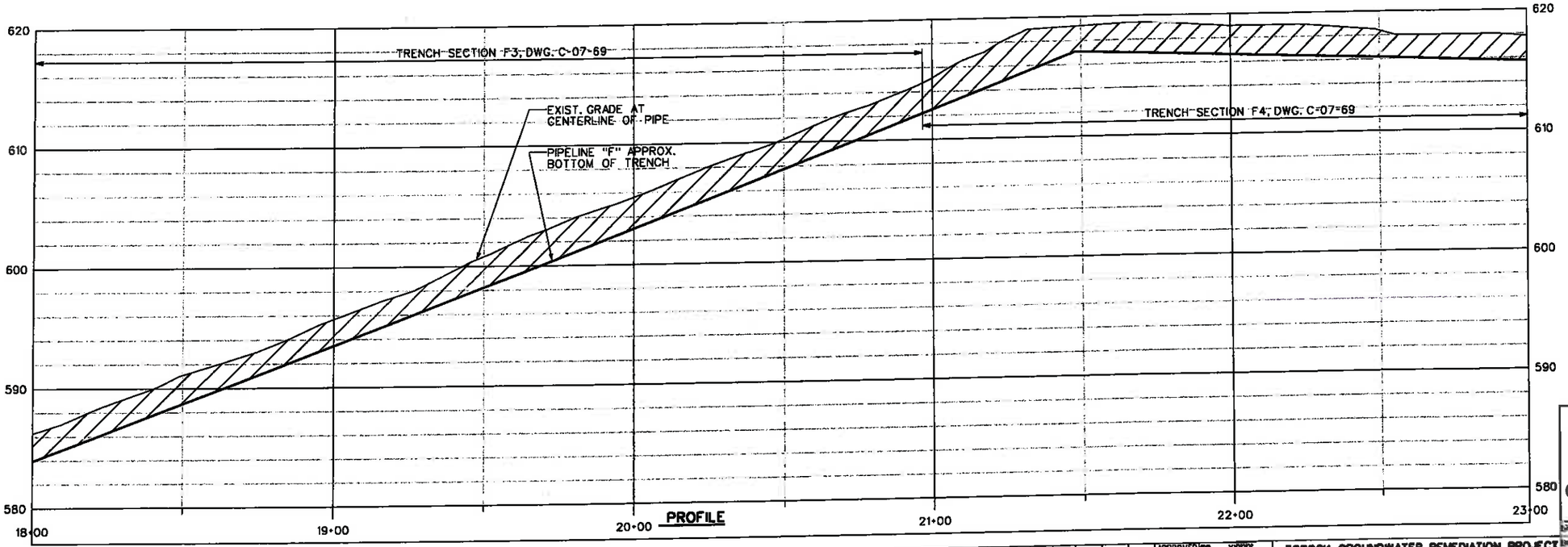
TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE F
PLAN AND PROFILE
13+05 TO 18+00
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

- DRAFT - NOT FOR CONSTRUCTION

DESIGN	
FILL OF MATL	
DISC LIST	
SUPERS	
SUPER BY	
SHEET NO. OF SHEETS	C-07-55 / 0



PLAN



PROFILE

0 5 10 20 40
GRAPHIC SCALE: 1"=20' HORIZ

0 5 10
GRAPHIC SCALE: 1"=5' VERT

- DRAFT - NOT FOR CONSTRUCTION

AECOM
2101 WEBSTER STREET SUITE 1000
OAKLAND, CA 94612-3060
PROJECT NO. 60272335

REVISIONS

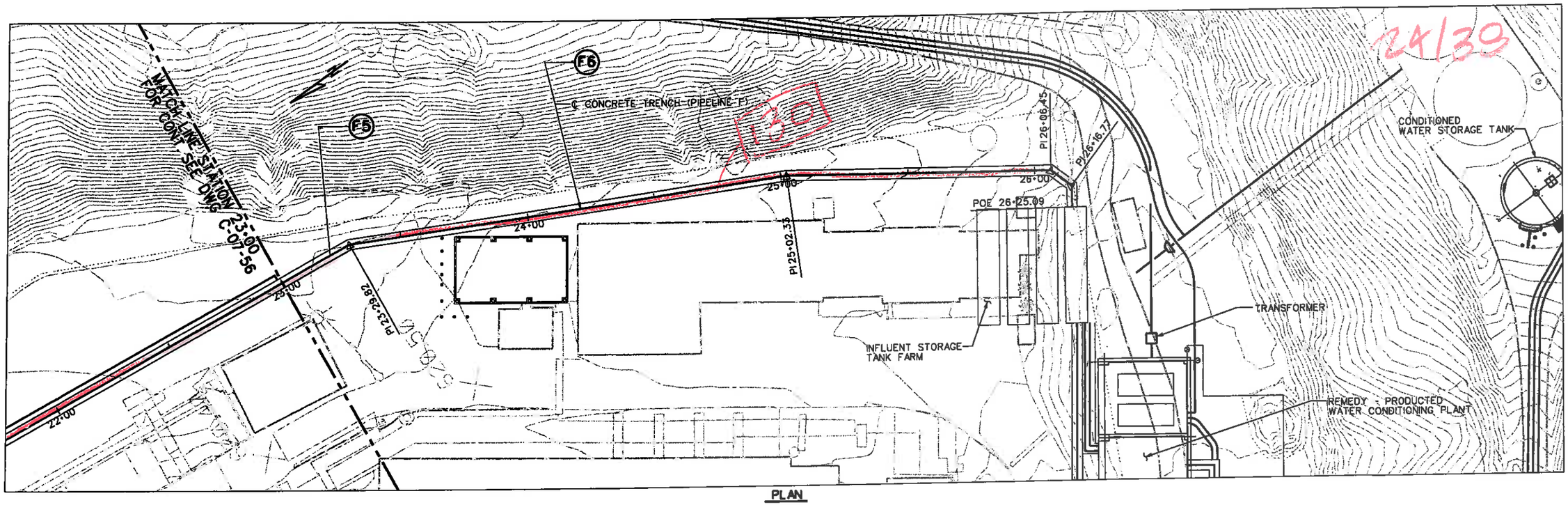
NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

APPROVED BY	
GM	XXXXX
SUPV	PD
SPEC	TL
DWN	TL
CHKD	JM
QC	PD
DATE	9/12/12
SCALES	1" = 20'-0

TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE F
PLAN AND PROFILE
18+00 TO 23+00
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

DATUM	
DATE OF DATA	
KING LIST	
DATUM	
DRAWN BY	
SHEET NO.	OF SHEETS

C-07-56 | REV 0



AECOM
2101 WEBSTER STREET SUITE 1600
OAKLAND, CA 94612-3065
PROJECT NO. 60272335

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

REVISIONS

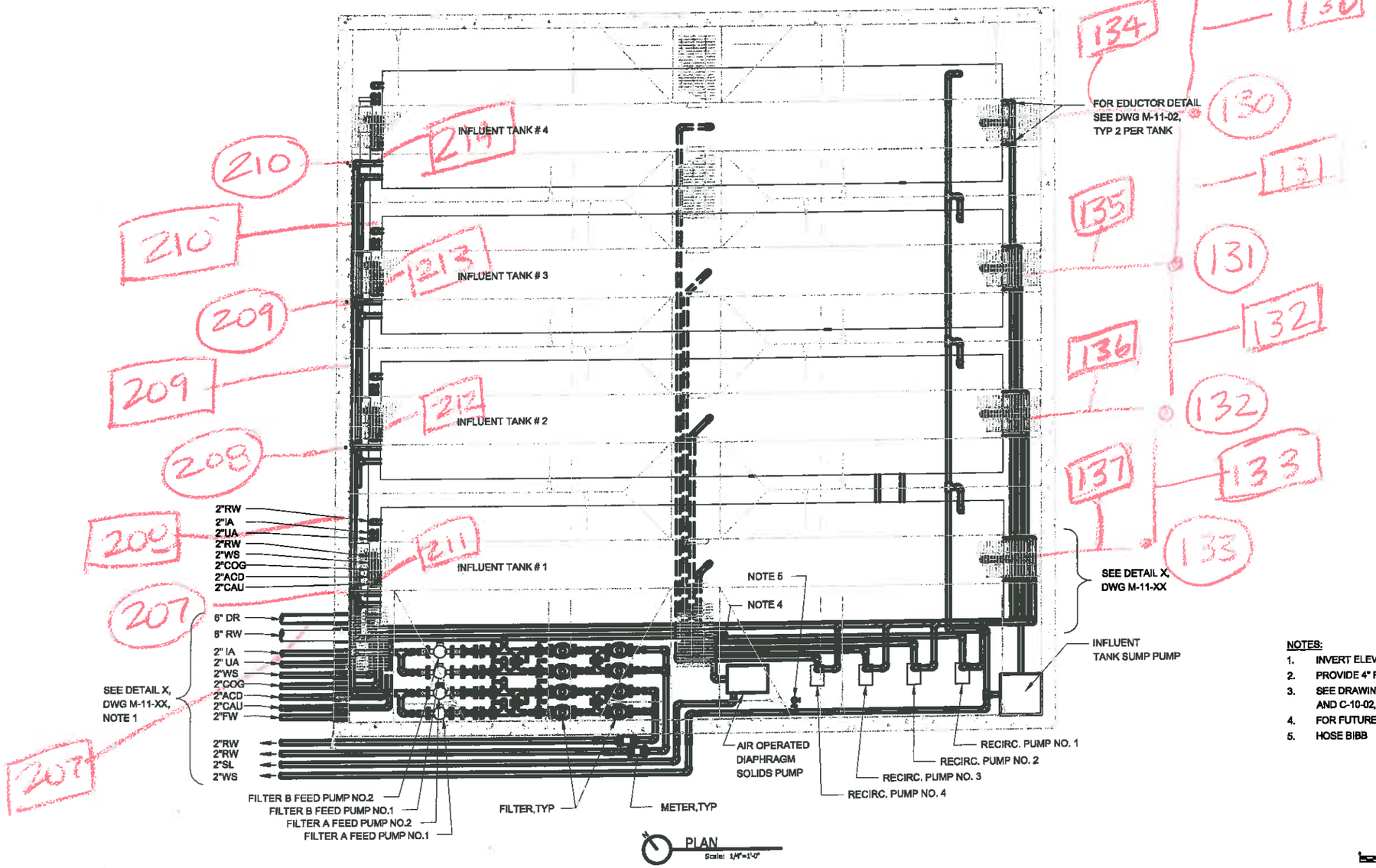
APPROVED BY		
GM	XXXXX	
SUPV	PD	
DSGN	TL	
DWN	TL	
CHKD	JM	
QA	PD	
DATE	9/12/12	
SCALES	1" = 20'-0"	

TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE F
PLAN AND PROFILE
23+00 TO 26+25
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

- DRAFT - NOT FOR CONSTRUCTION

MICROFILM	
BILL OF MATL	
SPEC LIST	
SUPSDS	
SUPSD BY	
DRAWING NO.	C-07-57
SHEET NO. OF SHEETS	
REV	0

25/38



PLAN
Scale: 1/4"=1'-0"

NOTES:
1. INVERT ELEVATION OF INLET AND OUTLET PIPING IS 624.5'
2. PROVIDE 4" FIBER AND 4" ELECTRICAL INTO THIS AREA.
3. SEE DRAWING S-11-01, 02, 03 FOR STRUCTURAL DETAILS AND C-10-02, C-11-01 FOR CIVIL DETAILS.
4. FOR FUTURE DEWATERING USE.
5. HOSE BIBB

DRAFT
NOT FOR
CONSTRUCTION

CH2MHILL

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	2012/09/12	INTERMEDIATE (60%) DESIGN SUBMITTAL		GJ			JP

REVISIONS

APPROVED BY
SO
SUPV
DSGN RH
DWN GJ
CHKD JP
QK JP
DATE
SCALES

TOPOCK GROUNDWATER REMEDIATION PROJECT

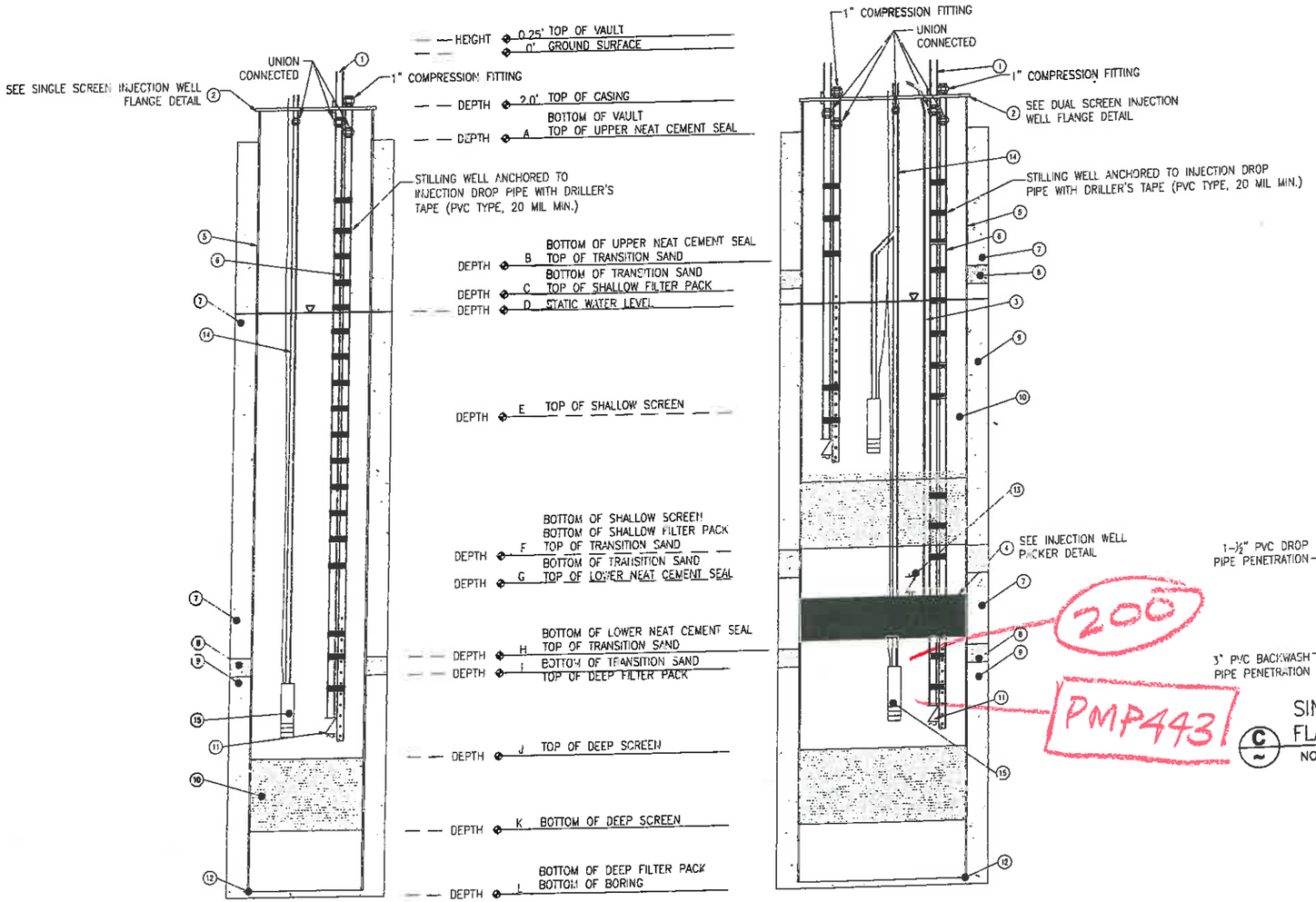
INFLUENT TANK FARM
PLAN

GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. of SHEETS
M-11-01
REV

PLOT DATE: $PLOTDATE PLOT TIME: $PLOTTIME
FILENAME: CH-M-XXX-1101AD.dwg

26/38



A SINGLE SCREEN INJECTION WELL WITH BACKWASH PUMP DETAIL
NOT TO SCALE. SEE WELL CONSTRUCTION SCHEDULE SHEET M-X-01 FOR REPRESENTATIVE DEPTHS. WELL DIAMETER EXAGGERATED TO SHOW DETAIL.

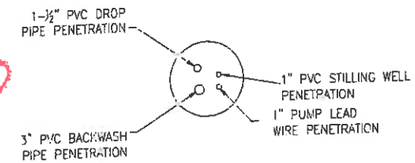
B DUAL SCREEN INJECTION WELL WITH BACKWASH PUMPS DETAIL
NOT TO SCALE. SEE WELL CONSTRUCTION SCHEDULE SHEET M-X-01 FOR REPRESENTATIVE DEPTHS. WELL DIAMETER EXAGGERATED TO SHOW DETAIL.

TCS-1

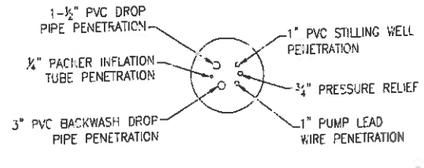
KEY

1	1-½" PVC DROP PIPE (MATERIALS TBD)
2	CUSTOM TAPPED WELL FLANGE
3	¼" DIAMETER HOSE FROM PACKER TO FILL ASSEMBLY
4	PNEUMATIC WELL PACKER
5	WELL CASING (MATERIALS TBD)
6	1" PVC TUBING (STILLING WELL WITH PRESSURE TRANSDUCER)
7	ANNULAR SPACE, 100% NEAT CEMENT GROUT
8	ANNULAR SPACE, TRANSITION SAND (SIZE TBD)
9	ANNULAR SPACE, FILTER PACK (TYPE TBD)
10	WELL SCREEN (MATERIALS TBD)
11	SPRING CHECK VALVE (TYPE AND MATERIALS TBD)
12	SUMP
13	¾" PACKER PRESSURE RELIEF SAFETY VALVE
14	3" BACKWASH PIPING
15	BACKWASH PUMP

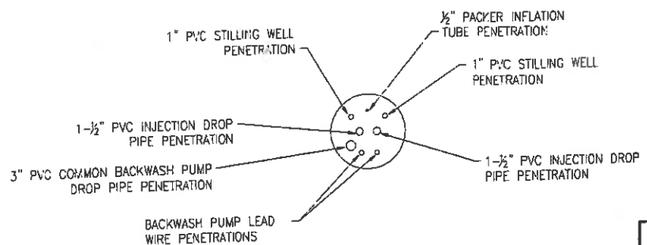
NOTES:
1. ALL DEPTH INTERVALS 'A' THRU 'K' ARE IN FEET BELOW GROUND SURFACE.
2. ALL COORDINATES BASED ON NAD83, CA ZONE V.
3. ALL WELL SEALS ARE 100% NEAT CEMENT.
4. ALL ABOVE-GRADE PIPING AND INSTRUMENTATION INSTALLED IN ACCORDANCE WITH THE P&ID AND THE WELLHEAD MECHANICAL LAYOUT



C SINGLE SCREEN WELL FLANGE DETAIL
NOT TO SCALE



D INJECTION WELL PACKER DETAIL
NOT TO SCALE



E DUAL SCREEN INJECTION WELL FLANGE DETAIL
NOT TO SCALE

- DRAFT - NOT FOR CONSTRUCTION

ETIC ENGINEERING

ARCADIS

NO.	DATE	DESCRIPTION	BY	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL	AJW	JPB	JPB	JEF

REVISIONS

APPROVED BY: JEF

SD	
SUPV	JPB
DSGN	JPB
DRN	AJW
CHKD	JPB
QC	JEF
DATE	9/12/12
SCALES	AS NOTED

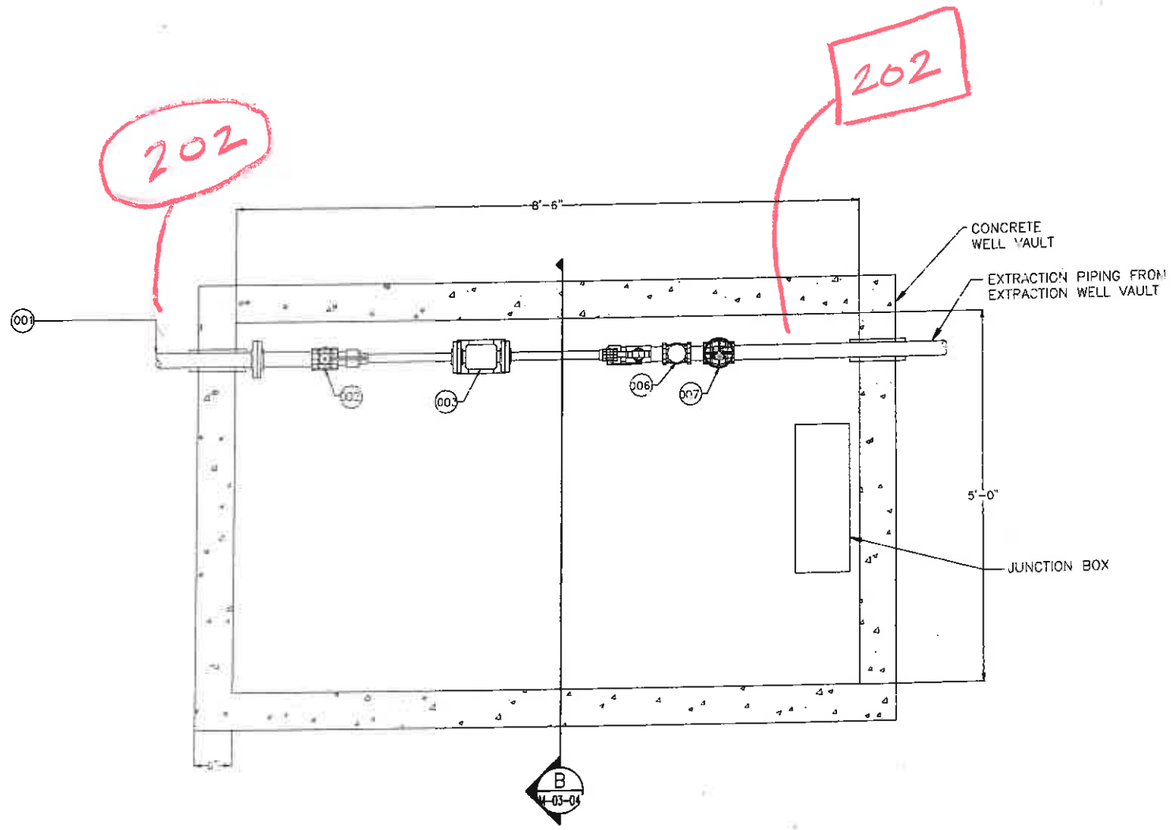
TOPOCK GROUNDWATER REMEDIATION PROJECT

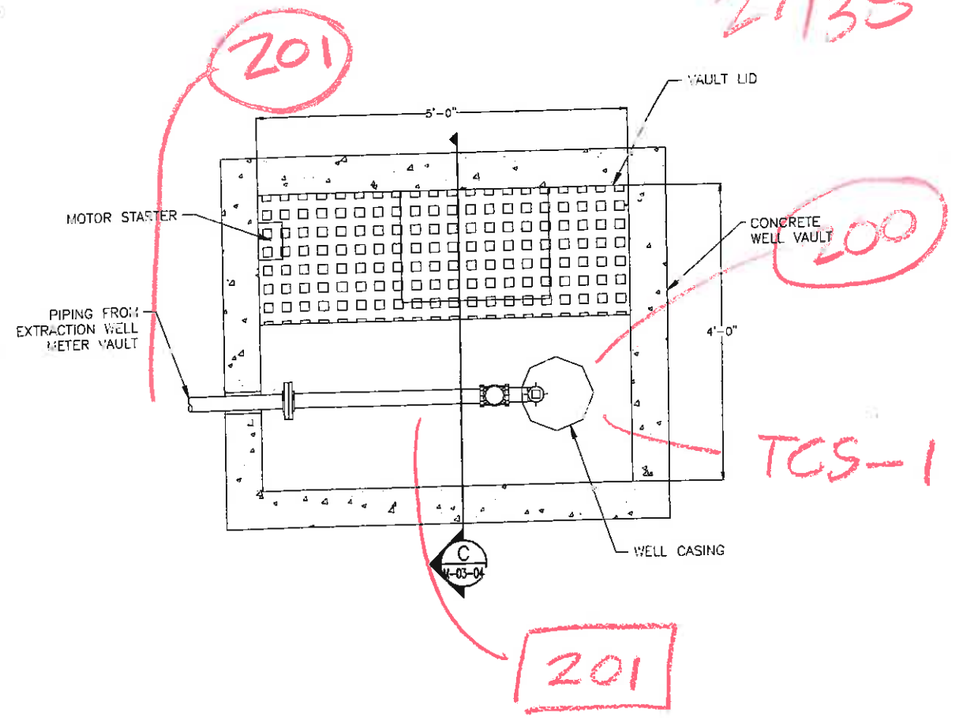
TCS LOOP INJECTION WELL CONSTRUCTION DETAILS

GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. M-03-02 of SHEETS
REV

08/10/2012, 17:02, G:\Engineer\ARCADIS\TOPOCK\Submittal_30-90%\Well Con\Section Details.dwg, Tab: M-03-02





EXTRACTION WELL METER VAULT AND WELL VAULT PLAN

0 1' 2' 3'
1"=1'

NOTES:
1. ALL PIPING, INSTRUMENTATION, AND OTHER COMPONENTS SHALL BE INSTALLED AS PER THE MANUFACTURER'S GUIDELINES.
2. ALL PIPING AND INSTRUMENTATION SHALL BE INSTALLED PER P&IDS.
3. INSTALLATION OF ELECTRIC COMPONENTS SHALL COMPLY WITH ALL APPLICABLE NEC AND LOCAL CODES.
4. CROSS SECTIONS SHOW ONLY THOSE COMPONENTS NECESSARY TO INDICATE ELEVATIONS AND SPACE REQUIREMENTS FOR PIPING AND MAJOR COMPONENTS. INSTALL PIPING AND INSTRUMENTATION AS PER THE P&IDS.
5. ALL INSTRUMENTATION SHALL BE INSTALLED SUCH THAT IT MAY BE READ WITHOUT ENTERING THE WELL VAULT.
6. ALL VALVE HANDLES SHALL BE INSTALLED SUCH THAT THEY ARE ACCESSIBLE WITHOUT ENTERING THE WELL VAULT AND OPERABLE THROUGH ENTIRE STROKE.
7. ALL PIPING AND CONDUIT SHALL BE SECURED TO THE WALLS OF THE CONCRETE WELL VAULT WITH ANCHOR BOLTS AND UNI-STRUT. SUPPORTS SHALL BE INSTALLED WHEREVER NECESSARY TO PROPERLY SUPPORT PIPING AND CONDUIT.
8. PIPE SIZES AND MATERIALS ARE SHOWN ON THE P&IDS.
9. PIPING KNOCKOUTS AND ROUTING OF PIPING SHOWN AS PROPOSED AND APPROXIMATE. ACTUAL ROUTING TO BE FIELD DETERMINED AND IS SUBJECT TO ENGINEER'S APPROVAL.
10. ALL FLANGES SHALL BE CLASS 150 RAISED FACE FLANGES UNLESS OTHERWISE NOTED.
11. ALL TRANSITION FITTINGS FOR HDPE PIPING SHALL BE FLANGED WITH BACKING RINGS.

WELL VAULT SCHEDULE

ITEM	PIPE SIZE	PIPE MAT.	PROCESS FLOW	DESCRIPTION
1	0'-2"	CPVC	GROUNDWATER	
2	0'-2"	CPVC	GROUNDWATER	ISOLATION BALL VALVE - EQUIPPED WITH STEM EXTENSION TO ALLOW FOR OPERATION FROM OUTSIDE OF VAULT
3	0'-2"	TEFLON	GROUNDWATER	MAGNETIC FLOWMETER
4	0'-0 1/2"	TBD	GROUNDWATER	PRESSURE GAUGE ASSEMBLY
5	0'-0 1/4"	TBD	GROUNDWATER	SAMPLE PORT
6	0'-2"	CPVC	GROUNDWATER	CHECK VALVE
7	0'-2"	CPVC	GROUNDWATER	GLOBE VALVE
8	0'-1 1/2"	CPVC	EXTRACTED GROUNDWATER	

- DRAFT - NOT FOR CONSTRUCTION

ETIC ENGINEERING

ARCADIS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL	LUK	JPB	JPB	JEF	

REVISIONS

APPROVED BY	
JEF	

SD	
SUPV	JPB
DSGN	JPB
DWN	LUK
CHKD	JPB
CK	JEF
DATE	9/12/12
SCALES	AS NOTED

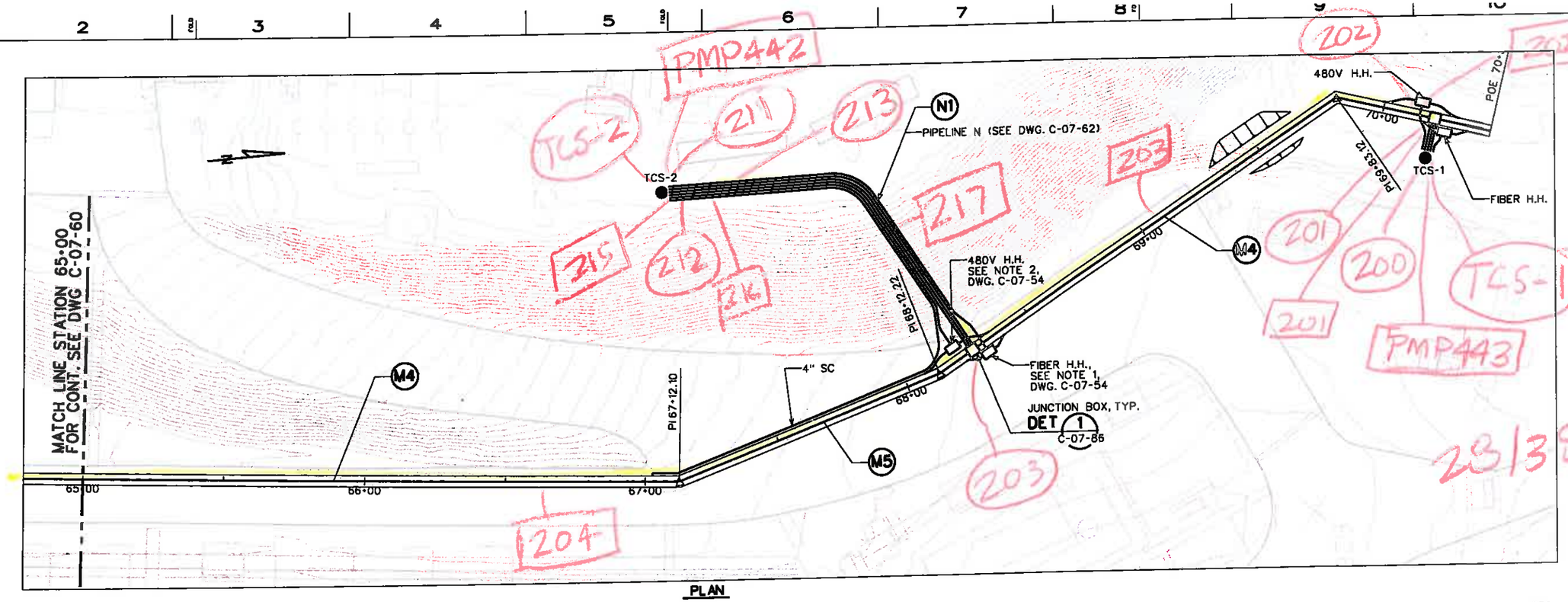
TOPOCK GROUNDWATER REMEDIATION PROJECT

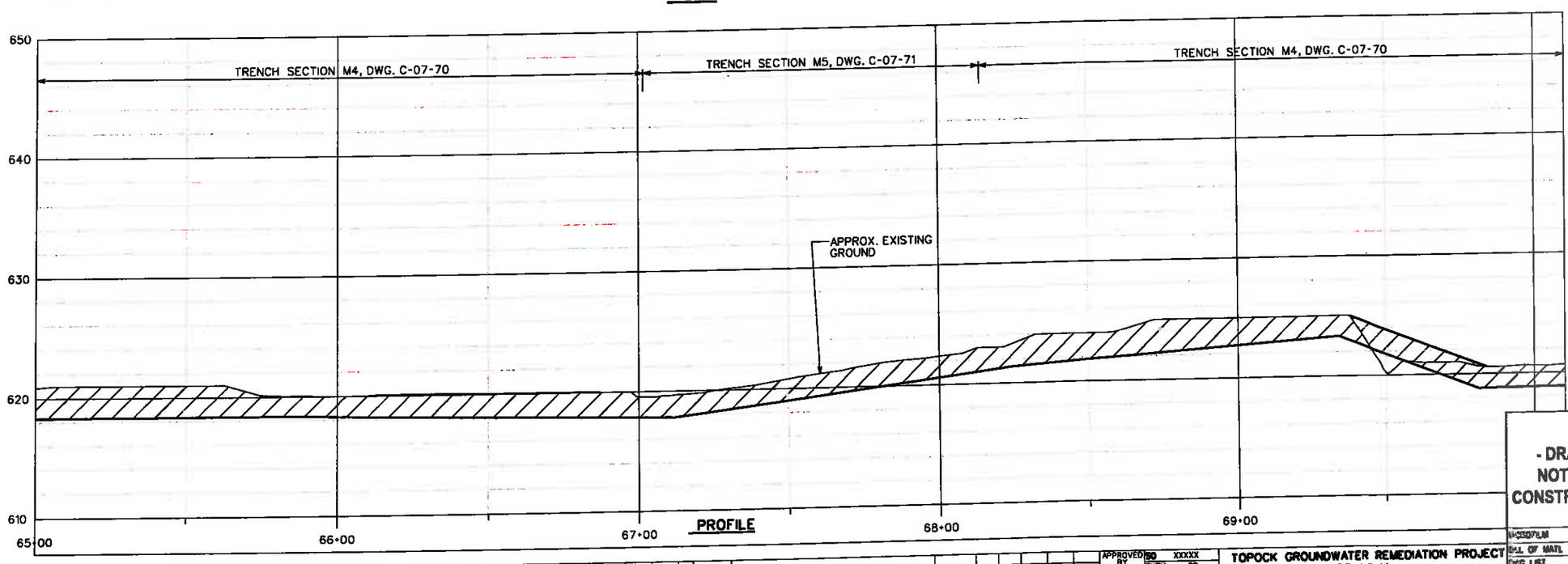
TCS LOOP EXTRACTION WELL VAULT MECHANICAL DETAILS

GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM	
BILL OF MATL	
DWG LIST	
SUPSDS	
SUPSD BY	
SHEET NO.	of SHEETS
M-03-03	REV

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0 5 10 20 40
GRAPHIC SCALE: 1"=20' HORIZ

0 5 10
GRAPHIC SCALE: 1"=5' VERT

- DRAFT -
NOT FOR CONSTRUCTION

AECOM
2101 WEBSTER STREET SUITE 1000
OAKLAND, CA 94612-3060
PROJECT NO. 60272335

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

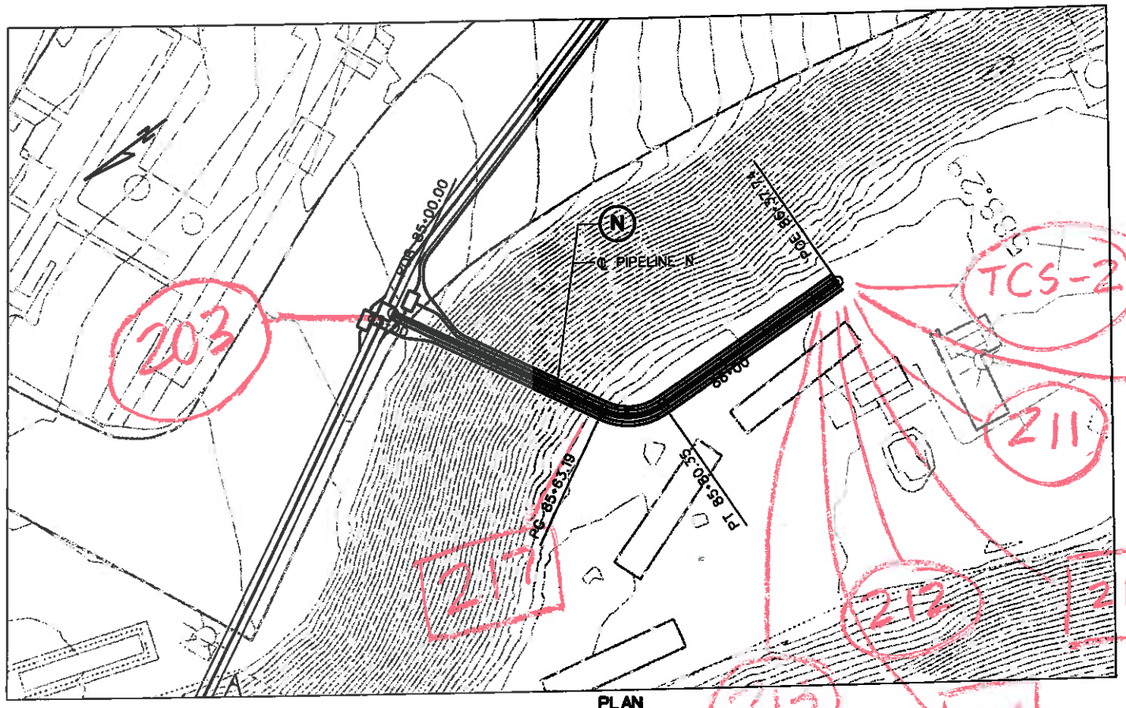
REVISIONS

APPROVED BY		
GO	XXXXX	
SUPV	PD	
QA/QC	TL	
GCM	TL	
CHKD	JM	
DR	PD	
DATE	9/12/12	
SCALES	1" = 20'-0"	

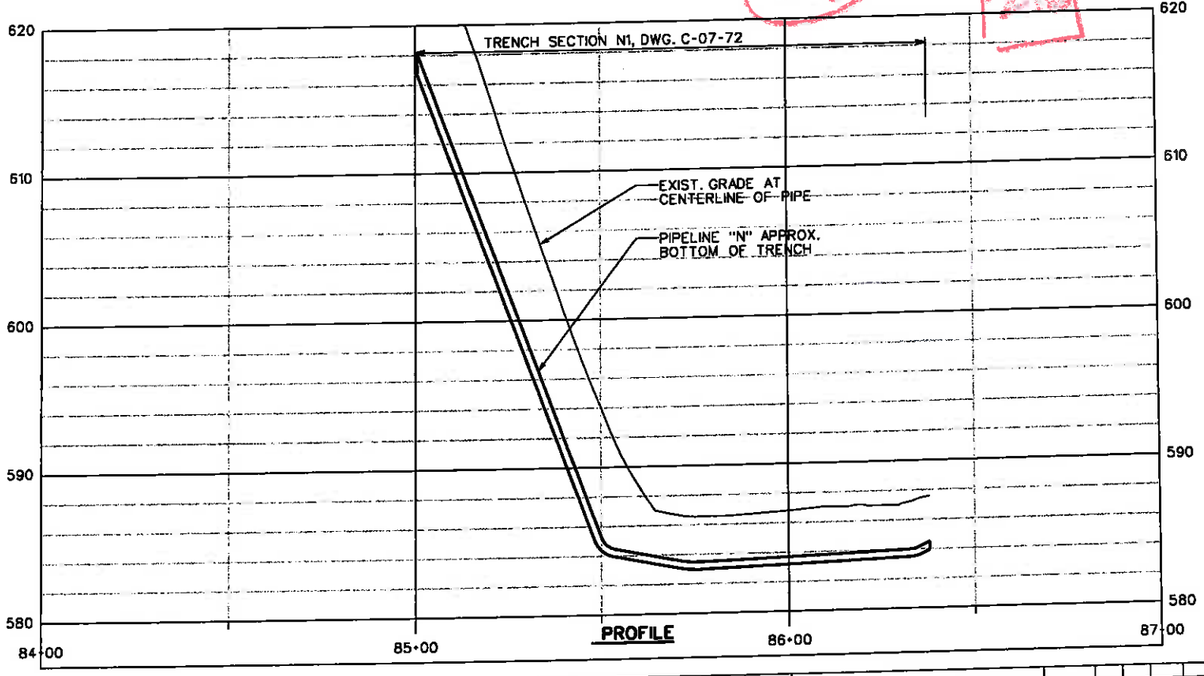
TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE M
PLAN AND PROFILE
65+00 TO 70+05
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MYLAR FILM	
FULL OF MAIL	
DWG LIST	
BLUEPRINTS	
STAMPED BY	
SHEET NO.	OF SHEETS
C-07-61	REV 0

29/38



PLAN



PROFILE

0 5 10 20 40
GRAPHIC SCALE: 1"=20' HORIZ

0 5 10
GRAPHIC SCALE: 1"=5' VERT

- DRAFT -
NOT FOR CONSTRUCTION

AECOM
2101 WEBSTER STREET SUITE 1600
OAKLAND, CA 94612-3060
PROJECT NO. 60272335

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

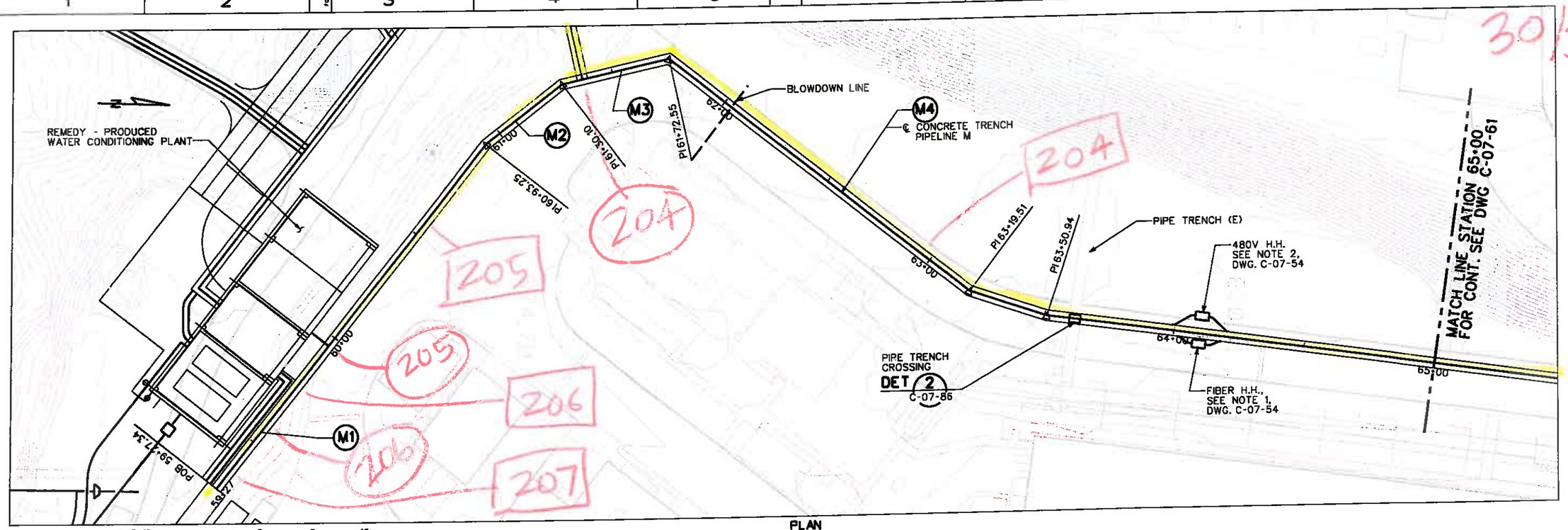
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APPROVED BY		
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SUPV	PD	
GM/SPEC	TL	
DWN	TL	
CHKD	JM	
QA	PD	
DATE	9/12/12	
SCALES	1" = 20'-0"	

TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE N
PLAN AND PROFILE
85+00 TO 86+38
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM	
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C-07-62	REV 0

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- DRAFT - NOT FOR CONSTRUCTION

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2101 WEBSTER STREET SUITE 1900
OAKLAND, CA 94612-3070
PROJECT NO. 60272335

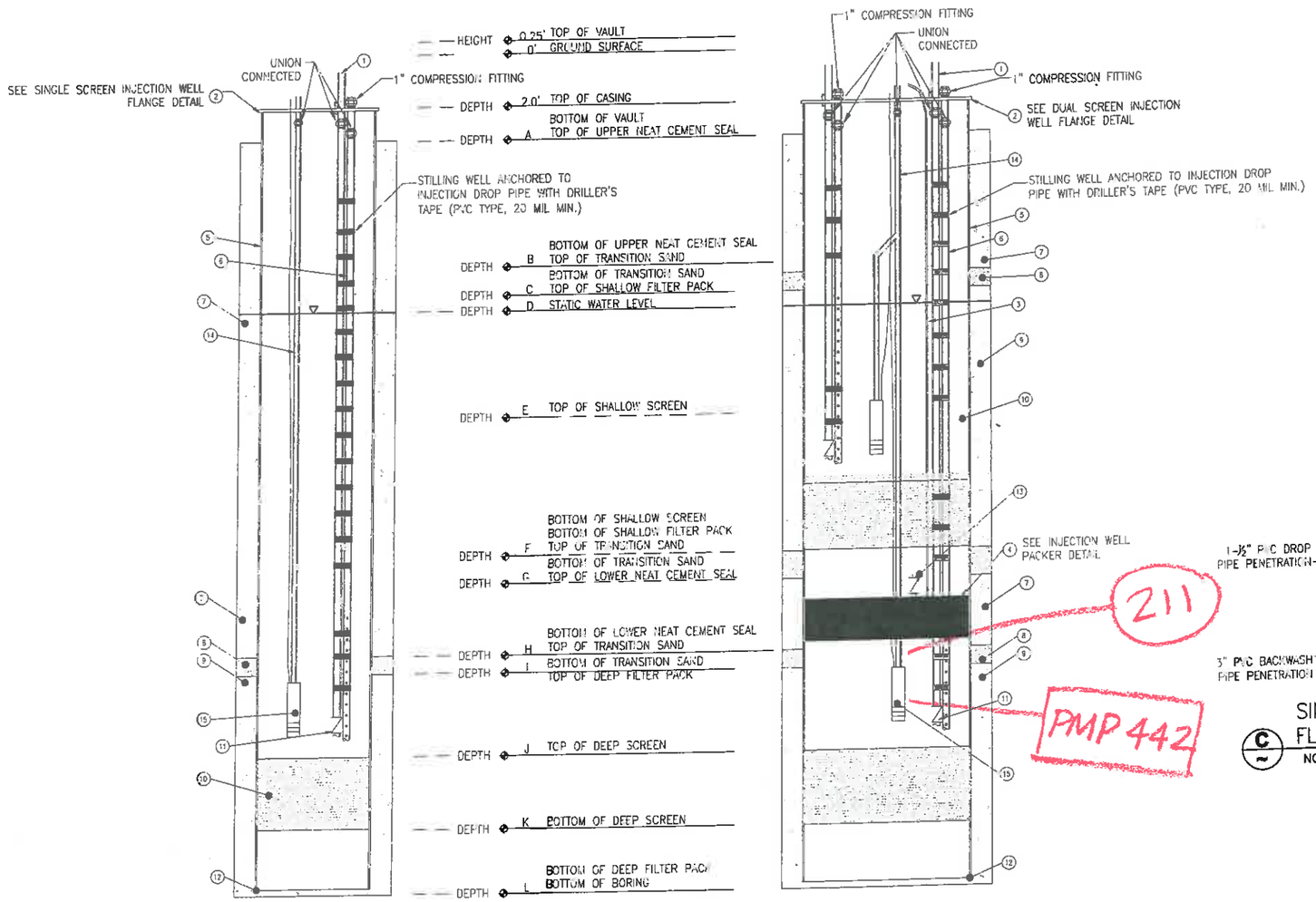
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0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

REVISIONS

APPROVED BY: XXXXX
SUPV: PD
DRWN: TL
DSGN: TL
CHKD: JM
QA: PD
DATE: 9/12/12
SCALES: 1" = 20'-0"

TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE M
PLAN AND PROFILE
60+00 TO 65+00
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

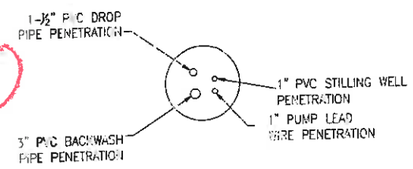
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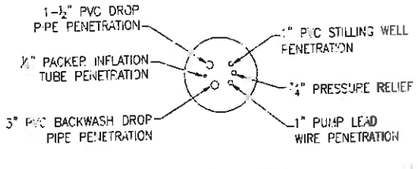
SINGLE SCREEN INJECTION WELL WITH BACKWASH PUMP DETAIL (A)
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DUAL SCREEN INJECTION WELL WITH BACKWASH PUMPS DETAIL (B)
NOT TO SCALE. SEE WELL CONSTRUCTION SCHEDULE SHEET M-X-01 FOR REPRESENTATIVE DEPTHS. WELL DIAMETER EXAGGERATED TO SHOW DETAIL.

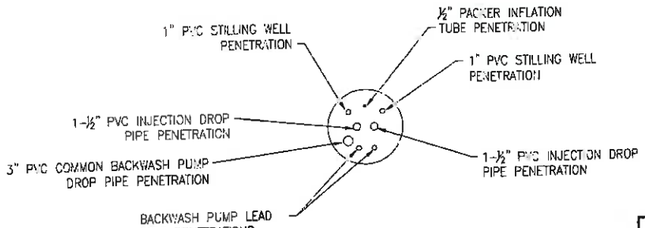
TCS-2



SINGLE SCREEN WELL FLANGE DETAIL (C)
NOT TO SCALE



INJECTION WELL PACKER DETAIL (D)
NOT TO SCALE



DUAL SCREEN INJECTION WELL FLANGE DETAIL (E)
NOT TO SCALE

KEY

1	1-½" PVC DROP PIPE (MATERIALS TBD)
2	CUSTOM TAPPED WELL FLANGE
3	¼" DIAMETER HOSE FROM PACKER TO FILL ASSEMBLY
4	PNEUMATIC WELL PACKER
5	WELL CASING (MATERIALS TBD)
6	1" PVC TUBING (STILLING WELL WITH PRESSURE TRANSDUCER)
7	ANNULAR SPACE, 100% NEAT CEMENT GROUT
8	ANNULAR SPACE, TRANSITION SAND (SIZE TBD)
9	ANNULAR SPACE, FILTER PACK (TYPE TBD)
10	WELL SCREEN (MATERIALS TBD)
11	SPRING CHECK VALVE (TYPE AND MATERIALS TBD)
12	SUMP
13	¾" PACKER PRESSURE RELIEF SAFETY VALVE
14	3" BACKWASH PIPING
15	BACKWASH PUMP

NOTES:
1. ALL DEPTH INTERVALS 'A' THRU 'K' ARE IN FEET BELOW GROUND SURFACE.
2. ALL COORDINATES BASED ON NAD83, CA ZONE V.
3. ALL WELL SEALS ARE 100% NEAT CEMENT.
4. ALL ABOVE-GRADE PIPING AND INSTRUMENTATION INSTALLED IN ACCORDANCE WITH THE P&ID AND THE WELLHEAD MECHANICAL LAYOUT

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ETIC ENGINEERING | ARCADIS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL	AJW	JPB	JPB	JEF	

REVISIONS

APPROVED BY	
SO	
SUPV	JPB
DSGN	JPB
DWN	AJW
CHKD	JPB
QK	JEF
DATE	9/12/12
SCALES	AS NOTED

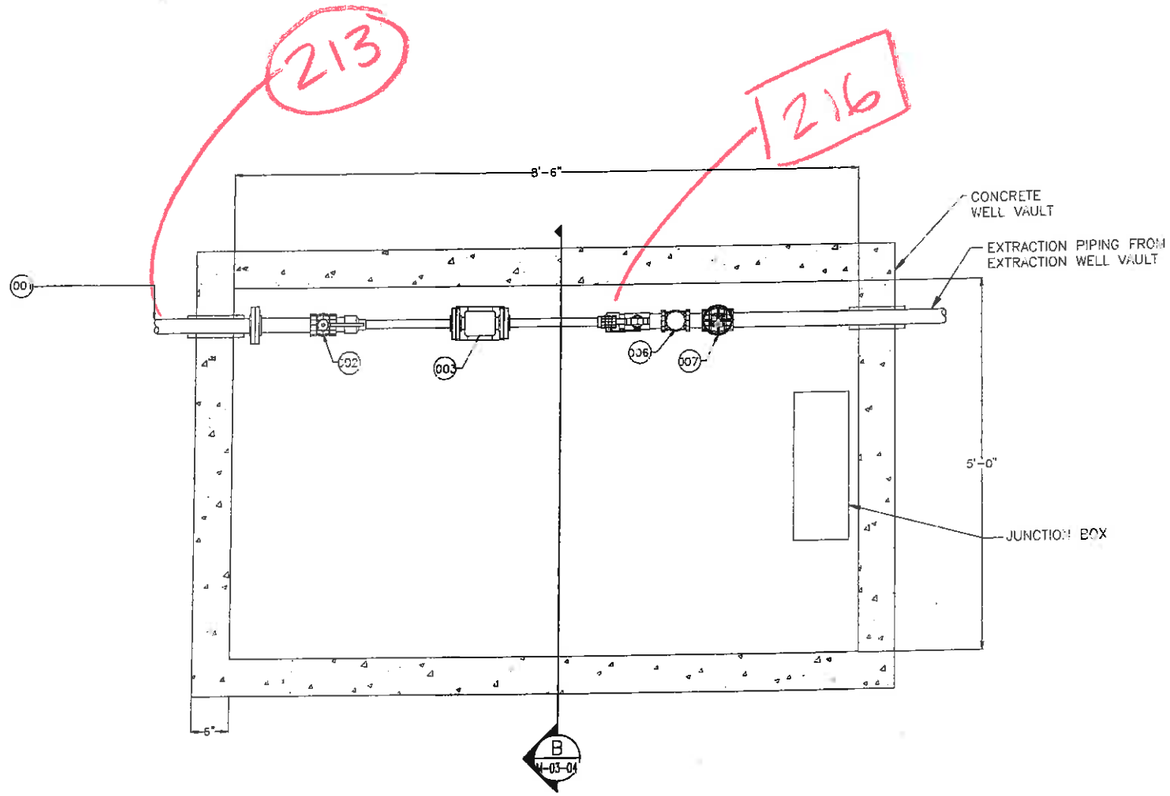
TOPOCK GROUNDWATER REMEDIATION PROJECT

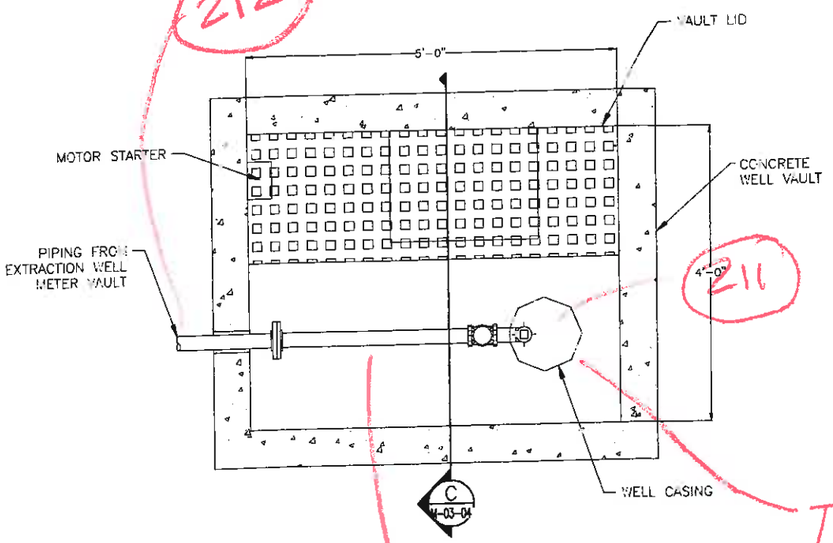
TCS LOOP INJECTION WELL CONSTRUCTION DETAILS

GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM	
BILL OF MATL	
DWG LIST	
SUPSDS	
SUPSD BY	
SHEET NO.	of SHEETS
M-03-02	REV

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EXTRACTION WELL METER VAULT AND WELL VAULT PLAN

0 1' 2' 3'
1"=1'

NOTES:
1. ALL PIPING, INSTRUMENTATION, AND OTHER COMPONENTS SHALL BE INSTALLED AS PER THE MANUFACTURER'S GUIDELINES.
2. ALL PIPING AND INSTRUMENTATION SHALL BE INSTALLED PER P&IDS.
3. INSTALLATION OF ELECTRIC COMPONENTS SHALL COMPLY WITH ALL APPLICABLE NEC AND LOCAL CODES.
4. CROSS SECTIONS SHOW ONLY THOSE COMPONENTS NECESSARY TO INDICATE ELEVATIONS AND SPACE REQUIREMENTS FOR PIPING AND MAJOR COMPONENTS. INSTALL PIPING AND INSTRUMENTATION AS PER THE P&IDS.
5. ALL INSTRUMENTATION SHALL BE INSTALLED SUCH THAT IT MAY BE READ WITHOUT ENTERING THE WELL VAULT.
6. ALL VALVE HANDLES SHALL BE INSTALLED SUCH THAT THEY ARE ACCESSIBLE WITHOUT ENTERING THE WELL VAULT AND OPERABLE THROUGH ENTIRE STROKE.
7. ALL PIPING AND CONDUIT SHALL BE SECURED TO THE WALLS OF THE CONCRETE WELL VAULT WITH ANCHOR BOLTS AND UNI-STRUT. SUPPORTS SHALL BE INSTALLED WHEREVER NECESSARY TO PROPERLY SUPPORT PIPING AND CONDUIT.
8. PIPE SIZES AND MATERIALS ARE SHOWN ON THE P&IDS.
9. PIPING KNOCKOUTS AND ROUTING OF PIPING SHOWN AS PROPOSED AND APPROXIMATE. ACTUAL ROUTING TO BE FIELD DETERMINED AND IS SUBJECT TO ENGINEER'S APPROVAL.
10. ALL FLANGES SHALL BE CLASS 150 RAISED FACE FLANGES UNLESS OTHERWISE NOTED.
11. ALL TRANSITION FITTINGS FOR HDPE PIPING SHALL BE FLANGED WITH BACKING RINGS.

WELL VAULT SCHEDULE

ITEM	PIPE SIZE	PIPE MAT.	PROCESS FLOW	DESCRIPTION
1	0'-2"	CPVC	GROUNDWATER	
2	0'-2"	CPVC	GROUNDWATER	ISOLATION BALL VALVE – EQUIPPED WITH STEM EXTENSION TO ALLOW FOR OPERATION FROM OUTSIDE OF VAULT
3	0'-2"	TEFLON	GROUNDWATER	MAGNETIC FLOWMETER
4	0'-0 1/2"	TBD	GROUNDWATER	PRESSURE GAUGE ASSEMBLY
5	0'-0 1/4"	TBD	GROUNDWATER	SAMPLE PORT
6	0'-2"	CPVC	GROUNDWATER	CHECK VALVE
7	0'-2"	CPVC	GROUNDWATER	GLOBE VALVE
8	0'-1 1/2"	CPVC	EXTRACTED GROUNDWATER	

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ETIC ENGINEERING

ARCADIS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL		LUK	JPB	JPB	JEF

REVISIONS

APPROVED BY: JEF

SO	
SUPV	JPB
DSGN	JPB
DWN	LUK
CHKD	JPB
QK	JEF
DATE	9/12/12
SCALES	AS NOTED

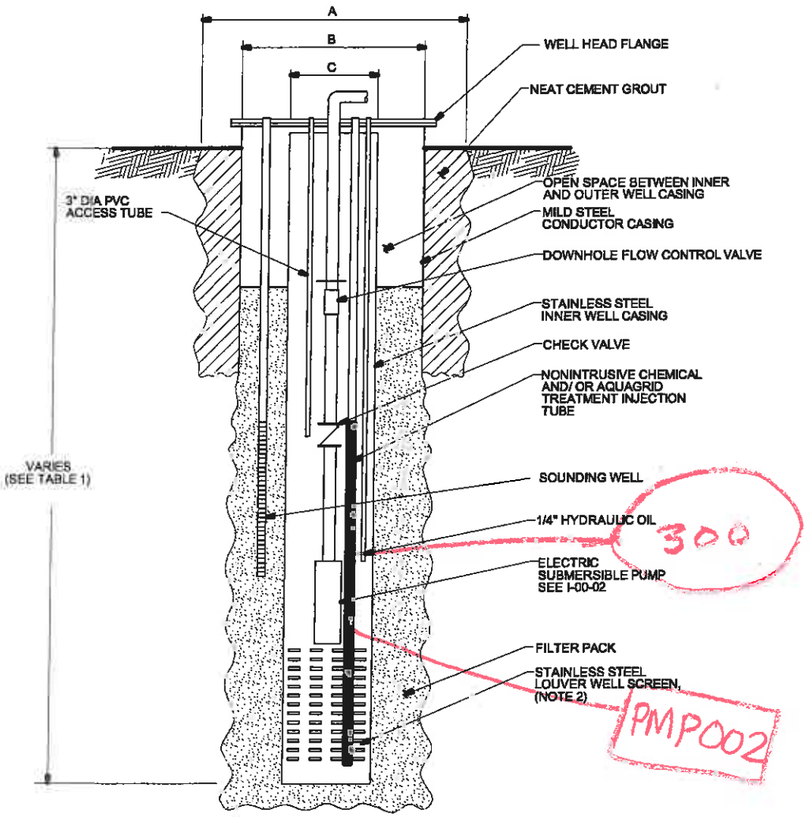
TOPOCK GROUNDWATER REMEDIATION PROJECT

TCS LOOP EXTRACTION WELL VAULT MECHANICAL DETAILS

GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM	
BILL OF MATL	
DWG LIST	
SUPSDS	
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SHEET NO.	of SHEETS
M-03-03	REV

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FW-2

NOTE:

1. WELL DEPTH AND WELL CASING DIMENSIONS (A,B & C) SHOWN IN TABLE 1 ON THIS SHEET
2. ENGINEER WILL DESIGN LOUVER SLOT SIZE AND FILTER PACK GRADE BASED ON GRAIN SIZE DISTRIBUTION ANALYSIS OF FORMATION SAMPLES

FRESH WATER INJECTION WELL WITH BACKWASH PUMP

NTS

TABLE 1

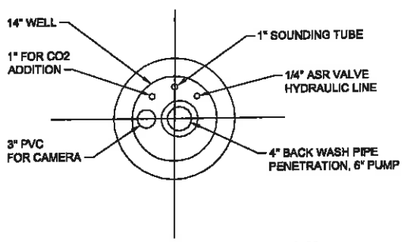
			A		B	C						
Well ID	Depth of Conductor Casing (ft)	Surface Elevation (ft , msl)	Diameter of Conductor Borehole (inches)	Depth of Borehole (ft)	Borehole Diameter (in)	Well Casing Diameter (inches)	Model Saturated Thickness (ft)	Depth to Water (ft)	Depth to Pump (ft)	Well Depth (ft)	Well Screen Length (ft)	Pump Submergence (ft)
FW-001	50	561	32	376	24	14	250	106	168.5	356	187.5	62.5
FW-002 *Note 1*	50	546	32	171	24	14	60	91	136	151	45	45
IRL-001	50	501	32	336	24	14	270	46	113.5	316	202.5	67.5
IRL-002	50	547	32	372	24	14	260	92	157	352	195	65
IRL-003	50	555	32	350	24	14	230	100	157.5	330	172.5	57.5
IRL-004	50	561	32	326	24	14	200	106	156	306	150	50

Note 1. It is assumed that pump in FW-002 will be equipped with a cooling shroud so that pump can be installed deeper in the well to increase pump submergence.

TABLE 2

	Pipe Sizes/MOC/Civil Drawing Reference							
	FW Into Meter Vault	FW Inside Meter Vault	FW Out of Meter Vault/Into Well Vault	FW Inside Well Vault	RW Out of Well Vault/Into Meter Vault	RW In Meter Vault	RW Out of Meter Vault	*Reference to Civil Site Plan*
MOC	*HPDE*	*CPVC*	*HDPE*	*CPVC*	*Double Contained HDPE*	*CPVC*	*Double Contained HDPE*	
FW-001	4"	4"	4"	4"	6" in 10"	6"	6" in 10"	C-02-03
FW-002	2"	3"	2"	3"	4" in 8"	4"	4" in 8"	C-02-04
IRL-001	4"	4"	4"	4"	6" in 10"	6"	6" in 10"	C-05-04
IRL-002	4"	4"	4"	4"	6" in 10"	6"	6" in 10"	C-05-05
IRL-003	4"	4"	4"	4"	6" in 10"	6"	6" in 10"	C-05-06
IRL-004	4"	4"	4"	4"	6" in 10"	6"	6" in 10"	C-05-07

NOTE: Six Vaults are represented by this drawing.
RW (remedy water) pipe is double contained leaving the vaults.
All HDPE piping is Standard Dimension Ratio - SDR-11
All CPVC piping is Schedule 80



WELL FLANGE DETAIL

NTS

NOTES:
1. FOR DISTANCE BETWEEN VAULTS, SEE TABLE 2 FOR CIVIL DRAWING REFERENCE.

PRELIMINARY PLANS-NOT FOR CONSTRUCTION

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NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	2012/09/12	INTERMEDIATE (60%) DESIGN SUBMITTAL		GJ			JP

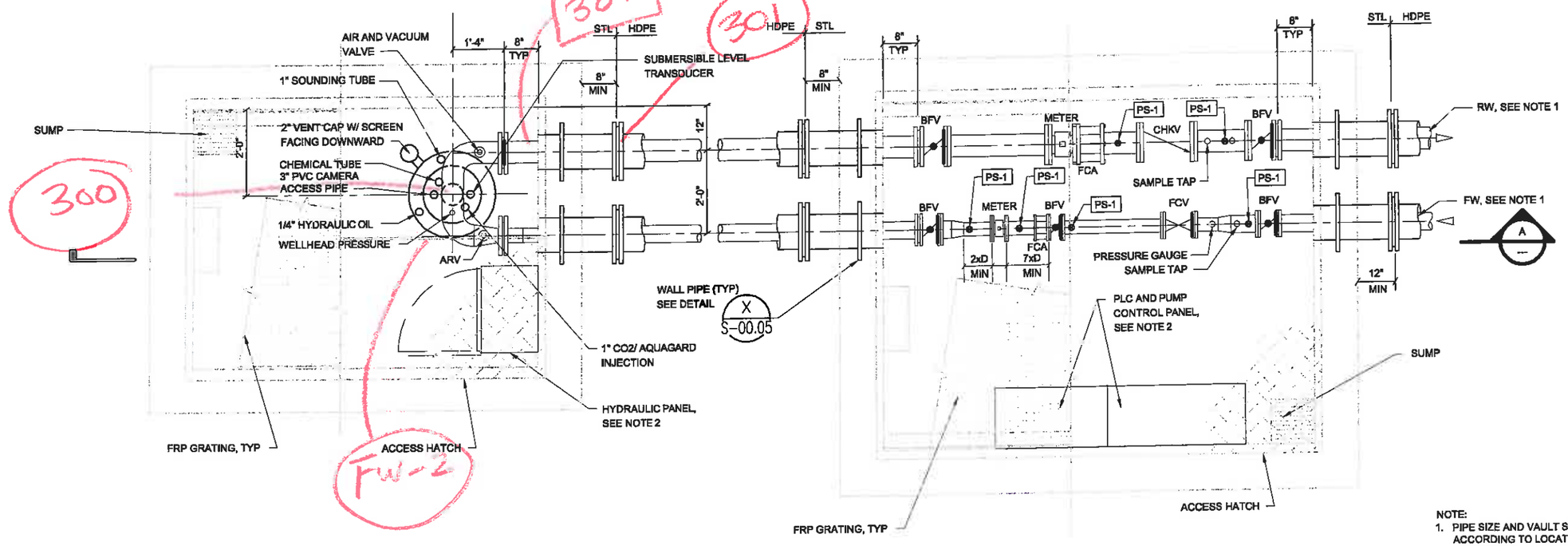
REVISIONS

APPROVED BY: SD
SUPV
DSGN GJ
DWN GJ
CHKD EL
OK JP
DATE 9/12/12
SCALES

TOPOCK GROUNDWATER REMEDIATION PROJECT
FRESHWATER INJECTION WELL CONSTRUCTION DETAILS
PACIFIC GAS AND ELECTRIC COMPANY
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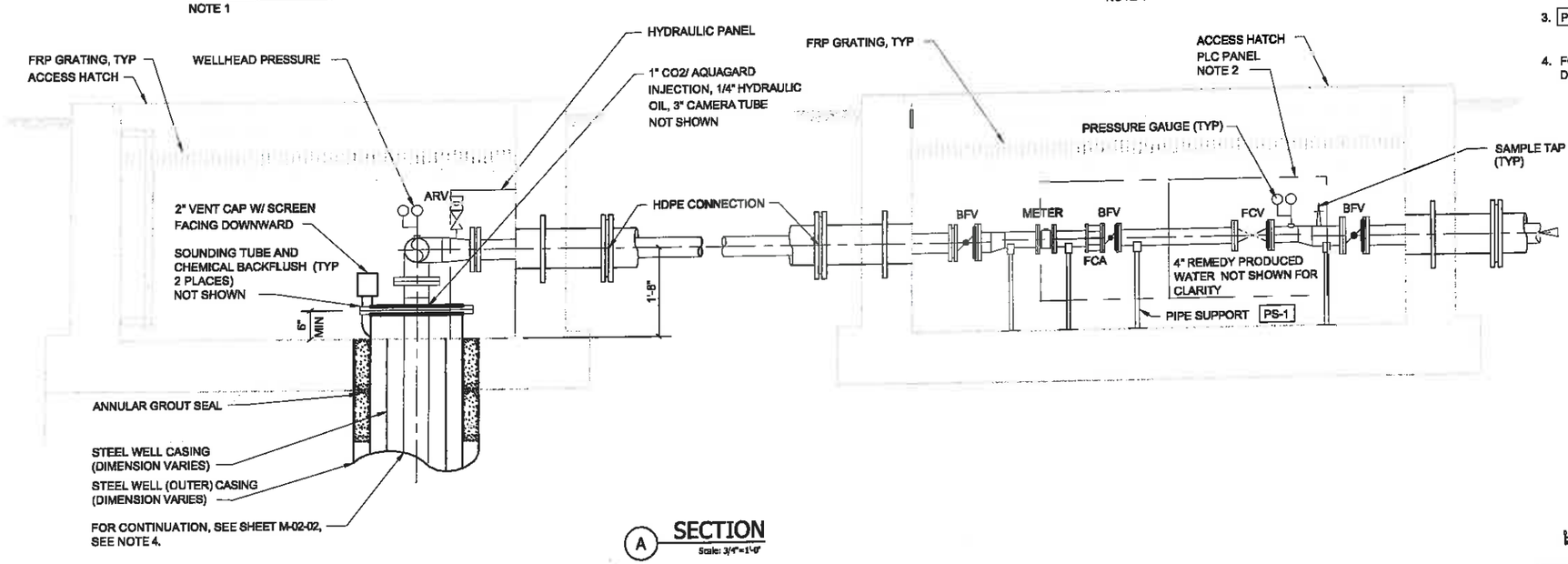
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SHEET NO. M-02-02 of SHEETS
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WELL VAULT PLAN

NOTE 1



A SECTION

Scale: 3/4"=1'-0"

METER VAULT PLAN

NOTE 1

NOTE:

1. PIPE SIZE AND VAULT SIZES VARY ACCORDING TO LOCATION, SEE TABLE 2 ON DWG M-02-02, TYP OF 6 SETS OF VAULTS
2. FOR CONTROL PANEL PLACEMENT SEE ELECTRICAL DRAWING E-02-01-A
3. PS-1 PIPE SUPPORT, SEE DETAIL 2 S-00.05
4. FOR STRUCTURAL VAULT DIMENSIONS SEE DRAWINGS S-02-01 AND S-02-02.

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NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	2012/09/12	INTERMEDIATE (60%) DESIGN SUBMITTAL		GJ			JP

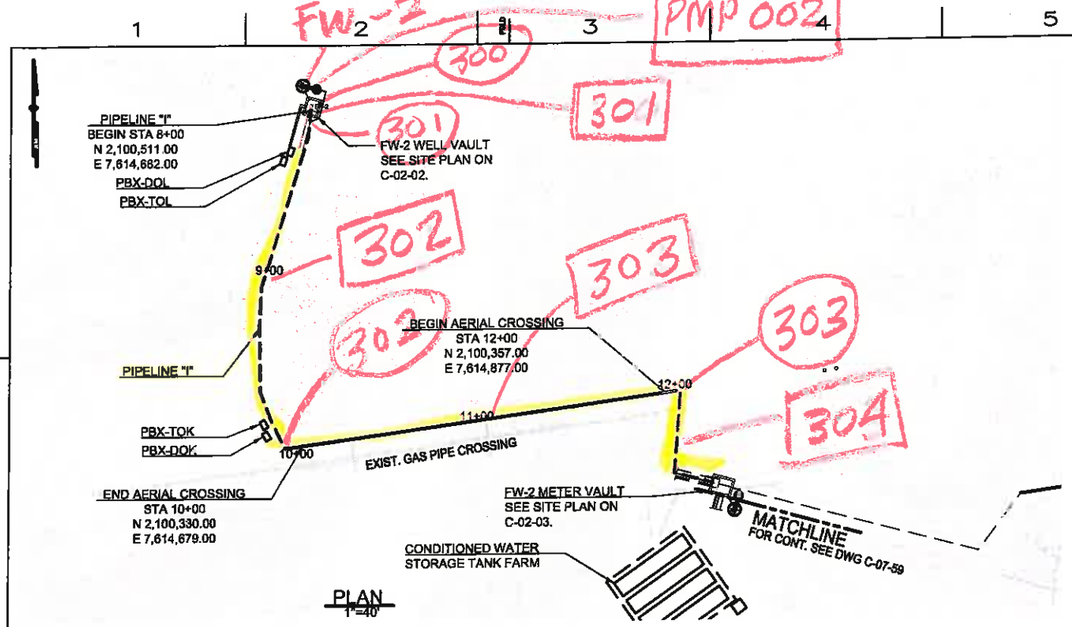
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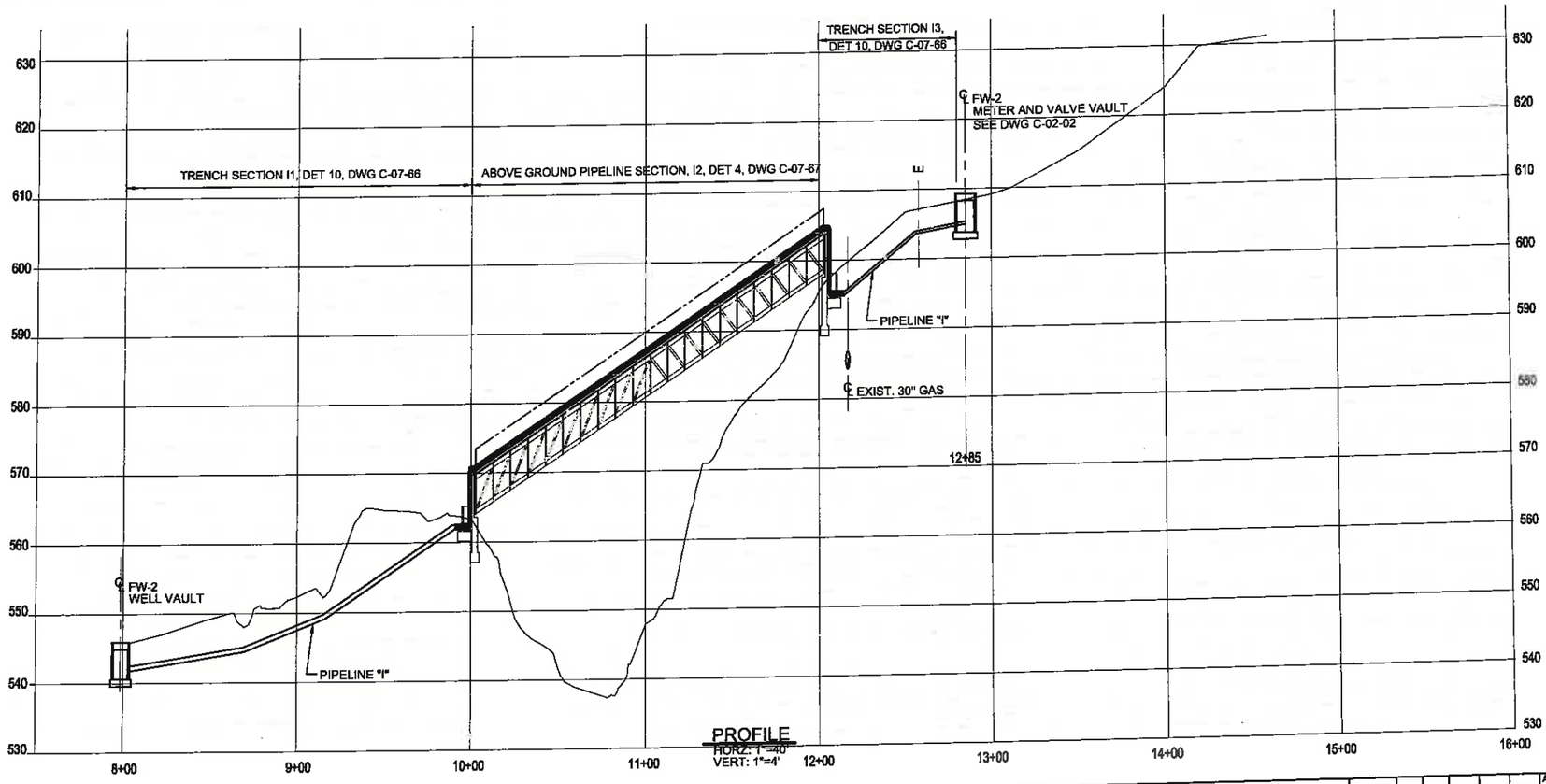
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TOPOCK GROUNDWATER REMEDIATION PROJECT
FRESHWATER INJECTION WELL AND METER VAULT PLAN AND SECTIONS
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. of SHEETS
M-02-01
REV

PLOT DATE: $PLOTDATE PLOT TIME: $PLOTTIME
FILENAME: CH-M-XXX-0201AD.dwg





NOTES

1. DEPTHS OF EXISTING UTILITIES ARE UNKNOWN. ALL POTENTIAL CONFLICTS BETWEEN NEW PIPE CONSTRUCTION AND EXISTING UTILITIES WILL BE POTHOLED PRIOR TO THE 100% DESIGN. A DETERMINATION WILL BE MADE WHETHER TO RELOCATE EXISTING UTILITIES OR RE-ROUTE NEW PIPE TRENCHES AROUND EXISTING UTILITIES. THIS WILL BE INCORPORATED INTO THE 100% DESIGN.
2. THE NEW PIPELINE ALIGNMENT SHOWS CENTER OF TRENCH. THE NUMBER AND SIZES OF PIPE IN EACH TRENCH VARIES. REFER TO PIPE SECTION NUMBER ON EACH PLAN AND PROFILE SHEET AND PIPE SCHEDULE ON DRAWING C-07-03 FOR NUMBER AND SIZE OF EACH PIPE. REFER TO TRENCH DETAILS ON DRAWINGS C-07-65, C-07-66 AND C-07-67 FOR ARRANGEMENT OF PIPING IN EACH TRENCH SECTION.

35/38

HORZ: SCALE: 1"=40'-0"
VERT: SCALE: 1"=10'-0"

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NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

REVISIONS

APPROVED BY: SO, SUPV, DSGN PT, DWN PC, CHKD PT, OK PT, DATE 9/12/12, SCALES 1" =40'

TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE "I" - PLAN AND PROFILE
STA 8+00 TO STA 12+85

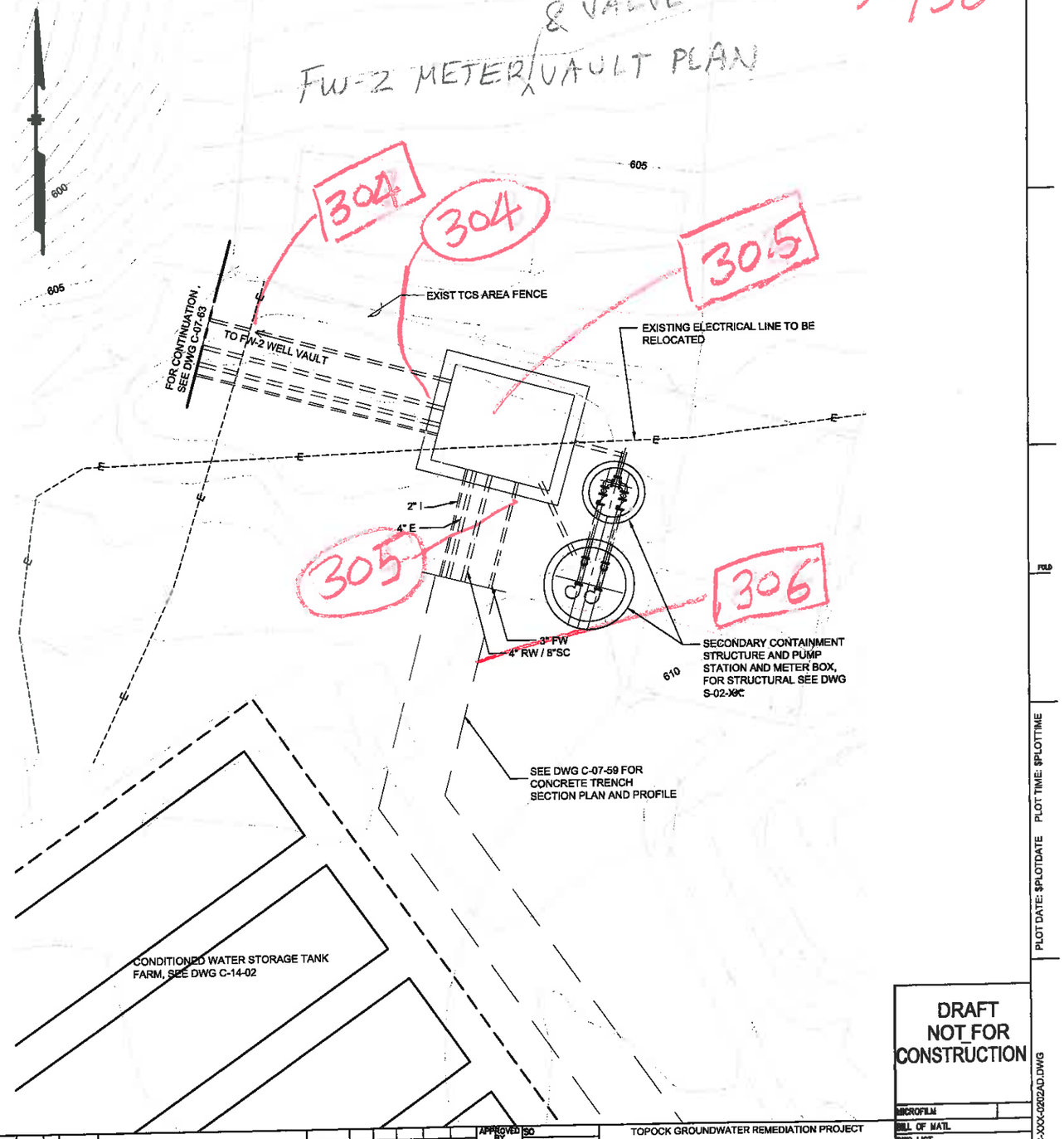
G/S TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
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SUPSD BY
SHEET NO. C-07-63 of SHEETS
REV

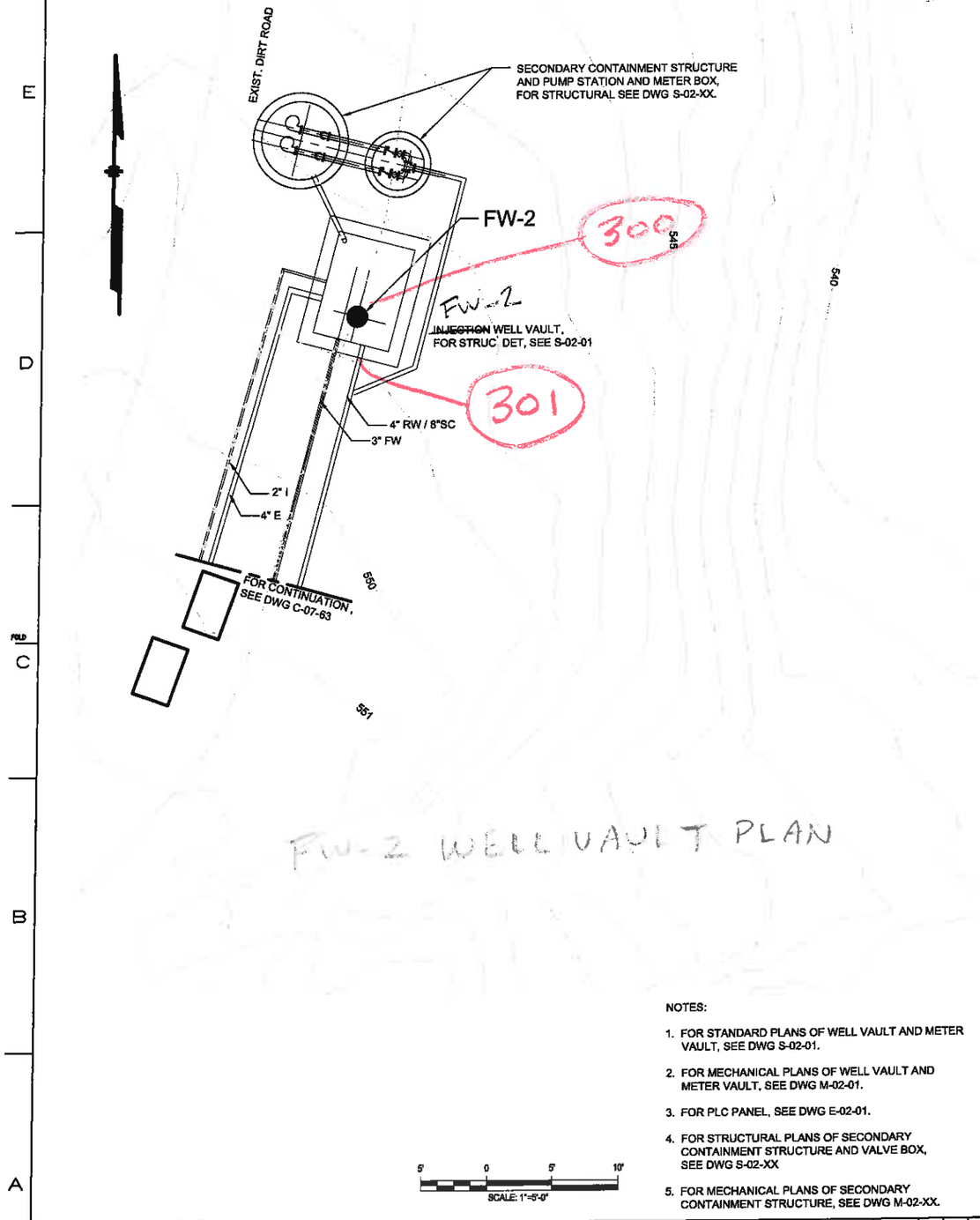
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36/38

FW-2 METER & VALVE VAULT PLAN



FW-2 WELL VAULT PLAN



NOTES:

1. FOR STANDARD PLANS OF WELL VAULT AND METER VAULT, SEE DWG S-02-01.
2. FOR MECHANICAL PLANS OF WELL VAULT AND METER VAULT, SEE DWG M-02-01.
3. FOR PLC PANEL, SEE DWG E-02-01.
4. FOR STRUCTURAL PLANS OF SECONDARY CONTAINMENT STRUCTURE AND VALVE BOX, SEE DWG S-02-XX
5. FOR MECHANICAL PLANS OF SECONDARY CONTAINMENT STRUCTURE, SEE DWG M-02-XX.

SCALE: 1"=5'-0"

E2 Consulting Engineers, Inc.
6080 Pearl Road, Ste. 200
Parma, OH 44129
(440) 888-7100

CH2MHILL.

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

REVISIONS

APPROVED BY: SO, SUPV, DSGN PT, DWN PC, CHKD PT, QK PT, DATE 9/12/12, SCALES 1" =5'-0"

TOPOCK GROUNDWATER REMEDIATION PROJECT

FRESH WATER INJECTION WELL FW-2 - SITE PLAN

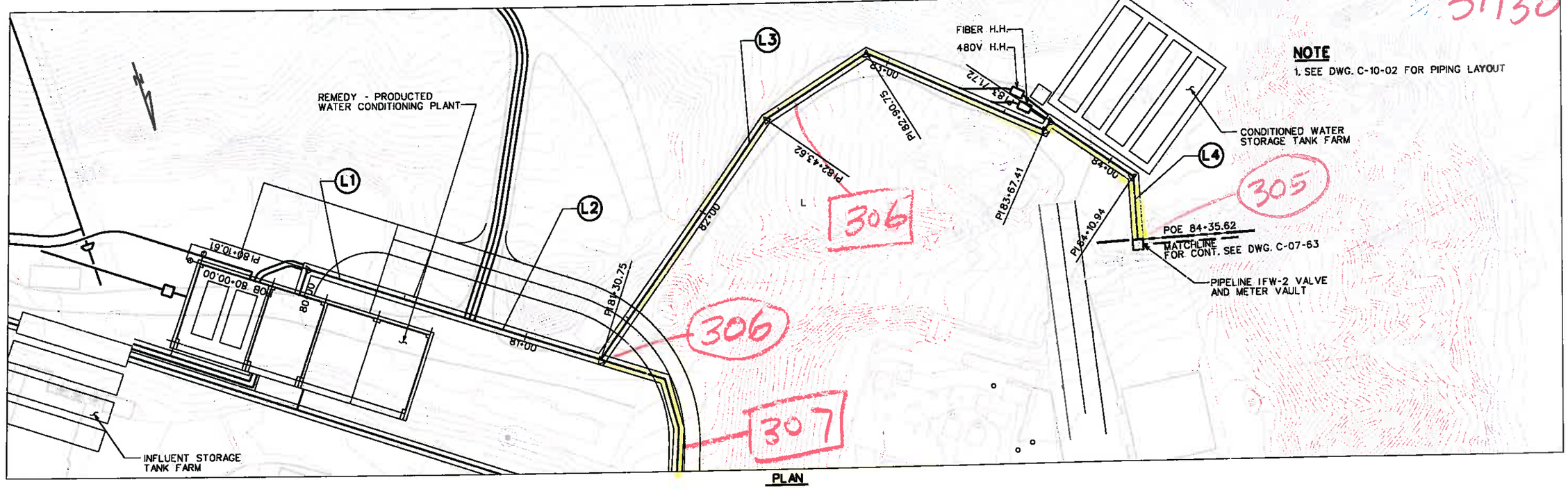
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

DRAFT NOT FOR CONSTRUCTION

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. of SHEETS
C-02-02
REV

PLOT DATE: $PLOTDATE PLOT TIME: $PLOTTIME
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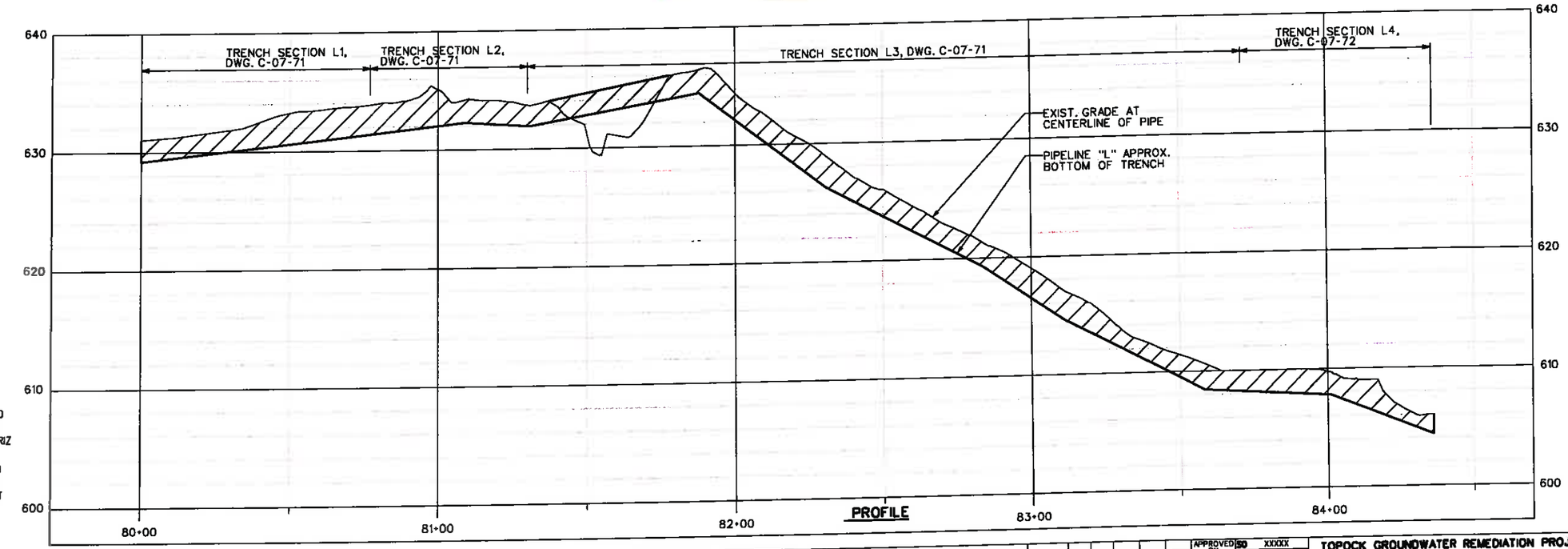
37/38



PLAN

NOTE

1. SEE DWG. C-10-02 FOR PIPING LAYOUT



PROFILE

GRAPHIC SCALE: 1"=20' HORIZ (0 5 10 20 40)

GRAPHIC SCALE: 1"=5' VERT (0 5 10)

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AECOM
2101 WEBSTER STREET SUITE 1000
OAKLAND, CA 94612-3060
PROJECT NO. 60272335

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

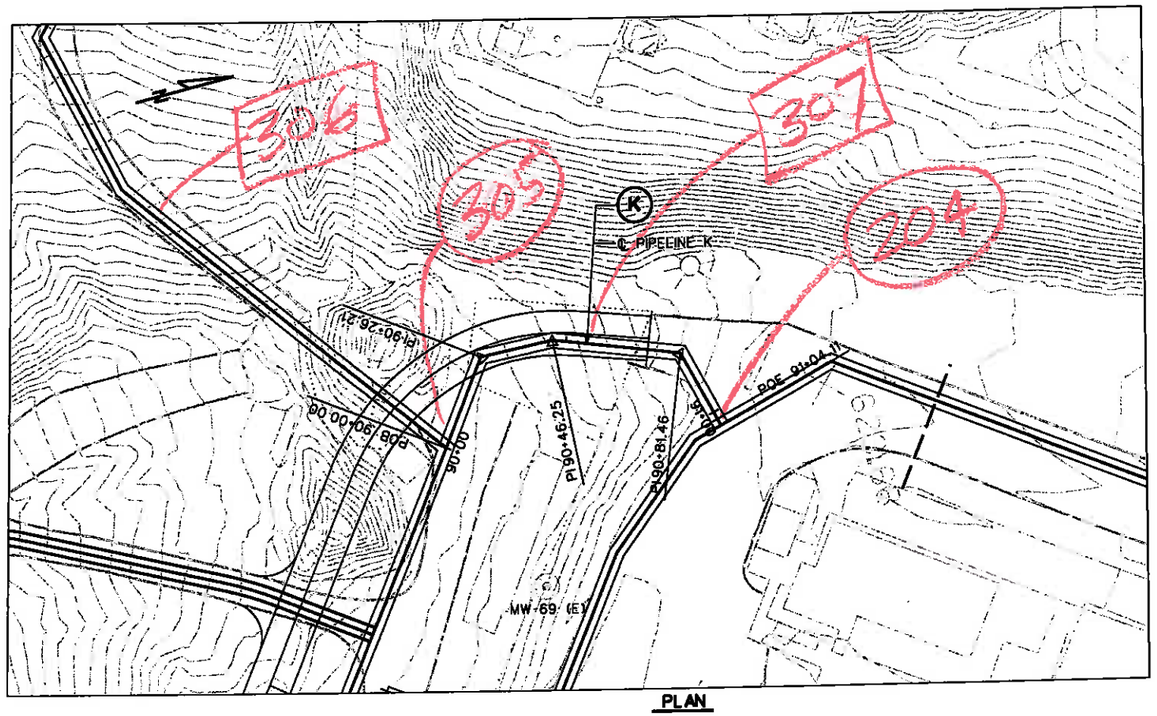
REVISIONS

APPROVED BY	
GM/SPEC	XXXXX
SUPV	PD
DWN	TL
CHKD	TL
CHKD	JM
APVD	PD
DATE	9/12/12
SCALES	1" = 20'-0"

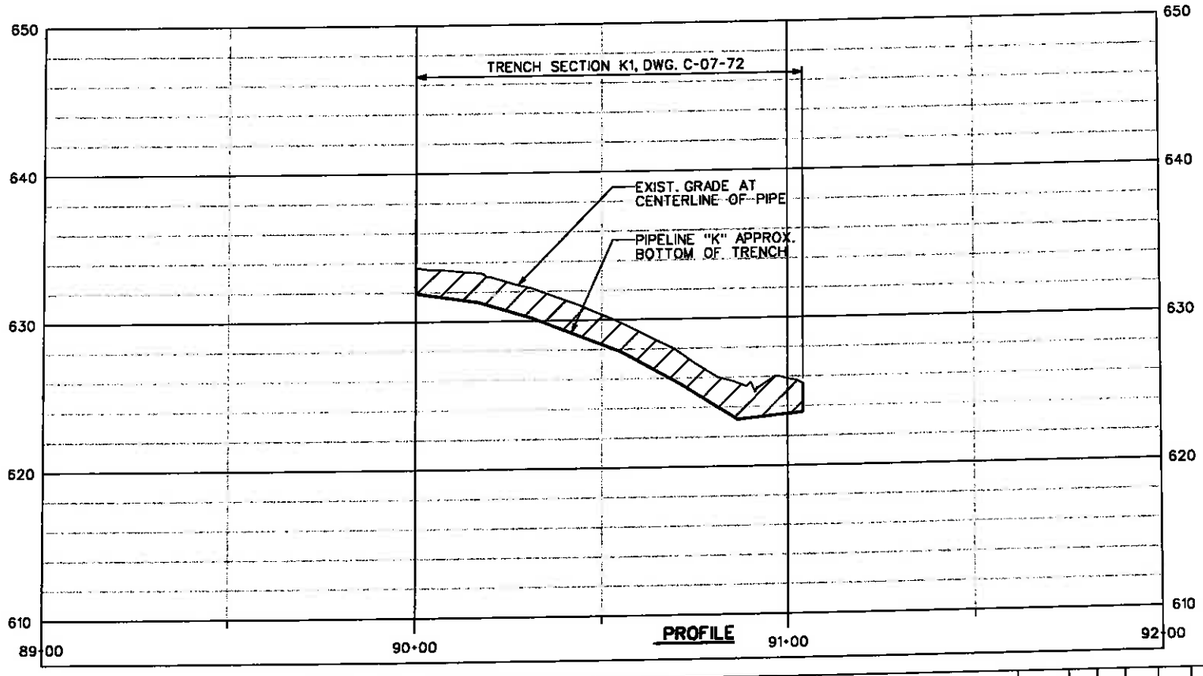
TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE L
PLAN AND PROFILE
80+00 TO 84+46
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

ACCEPTED	
BILL OF MATL	
CHG LIST	
DESIGN	
DRAFTED BY	
SHEET NO.	OF SHEETS
C-07-59	REV 0

38/38



PLAN



PROFILE

0 5 10 20 40
GRAPHIC SCALE: 1"=20' HORIZ

0 5 10
GRAPHIC SCALE: 1"=5' VERT

AECOM
2101 WEBSTER STREET SUITE 1000
OAKLAND, CA 94612-3068
PROJECT NO. 60272335

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

REVISIONS

APPROVED BY		
GD	XXXXX	
SUPV	PD	
DSGN	TL	
DWN	TL	
CHKD	JM	
QA	PD	
DATE	9/12/12	
SCALES	1" = 20'-0"	

TOPOCK GROUNDWATER REMEDIATION PROJECT
PIPELINE K
PLAN AND PROFILE
90+00 TO 91+04
GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

- DRAFT -
NOT FOR CONSTRUCTION

MICROFILM	
BILL OF MAT'L	
DWG LIST	
SUPSDS	
SUPSD BY	
SHEET NO.	OF SHEETS
C-07-58	REV 0

Backwash pump at FW-1 operating

Network Table - Nodes

Node ID	Demand GPM	Head ft	Pressure psi
Junc 100	0.00	553.70	69.63
Junc 101	0.00	550.90	-3.08
Junc 102	0.00	537.48	-7.59
Junc 103	0.00	536.86	-7.86
Junc 104	0.00	534.42	-6.75
Junc 105	0.00	525.12	11.75
Junc 106	0.00	523.70	19.80
Junc 107	0.00	522.27	18.32
Junc 108	0.00	511.67	-7.94
Junc 109	0.00	511.41	14.48
Junc 110	0.00	510.99	14.29
Junc 111	0.00	510.11	7.41
Junc 112	0.00	509.57	6.75
Junc 113	0.00	509.39	6.23
Junc 114	0.00	509.05	6.09
Junc 115	0.00	508.37	3.63
Junc 116	0.00	537.48	57.40
Junc 117	0.00	537.48	-8.46
Junc 118	0.00	536.86	60.60
Junc 119	0.00	536.86	-6.56
Junc 120	0.00	534.42	62.58
Junc 121	0.00	534.42	-7.18
Junc 122	0.00	525.12	59.85
Junc 123	0.00	525.12	11.32
Junc 124	0.00	508.00	4.77

Backwash pump at FW-1 operating

Node ID	Demand GPM	Head ft	Pressure psi
Junc 125	0.00	508.00	4.77
Junc 126	0.00	508.00	4.77
Junc 127	0.00	508.00	4.77
Junc 128	0.00	638.00	61.10
Junc 129	0.00	638.00	61.10
Junc 130	0.00	638.00	4.77
Junc 131	0.00	638.00	4.77
Junc 132	0.00	638.00	4.77
Junc 133	0.00	638.00	4.77
Junc 200	0.00	638.00	107.46
Junc 201	0.00	638.00	9.53
Junc 202	0.00	638.00	9.53
Junc 203	0.00	638.00	8.67
Junc 204	0.00	638.00	5.63
Junc 205	0.00	638.00	6.50
Junc 206	0.00	638.00	6.50
Junc 207	0.00	638.00	4.33
Junc 208	0.00	638.00	4.33
Junc 209	0.00	638.00	4.33
Junc 210	0.00	638.00	4.33
Junc 211	0.00	638.00	107.46
Junc 212	0.00	638.00	23.40
Junc 213	0.00	638.00	23.40
Junc 300	0.00	638.00	98.79
Junc 301	0.00	638.00	41.16
Junc 302	0.00	638.00	32.50

Backwash pump at FW-1 operating

Node ID	Demand GPM	Head ft	Pressure psi
Junc 303	0.00	638.00	13.87
Junc 304	0.00	638.00	13.87
Junc 305	0.00	638.00	13.87
Junc 306	0.00	638.00	5.63
Resvr FW-1	-400.00	405.00	0.00
Resvr FW-2	0.00	420.00	0.00
Resvr IRL-1	0.00	405.00	0.00
Resvr IRL-2	0.00	405.00	0.00
Resvr IRL-3	0.00	405.00	0.00
Resvr IRL-4	0.00	405.00	0.00
Resvr TCS-1	0.00	405.00	0.00
Resvr TCS-2	0.00	405.00	0.00
Tank T721	399.99	508.00	4.33
Tank T201	-0.14	638.00	4.33
Tank T202	-0.05	638.00	4.33
Tank T203	0.05	638.00	4.33
Tank T204	0.14	638.00	4.33

Backwash pump at FW-1 operating

Network Table - Links

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 101	400.00	4.92	12.71	Open
Pipe 102	400.00	4.92	12.71	Open
Pipe 103	400.00	5.56	17.09	Open
Pipe 104	400.00	5.56	17.09	Open
Pipe 105	399.99	5.56	17.09	Open
Pipe 106	399.99	3.28	4.73	Open
Pipe 107	399.99	2.92	4.64	Open
Pipe 108	399.99	3.28	4.73	Open
Pipe 109	399.99	3.28	4.73	Open
Pipe 110	399.99	3.28	4.73	Open
Pipe 111	399.99	3.28	4.73	Open
Pipe 112	399.99	3.28	4.73	Open
Pipe 113	399.99	3.28	4.73	Open
Pipe 114	399.99	3.28	4.73	Open
Pipe 115	399.99	3.28	4.73	Open
Pipe 116	399.99	2.92	4.64	Open
Pipe 117	0.00	0.00	0.00	Open
Pipe 118	0.00	0.00	0.00	Open
Pipe 119	0.00	0.00	0.00	Open
Pipe 120	0.00	0.00	0.00	Open
Pipe 121	0.00	0.00	0.00	Open
Pipe 122	0.00	0.00	0.00	Open
Pipe 123	0.00	0.00	0.00	Open
Pipe 124	0.00	0.00	0.00	Open
Pipe 125	0.00	0.00	0.00	Open

Backwash pump at FW-1 operating

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 126	0.00	0.00	0.00	Open
Pipe 127	0.00	0.00	0.00	Open
Pipe 128	0.00	0.00	0.00	Open
Pipe 129	0.00	0.00	0.00	Open
Pipe 130	0.00	0.00	0.00	Open
Pipe 131	0.35	0.01	0.00	Open
Pipe 132	0.46	0.01	0.00	Open
Pipe 133	0.35	0.01	0.00	Open
Pipe 134	-0.35	0.03	0.00	Open
Pipe 135	-0.11	0.01	0.00	Open
Pipe 136	0.11	0.01	0.00	Open
Pipe 137	0.35	0.03	0.00	Open
Pipe 201	0.00	0.00	0.00	Open
Pipe 202	0.00	0.00	0.00	Open
Pipe 203	0.00	0.00	0.00	Open
Pipe 204	0.00	0.00	0.00	Open
Pipe 205	0.00	0.00	0.00	Open
Pipe 206	0.00	0.00	0.00	Open
Pipe 207	0.00	0.00	0.00	Open
Pipe 208	0.48	0.00	0.00	Open
Pipe 209	0.64	0.00	0.00	Open
Pipe 210	0.48	0.00	0.00	Open
Pipe 211	-0.49	0.03	0.00	Open
Pipe 212	-0.16	0.01	0.00	Open
Pipe 213	0.16	0.01	0.00	Open
Pipe 214	0.48	0.03	0.00	Open

Backwash pump at FW-1 operating

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 215	0.00	0.00	0.00	Open
Pipe 216	0.00	0.00	0.00	Open
Pipe 217	0.00	0.00	0.00	Open
Pipe 301	0.00	0.00	0.00	Open
Pipe 302	0.00	0.00	0.00	Open
Pipe 303	0.00	0.00	0.00	Open
Pipe 304	0.00	0.00	0.00	Open
Pipe 305	0.00	0.00	0.00	Open
Pipe 306	0.00	0.00	0.00	Open
Pipe 307	0.00	0.00	0.00	Open
Pump PMP001	400.00	0.00	-148.70	Open
Pump PMP002	0.00	0.00	0.00	Closed
Pump PMP442	0.00	0.00	0.00	Closed
Pump PMP443	0.00	0.00	0.00	Closed
Pump PMP641	0.00	0.00	0.00	Closed
Pump PMP642	0.00	0.00	0.00	Closed
Pump PMP643	0.00	0.00	0.00	Closed
Pump PMP644	0.00	0.00	0.00	Closed
Pump PMP745	0.00	0.00	0.00	Closed

Backwash pump at FW-2 operating

Network Table - Nodes

Node ID	Demand GPM	Head ft	Pressure psi
Junc 100	0.00	508.00	49.83
Junc 101	0.00	508.00	-21.67
Junc 102	0.00	508.00	-20.37
Junc 103	0.00	508.00	-20.37
Junc 104	0.00	508.00	-18.20
Junc 105	0.00	508.00	4.33
Junc 106	0.00	508.00	13.00
Junc 107	0.00	508.00	12.13
Junc 108	0.00	508.00	-9.53
Junc 109	0.00	508.00	13.00
Junc 110	0.00	508.00	13.00
Junc 111	0.00	508.00	6.50
Junc 112	0.00	508.00	6.07
Junc 113	0.00	508.00	5.63
Junc 114	0.00	508.00	5.63
Junc 115	0.00	508.00	3.47
Junc 116	0.00	508.00	44.63
Junc 117	0.00	508.00	-21.23
Junc 118	0.00	508.00	48.10
Junc 119	0.00	508.00	-19.07
Junc 120	0.00	508.00	51.13
Junc 121	0.00	508.00	-18.63
Junc 122	0.00	508.00	52.43
Junc 123	0.00	508.00	3.90
Junc 124	0.00	508.00	4.77

Backwash pump at FW-2 operating

Node ID	Demand GPM	Head ft	Pressure psi
Junc 125	0.00	508.00	4.77
Junc 126	0.00	508.00	4.77
Junc 127	0.00	508.00	4.77
Junc 128	0.00	638.00	61.10
Junc 129	0.00	638.00	61.10
Junc 130	0.00	638.00	4.77
Junc 131	0.00	638.00	4.77
Junc 132	0.00	638.00	4.77
Junc 133	0.00	638.00	4.77
Junc 200	0.00	638.65	107.74
Junc 201	0.00	638.65	9.81
Junc 202	0.00	638.65	9.81
Junc 203	0.00	638.65	8.95
Junc 204	0.00	638.65	5.91
Junc 205	0.00	638.46	6.70
Junc 206	0.00	638.40	6.67
Junc 207	0.00	638.33	4.48
Junc 208	0.00	638.31	4.47
Junc 209	0.00	638.30	4.46
Junc 210	0.00	638.29	4.46
Junc 211	0.00	638.65	107.74
Junc 212	0.00	638.65	23.68
Junc 213	0.00	638.65	23.68
Junc 300	0.00	683.66	118.58
Junc 301	0.00	679.42	59.11
Junc 302	0.00	672.81	47.58

Backwash pump at FW-2 operating

Node ID	Demand GPM	Head ft	Pressure psi
Junc 303	0.00	660.44	23.59
Junc 304	0.00	653.93	20.77
Junc 305	0.00	652.46	20.13
Junc 306	0.00	643.51	8.02
Resvr FW-1	0.00	405.00	0.00
Resvr FW-2	-200.00	420.00	0.00
Resvr IRL-1	0.00	405.00	0.00
Resvr IRL-2	0.00	405.00	0.00
Resvr IRL-3	0.00	405.00	0.00
Resvr IRL-4	0.00	405.00	0.00
Resvr TCS-1	0.00	405.00	0.00
Resvr TCS-2	0.00	405.00	0.00
Tank T721	0.00	508.00	4.33
Tank T201	51.93	638.00	4.33
Tank T202	50.05	638.00	4.33
Tank T203	49.14	638.00	4.33
Tank T204	48.88	638.00	4.33

Backwash pump at FW-2 operating

Network Table - Links

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 101	0.00	0.00	0.00	Open
Pipe 102	0.00	0.00	0.00	Open
Pipe 103	0.00	0.00	0.00	Open
Pipe 104	0.00	0.00	0.00	Open
Pipe 105	0.00	0.00	0.00	Open
Pipe 106	0.00	0.00	0.00	Open
Pipe 107	0.00	0.00	0.00	Open
Pipe 108	0.00	0.00	0.00	Open
Pipe 109	0.00	0.00	0.00	Open
Pipe 110	0.00	0.00	0.00	Open
Pipe 111	0.00	0.00	0.00	Open
Pipe 112	0.00	0.00	0.00	Open
Pipe 113	0.00	0.00	0.00	Open
Pipe 114	0.00	0.00	0.00	Open
Pipe 115	0.00	0.00	0.00	Open
Pipe 116	0.00	0.00	0.00	Open
Pipe 117	0.00	0.00	0.00	Open
Pipe 118	0.00	0.00	0.00	Open
Pipe 119	0.00	0.00	0.00	Open
Pipe 120	0.00	0.00	0.00	Open
Pipe 121	0.00	0.00	0.00	Open
Pipe 122	0.00	0.00	0.00	Open
Pipe 123	0.00	0.00	0.00	Open
Pipe 124	0.00	0.00	0.00	Open
Pipe 125	0.00	0.00	0.00	Open

Backwash pump at FW-2 operating

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 126	0.00	0.00	0.00	Open
Pipe 127	0.00	0.00	0.00	Open
Pipe 128	0.00	0.00	0.00	Open
Pipe 129	0.00	0.00	0.00	Open
Pipe 130	0.00	0.00	0.00	Open
Pipe 131	0.03	0.00	0.00	Open
Pipe 132	0.04	0.00	0.00	Open
Pipe 133	0.03	0.00	0.00	Open
Pipe 134	-0.03	0.00	0.00	Open
Pipe 135	-0.01	0.00	0.00	Open
Pipe 136	0.01	0.00	0.00	Open
Pipe 137	0.03	0.00	0.00	Open
Pipe 201	0.00	0.00	0.00	Open
Pipe 202	0.00	0.00	0.00	Open
Pipe 203	0.00	0.00	0.00	Open
Pipe 204	0.00	0.00	0.00	Open
Pipe 205	200.00	1.64	1.31	Open
Pipe 206	200.00	1.64	1.31	Open
Pipe 207	200.00	1.64	1.31	Open
Pipe 208	148.11	1.08	0.74	Open
Pipe 209	98.07	0.72	0.35	Open
Pipe 210	48.91	0.36	0.09	Open
Pipe 211	51.89	3.21	19.31	Open
Pipe 212	50.04	3.10	18.06	Open
Pipe 213	49.16	3.04	17.47	Open
Pipe 214	48.91	3.03	17.31	Open

Backwash pump at FW-2 operating

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 215	0.00	0.00	0.00	Open
Pipe 216	0.00	0.00	0.00	Open
Pipe 217	0.00	0.00	0.00	Open
Pipe 301	200.00	5.58	25.85	Open
Pipe 302	200.00	6.03	31.16	Open
Pipe 303	200.00	6.56	49.88	Open
Pipe 304	200.00	6.03	31.16	Open
Pipe 305	200.00	5.58	25.85	Open
Pipe 306	200.00	5.58	25.85	Open
Pipe 307	200.00	6.03	31.16	Open
Pump PMP001	0.00	0.00	0.00	Closed
Pump PMP002	200.00	0.00	-263.66	Open
Pump PMP442	0.00	0.00	0.00	Closed
Pump PMP443	0.00	0.00	0.00	Closed
Pump PMP641	0.00	0.00	0.00	Closed
Pump PMP642	0.00	0.00	0.00	Closed
Pump PMP643	0.00	0.00	0.00	Closed
Pump PMP644	0.00	0.00	0.00	Closed
Pump PMP745	0.00	0.00	0.00	Closed

Backwash pump at TCS-2 operating

Network Table - Nodes

Node ID	Demand GPM	Head ft	Pressure psi
Junc 100	0.00	508.00	49.83
Junc 101	0.00	508.00	-21.67
Junc 102	0.00	508.00	-20.37
Junc 103	0.00	508.00	-20.37
Junc 104	0.00	508.00	-18.20
Junc 105	0.00	508.00	4.33
Junc 106	0.00	508.00	13.00
Junc 107	0.00	508.00	12.13
Junc 108	0.00	508.00	-9.53
Junc 109	0.00	508.00	13.00
Junc 110	0.00	508.00	13.00
Junc 111	0.00	508.00	6.50
Junc 112	0.00	508.00	6.07
Junc 113	0.00	508.00	5.63
Junc 114	0.00	508.00	5.63
Junc 115	0.00	508.00	3.47
Junc 116	0.00	508.00	44.63
Junc 117	0.00	508.00	-21.23
Junc 118	0.00	508.00	48.10
Junc 119	0.00	508.00	-19.07
Junc 120	0.00	508.00	51.13
Junc 121	0.00	508.00	-18.63
Junc 122	0.00	508.00	52.43
Junc 123	0.00	508.00	3.90
Junc 124	0.00	508.00	4.77

Backwash pump at TCS-2 operating

Node ID	Demand GPM	Head ft	Pressure psi
Junc 125	0.00	508.00	4.77
Junc 126	0.00	508.00	4.77
Junc 127	0.00	508.00	4.77
Junc 128	0.00	638.00	61.10
Junc 129	0.00	638.00	61.10
Junc 130	0.00	638.00	4.77
Junc 131	0.00	638.00	4.77
Junc 132	0.00	638.00	4.77
Junc 133	0.00	638.00	4.77
Junc 200	0.00	651.18	113.17
Junc 201	0.00	651.18	15.24
Junc 202	0.00	651.18	15.24
Junc 203	0.00	651.18	14.38
Junc 204	0.00	638.11	5.68
Junc 205	0.00	638.08	6.53
Junc 206	0.00	638.06	6.53
Junc 207	0.00	638.05	4.36
Junc 208	0.00	638.05	4.35
Junc 209	0.00	638.05	4.35
Junc 210	0.00	638.05	4.35
Junc 211	0.00	661.37	117.58
Junc 212	0.00	658.06	32.09
Junc 213	0.00	653.96	30.31
Junc 300	0.00	638.11	98.84
Junc 301	0.00	638.11	41.21
Junc 302	0.00	638.11	32.54

Backwash pump at TCS-2 operating

Node ID	Demand GPM	Head ft	Pressure psi
Junc 303	0.00	638.11	13.91
Junc 304	0.00	638.11	13.91
Junc 305	0.00	638.11	13.91
Junc 306	0.00	638.11	5.68
Resvr FW-1	0.00	405.00	0.00
Resvr FW-2	0.00	420.00	0.00
Resvr IRL-1	0.00	405.00	0.00
Resvr IRL-2	0.00	405.00	0.00
Resvr IRL-3	0.00	405.00	0.00
Resvr IRL-4	0.00	405.00	0.00
Resvr TCS-1	0.00	405.00	0.00
Resvr TCS-2	-75.00	405.00	0.00
Tank T721	0.00	508.00	4.33
Tank T201	19.48	638.00	4.33
Tank T202	18.77	638.00	4.33
Tank T203	18.43	638.00	4.33
Tank T204	18.33	638.00	4.33

Backwash pump at TCS-2 operating

Network Table - Links

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 101	0.00	0.00	0.00	Open
Pipe 102	0.00	0.00	0.00	Open
Pipe 103	0.00	0.00	0.00	Open
Pipe 104	0.00	0.00	0.00	Open
Pipe 105	0.00	0.00	0.00	Open
Pipe 106	0.00	0.00	0.00	Open
Pipe 107	0.00	0.00	0.00	Open
Pipe 108	0.00	0.00	0.00	Open
Pipe 109	0.00	0.00	0.00	Open
Pipe 110	0.00	0.00	0.00	Open
Pipe 111	0.00	0.00	0.00	Open
Pipe 112	0.00	0.00	0.00	Open
Pipe 113	0.00	0.00	0.00	Open
Pipe 114	0.00	0.00	0.00	Open
Pipe 115	0.00	0.00	0.00	Open
Pipe 116	0.00	0.00	0.00	Open
Pipe 117	0.00	0.00	0.00	Open
Pipe 118	0.00	0.00	0.00	Open
Pipe 119	0.00	0.00	0.00	Open
Pipe 120	0.00	0.00	0.00	Open
Pipe 121	0.00	0.00	0.00	Open
Pipe 122	0.00	0.00	0.00	Open
Pipe 123	0.00	0.00	0.00	Open
Pipe 124	0.00	0.00	0.00	Open
Pipe 125	0.00	0.00	0.00	Open

Backwash pump at TCS-2 operating

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 126	0.00	0.00	0.00	Open
Pipe 127	0.00	0.00	0.00	Open
Pipe 128	0.00	0.00	0.00	Open
Pipe 129	0.00	0.00	0.00	Open
Pipe 130	0.00	0.00	0.00	Open
Pipe 131	0.02	0.00	0.00	Open
Pipe 132	0.02	0.00	0.00	Open
Pipe 133	0.02	0.00	0.00	Open
Pipe 134	-0.02	0.00	0.00	Open
Pipe 135	-0.01	0.00	0.00	Open
Pipe 136	0.00	0.00	0.00	Open
Pipe 137	0.02	0.00	0.00	Open
Pipe 201	0.00	0.00	0.00	Open
Pipe 202	0.00	0.00	0.00	Open
Pipe 203	0.00	0.00	0.00	Open
Pipe 204	75.00	3.80	17.98	Open
Pipe 205	75.00	0.62	0.21	Open
Pipe 206	75.00	0.62	0.21	Open
Pipe 207	75.00	0.62	0.21	Open
Pipe 208	55.54	0.41	0.12	Open
Pipe 209	36.77	0.27	0.06	Open
Pipe 210	18.34	0.13	0.01	Open
Pipe 211	19.46	1.21	3.14	Open
Pipe 212	18.76	1.16	2.94	Open
Pipe 213	18.43	1.14	2.84	Open
Pipe 214	18.34	1.14	2.81	Open

Backwash pump at TCS-2 operating

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 215	75.00	3.64	16.21	Open
Pipe 216	75.00	3.80	17.98	Open
Pipe 217	75.00	3.80	17.98	Open
Pipe 301	0.00	0.00	0.00	Open
Pipe 302	0.00	0.00	0.00	Open
Pipe 303	0.00	0.00	0.00	Open
Pipe 304	0.00	0.00	0.00	Open
Pipe 305	0.00	0.00	0.00	Open
Pipe 306	0.00	0.00	0.00	Open
Pipe 307	0.00	0.00	0.00	Open
Pump PMP001	0.00	0.00	0.00	Closed
Pump PMP002	0.00	0.00	0.00	Closed
Pump PMP442	75.00	0.00	-256.37	Open
Pump PMP443	0.00	0.00	0.00	Closed
Pump PMP641	0.00	0.00	0.00	Closed
Pump PMP642	0.00	0.00	0.00	Closed
Pump PMP643	0.00	0.00	0.00	Closed
Pump PMP644	0.00	0.00	0.00	Closed
Pump PMP745	0.00	0.00	0.00	Closed

Backwash pump at TCS-1 operating

Network Table - Nodes

Node ID	Demand GPM	Head ft	Pressure psi
Junc 100	0.00	508.00	49.83
Junc 101	0.00	508.00	-21.67
Junc 102	0.00	508.00	-20.37
Junc 103	0.00	508.00	-20.37
Junc 104	0.00	508.00	-18.20
Junc 105	0.00	508.00	4.33
Junc 106	0.00	508.00	13.00
Junc 107	0.00	508.00	12.13
Junc 108	0.00	508.00	-9.53
Junc 109	0.00	508.00	13.00
Junc 110	0.00	508.00	13.00
Junc 111	0.00	508.00	6.50
Junc 112	0.00	508.00	6.07
Junc 113	0.00	508.00	5.63
Junc 114	0.00	508.00	5.63
Junc 115	0.00	508.00	3.47
Junc 116	0.00	508.00	44.63
Junc 117	0.00	508.00	-21.23
Junc 118	0.00	508.00	48.10
Junc 119	0.00	508.00	-19.07
Junc 120	0.00	508.00	51.13
Junc 121	0.00	508.00	-18.63
Junc 122	0.00	508.00	52.43
Junc 123	0.00	508.00	3.90
Junc 124	0.00	508.00	4.77

Backwash pump at TCS-1 operating

Node ID	Demand GPM	Head ft	Pressure psi
Junc 125	0.00	508.00	4.77
Junc 126	0.00	508.00	4.77
Junc 127	0.00	508.00	4.77
Junc 128	0.00	638.00	61.10
Junc 129	0.00	638.00	61.10
Junc 130	0.00	638.00	4.77
Junc 131	0.00	638.00	4.77
Junc 132	0.00	638.00	4.77
Junc 133	0.00	638.00	4.77
Junc 200	0.00	664.35	118.88
Junc 201	0.00	660.36	19.22
Junc 202	0.00	653.01	16.04
Junc 203	0.00	651.18	14.38
Junc 204	0.00	638.11	5.68
Junc 205	0.00	638.08	6.53
Junc 206	0.00	638.06	6.53
Junc 207	0.00	638.05	4.36
Junc 208	0.00	638.05	4.35
Junc 209	0.00	638.05	4.35
Junc 210	0.00	638.05	4.35
Junc 211	0.00	651.18	113.17
Junc 212	0.00	651.18	29.11
Junc 213	0.00	651.18	29.11
Junc 300	0.00	638.11	98.84
Junc 301	0.00	638.11	41.21
Junc 302	0.00	638.11	32.54

Backwash pump at TCS-1 operating

Node ID	Demand GPM	Head ft	Pressure psi
Junc 303	0.00	638.11	13.91
Junc 304	0.00	638.11	13.91
Junc 305	0.00	638.11	13.91
Junc 306	0.00	638.11	5.68
Resvr FW-1	0.00	405.00	0.00
Resvr FW-2	0.00	420.00	0.00
Resvr IRL-1	0.00	405.00	0.00
Resvr IRL-2	0.00	405.00	0.00
Resvr IRL-3	0.00	405.00	0.00
Resvr IRL-4	0.00	405.00	0.00
Resvr TCS-1	-75.00	405.00	0.00
Resvr TCS-2	0.00	405.00	0.00
Tank T721	0.00	508.00	4.33
Tank T201	19.48	638.00	4.33
Tank T202	18.77	638.00	4.33
Tank T203	18.43	638.00	4.33
Tank T204	18.33	638.00	4.33

Backwash pump at TCS-1 operating

Network Table - Links

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 101	0.00	0.00	0.00	Open
Pipe 102	0.00	0.00	0.00	Open
Pipe 103	0.00	0.00	0.00	Open
Pipe 104	0.00	0.00	0.00	Open
Pipe 105	0.00	0.00	0.00	Open
Pipe 106	0.00	0.00	0.00	Open
Pipe 107	0.00	0.00	0.00	Open
Pipe 108	0.00	0.00	0.00	Open
Pipe 109	0.00	0.00	0.00	Open
Pipe 110	0.00	0.00	0.00	Open
Pipe 111	0.00	0.00	0.00	Open
Pipe 112	0.00	0.00	0.00	Open
Pipe 113	0.00	0.00	0.00	Open
Pipe 114	0.00	0.00	0.00	Open
Pipe 115	0.00	0.00	0.00	Open
Pipe 116	0.00	0.00	0.00	Open
Pipe 117	0.00	0.00	0.00	Open
Pipe 118	0.00	0.00	0.00	Open
Pipe 119	0.00	0.00	0.00	Open
Pipe 120	0.00	0.00	0.00	Open
Pipe 121	0.00	0.00	0.00	Open
Pipe 122	0.00	0.00	0.00	Open
Pipe 123	0.00	0.00	0.00	Open
Pipe 124	0.00	0.00	0.00	Open
Pipe 125	0.00	0.00	0.00	Open

Backwash pump at TCS-1 operating

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 126	0.00	0.00	0.00	Open
Pipe 127	0.00	0.00	0.00	Open
Pipe 128	0.00	0.00	0.00	Open
Pipe 129	0.00	0.00	0.00	Open
Pipe 130	0.00	0.00	0.00	Open
Pipe 131	0.02	0.00	0.00	Open
Pipe 132	0.02	0.00	0.00	Open
Pipe 133	0.02	0.00	0.00	Open
Pipe 134	-0.02	0.00	0.00	Open
Pipe 135	-0.01	0.00	0.00	Open
Pipe 136	0.00	0.00	0.00	Open
Pipe 137	0.02	0.00	0.00	Open
Pipe 201	75.00	3.64	16.21	Open
Pipe 202	75.00	3.80	17.98	Open
Pipe 203	75.00	3.80	17.98	Open
Pipe 204	75.00	3.80	17.98	Open
Pipe 205	75.00	0.62	0.21	Open
Pipe 206	75.00	0.62	0.21	Open
Pipe 207	75.00	0.62	0.21	Open
Pipe 208	55.54	0.41	0.12	Open
Pipe 209	36.77	0.27	0.06	Open
Pipe 210	18.34	0.13	0.01	Open
Pipe 211	19.46	1.21	3.14	Open
Pipe 212	18.76	1.16	2.94	Open
Pipe 213	18.43	1.14	2.84	Open
Pipe 214	18.34	1.14	2.81	Open

Backwash pump at TCS-1 operating

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 215	0.00	0.00	0.00	Open
Pipe 216	0.00	0.00	0.00	Open
Pipe 217	0.00	0.00	0.00	Open
Pipe 301	0.00	0.00	0.00	Open
Pipe 302	0.00	0.00	0.00	Open
Pipe 303	0.00	0.00	0.00	Open
Pipe 304	0.00	0.00	0.00	Open
Pipe 305	0.00	0.00	0.00	Open
Pipe 306	0.00	0.00	0.00	Open
Pipe 307	0.00	0.00	0.00	Open
Pump PMP001	0.00	0.00	0.00	Closed
Pump PMP002	0.00	0.00	0.00	Closed
Pump PMP442	0.00	0.00	0.00	Closed
Pump PMP443	75.00	0.00	-259.35	Open
Pump PMP641	0.00	0.00	0.00	Closed
Pump PMP642	0.00	0.00	0.00	Closed
Pump PMP643	0.00	0.00	0.00	Closed
Pump PMP644	0.00	0.00	0.00	Closed
Pump PMP745	0.00	0.00	0.00	Closed

Backwash pump at IRL-1 operating

Network Table - Nodes

Node ID	Demand GPM	Head ft	Pressure psi
Junc 100	0.00	525.12	57.25
Junc 101	0.00	525.12	-14.25
Junc 102	0.00	525.12	-12.95
Junc 103	0.00	525.12	-12.95
Junc 104	0.00	525.12	-10.78
Junc 105	0.00	525.12	11.75
Junc 106	0.00	523.70	19.80
Junc 107	0.00	522.27	18.32
Junc 108	0.00	511.67	-7.94
Junc 109	0.00	511.41	14.48
Junc 110	0.00	510.99	14.29
Junc 111	0.00	510.11	7.41
Junc 112	0.00	509.57	6.75
Junc 113	0.00	509.39	6.23
Junc 114	0.00	509.05	6.09
Junc 115	0.00	508.37	3.63
Junc 116	0.00	525.12	52.05
Junc 117	0.00	525.12	-13.81
Junc 118	0.00	525.12	55.52
Junc 119	0.00	525.12	-11.65
Junc 120	0.00	525.12	58.55
Junc 121	0.00	525.12	-11.21
Junc 122	0.00	535.27	64.24
Junc 123	0.00	525.67	11.56
Junc 124	0.00	508.00	4.77

Backwash pump at IRL-1 operating

Node ID	Demand GPM	Head ft	Pressure psi
Junc 125	0.00	508.00	4.77
Junc 126	0.00	508.00	4.77
Junc 127	0.00	508.00	4.77
Junc 128	0.00	638.00	61.10
Junc 129	0.00	638.00	61.10
Junc 130	0.00	638.00	4.77
Junc 131	0.00	638.00	4.77
Junc 132	0.00	638.00	4.77
Junc 133	0.00	638.00	4.77
Junc 200	0.00	638.00	107.46
Junc 201	0.00	638.00	9.53
Junc 202	0.00	638.00	9.53
Junc 203	0.00	638.00	8.67
Junc 204	0.00	638.00	5.63
Junc 205	0.00	638.00	6.50
Junc 206	0.00	638.00	6.50
Junc 207	0.00	638.00	4.33
Junc 208	0.00	638.00	4.33
Junc 209	0.00	638.00	4.33
Junc 210	0.00	638.00	4.33
Junc 211	0.00	638.00	107.46
Junc 212	0.00	638.00	23.40
Junc 213	0.00	638.00	23.40
Junc 300	0.00	638.00	98.79
Junc 301	0.00	638.00	41.16
Junc 302	0.00	638.00	32.50

Backwash pump at IRL-1 operating

Node ID	Demand GPM	Head ft	Pressure psi
Junc 303	0.00	638.00	13.87
Junc 304	0.00	638.00	13.87
Junc 305	0.00	638.00	13.87
Junc 306	0.00	638.00	5.63
Resvr FW-1	0.00	405.00	0.00
Resvr FW-2	0.00	420.00	0.00
Resvr IRL-1	-400.00	405.00	0.00
Resvr IRL-2	0.00	405.00	0.00
Resvr IRL-3	0.00	405.00	0.00
Resvr IRL-4	0.00	405.00	0.00
Resvr TCS-1	0.00	405.00	0.00
Resvr TCS-2	0.00	405.00	0.00
Tank T721	400.00	508.00	4.33
Tank T201	-0.06	638.00	4.33
Tank T202	-0.02	638.00	4.33
Tank T203	0.02	638.00	4.33
Tank T204	0.06	638.00	4.33

Backwash pump at IRL-1 operating

Network Table - Links

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 101	0.00	0.00	0.00	Open
Pipe 102	0.00	0.00	0.00	Open
Pipe 103	0.00	0.00	0.00	Open
Pipe 104	0.00	0.00	0.00	Open
Pipe 105	0.00	0.00	0.00	Open
Pipe 106	400.00	3.28	4.73	Open
Pipe 107	400.00	2.92	4.64	Open
Pipe 108	400.00	3.28	4.73	Open
Pipe 109	400.00	3.28	4.73	Open
Pipe 110	400.00	3.28	4.73	Open
Pipe 111	400.00	3.28	4.73	Open
Pipe 112	400.00	3.28	4.73	Open
Pipe 113	400.00	3.28	4.73	Open
Pipe 114	400.00	3.28	4.73	Open
Pipe 115	400.00	3.28	4.73	Open
Pipe 116	400.00	2.92	4.64	Open
Pipe 117	0.00	0.00	0.00	Open
Pipe 118	0.00	0.00	0.00	Open
Pipe 119	0.00	0.00	0.00	Open
Pipe 120	0.00	0.00	0.00	Open
Pipe 121	0.00	0.00	0.00	Open
Pipe 122	0.00	0.00	0.00	Open
Pipe 123	400.00	4.92	12.71	Open
Pipe 124	400.00	5.56	17.09	Open
Pipe 125	0.00	0.00	0.00	Open

Backwash pump at IRL-1 operating

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 126	0.00	0.00	0.00	Open
Pipe 127	0.00	0.00	0.00	Open
Pipe 128	0.00	0.00	0.00	Open
Pipe 129	0.00	0.00	0.00	Open
Pipe 130	0.00	0.00	0.00	Open
Pipe 131	0.16	0.00	0.00	Open
Pipe 132	0.21	0.01	0.00	Open
Pipe 133	0.16	0.00	0.00	Open
Pipe 134	-0.16	0.02	0.00	Open
Pipe 135	-0.05	0.00	0.00	Open
Pipe 136	0.05	0.00	0.00	Open
Pipe 137	0.16	0.02	0.00	Open
Pipe 201	0.00	0.00	0.00	Open
Pipe 202	0.00	0.00	0.00	Open
Pipe 203	0.00	0.00	0.00	Open
Pipe 204	0.00	0.00	0.00	Open
Pipe 205	0.00	0.00	0.00	Open
Pipe 206	0.00	0.00	0.00	Open
Pipe 207	0.00	0.00	0.00	Open
Pipe 208	0.22	0.00	0.00	Open
Pipe 209	0.29	0.00	0.00	Open
Pipe 210	0.22	0.00	0.00	Open
Pipe 211	-0.22	0.01	0.00	Open
Pipe 212	-0.07	0.00	0.00	Open
Pipe 213	0.07	0.00	0.00	Open
Pipe 214	0.22	0.01	0.00	Open

Backwash pump at IRL-1 operating

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 215	0.00	0.00	0.00	Open
Pipe 216	0.00	0.00	0.00	Open
Pipe 217	0.00	0.00	0.00	Open
Pipe 301	0.00	0.00	0.00	Open
Pipe 302	0.00	0.00	0.00	Open
Pipe 303	0.00	0.00	0.00	Open
Pipe 304	0.00	0.00	0.00	Open
Pipe 305	0.00	0.00	0.00	Open
Pipe 306	0.00	0.00	0.00	Open
Pipe 307	0.00	0.00	0.00	Open
Pump PMP001	0.00	0.00	0.00	Closed
Pump PMP002	0.00	0.00	0.00	Closed
Pump PMP442	0.00	0.00	0.00	Closed
Pump PMP443	0.00	0.00	0.00	Closed
Pump PMP641	400.00	0.00	-130.27	Open
Pump PMP642	0.00	0.00	0.00	Closed
Pump PMP643	0.00	0.00	0.00	Closed
Pump PMP644	0.00	0.00	0.00	Closed
Pump PMP745	0.00	0.00	0.00	Closed

Backwash pump at IRL-2 operating

Network Table - Nodes

Node ID	Demand GPM	Head ft	Pressure psi
Junc 100	0.00	534.42	61.28
Junc 101	0.00	534.42	-10.22
Junc 102	0.00	534.42	-8.92
Junc 103	0.00	534.42	-8.92
Junc 104	0.00	534.42	-6.75
Junc 105	0.00	525.12	11.75
Junc 106	0.00	523.70	19.80
Junc 107	0.00	522.27	18.32
Junc 108	0.00	511.67	-7.94
Junc 109	0.00	511.41	14.48
Junc 110	0.00	510.99	14.29
Junc 111	0.00	510.11	7.41
Junc 112	0.00	509.57	6.75
Junc 113	0.00	509.39	6.23
Junc 114	0.00	509.05	6.09
Junc 115	0.00	508.37	3.63
Junc 116	0.00	534.42	56.08
Junc 117	0.00	534.42	-9.78
Junc 118	0.00	534.42	59.54
Junc 119	0.00	534.42	-7.62
Junc 120	0.00	546.38	67.76
Junc 121	0.00	536.22	-6.41
Junc 122	0.00	525.12	59.85
Junc 123	0.00	525.12	11.32
Junc 124	0.00	508.00	4.77

Backwash pump at IRL-2 operating

Node ID	Demand GPM	Head ft	Pressure psi
Junc 125	0.00	508.00	4.77
Junc 126	0.00	508.00	4.77
Junc 127	0.00	508.00	4.77
Junc 128	0.00	638.00	61.10
Junc 129	0.00	638.00	61.10
Junc 130	0.00	638.00	4.77
Junc 131	0.00	638.00	4.77
Junc 132	0.00	638.00	4.77
Junc 133	0.00	638.00	4.77
Junc 200	0.00	638.00	107.46
Junc 201	0.00	638.00	9.53
Junc 202	0.00	638.00	9.53
Junc 203	0.00	638.00	8.67
Junc 204	0.00	638.00	5.63
Junc 205	0.00	638.00	6.50
Junc 206	0.00	638.00	6.50
Junc 207	0.00	638.00	4.33
Junc 208	0.00	638.00	4.33
Junc 209	0.00	638.00	4.33
Junc 210	0.00	638.00	4.33
Junc 211	0.00	638.00	107.46
Junc 212	0.00	638.00	23.40
Junc 213	0.00	638.00	23.40
Junc 300	0.00	638.00	98.79
Junc 301	0.00	638.00	41.16
Junc 302	0.00	638.00	32.50

Backwash pump at IRL-2 operating

Node ID	Demand GPM	Head ft	Pressure psi
Junc 303	0.00	638.00	13.87
Junc 304	0.00	638.00	13.87
Junc 305	0.00	638.00	13.87
Junc 306	0.00	638.00	5.63
Resvr FW-1	0.00	405.00	0.00
Resvr FW-2	0.00	420.00	0.00
Resvr IRL-1	0.00	405.00	0.00
Resvr IRL-2	-400.00	405.00	0.00
Resvr IRL-3	0.00	405.00	0.00
Resvr IRL-4	0.00	405.00	0.00
Resvr TCS-1	0.00	405.00	0.00
Resvr TCS-2	0.00	405.00	0.00
Tank T721	400.00	508.00	4.33
Tank T201	-0.06	638.00	4.33
Tank T202	-0.02	638.00	4.33
Tank T203	0.02	638.00	4.33
Tank T204	0.06	638.00	4.33

Backwash pump at IRL-2 operating

Network Table - Links

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 101	0.00	0.00	0.00	Open
Pipe 102	0.00	0.00	0.00	Open
Pipe 103	0.00	0.00	0.00	Open
Pipe 104	0.00	0.00	0.00	Open
Pipe 105	400.00	5.56	17.09	Open
Pipe 106	400.00	3.28	4.73	Open
Pipe 107	400.00	2.92	4.64	Open
Pipe 108	400.00	3.28	4.73	Open
Pipe 109	400.00	3.28	4.73	Open
Pipe 110	400.00	3.28	4.73	Open
Pipe 111	400.00	3.28	4.73	Open
Pipe 112	400.00	3.28	4.73	Open
Pipe 113	400.00	3.28	4.73	Open
Pipe 114	400.00	3.28	4.73	Open
Pipe 115	400.00	3.28	4.73	Open
Pipe 116	400.00	2.92	4.64	Open
Pipe 117	0.00	0.00	0.00	Open
Pipe 118	0.00	0.00	0.00	Open
Pipe 119	0.00	0.00	0.00	Open
Pipe 120	0.00	0.00	0.00	Open
Pipe 121	400.00	4.92	12.71	Open
Pipe 122	400.00	5.56	17.09	Open
Pipe 123	0.00	0.00	0.00	Open
Pipe 124	0.00	0.00	0.00	Open
Pipe 125	0.00	0.00	0.00	Open

Backwash pump at IRL-2 operating

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 126	0.00	0.00	0.00	Open
Pipe 127	0.00	0.00	0.00	Open
Pipe 128	0.00	0.00	0.00	Open
Pipe 129	0.00	0.00	0.00	Open
Pipe 130	0.00	0.00	0.00	Open
Pipe 131	0.16	0.00	0.00	Open
Pipe 132	0.21	0.01	0.00	Open
Pipe 133	0.16	0.00	0.00	Open
Pipe 134	-0.16	0.02	0.00	Open
Pipe 135	-0.05	0.00	0.00	Open
Pipe 136	0.05	0.00	0.00	Open
Pipe 137	0.16	0.02	0.00	Open
Pipe 201	0.00	0.00	0.00	Open
Pipe 202	0.00	0.00	0.00	Open
Pipe 203	0.00	0.00	0.00	Open
Pipe 204	0.00	0.00	0.00	Open
Pipe 205	0.00	0.00	0.00	Open
Pipe 206	0.00	0.00	0.00	Open
Pipe 207	0.00	0.00	0.00	Open
Pipe 208	0.22	0.00	0.00	Open
Pipe 209	0.29	0.00	0.00	Open
Pipe 210	0.22	0.00	0.00	Open
Pipe 211	-0.22	0.01	0.00	Open
Pipe 212	-0.07	0.00	0.00	Open
Pipe 213	0.07	0.00	0.00	Open
Pipe 214	0.22	0.01	0.00	Open

Backwash pump at IRL-2 operating

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 215	0.00	0.00	0.00	Open
Pipe 216	0.00	0.00	0.00	Open
Pipe 217	0.00	0.00	0.00	Open
Pipe 301	0.00	0.00	0.00	Open
Pipe 302	0.00	0.00	0.00	Open
Pipe 303	0.00	0.00	0.00	Open
Pipe 304	0.00	0.00	0.00	Open
Pipe 305	0.00	0.00	0.00	Open
Pipe 306	0.00	0.00	0.00	Open
Pipe 307	0.00	0.00	0.00	Open
Pump PMP001	0.00	0.00	0.00	Closed
Pump PMP002	0.00	0.00	0.00	Closed
Pump PMP442	0.00	0.00	0.00	Closed
Pump PMP443	0.00	0.00	0.00	Closed
Pump PMP641	0.00	0.00	0.00	Closed
Pump PMP642	400.00	0.00	-141.38	Open
Pump PMP643	0.00	0.00	0.00	Closed
Pump PMP644	0.00	0.00	0.00	Closed
Pump PMP745	0.00	0.00	0.00	Closed

Backwash pump at IRL-3 operating

Network Table - Nodes

Node ID	Demand GPM	Head ft	Pressure psi
Junc 100	0.00	536.87	62.34
Junc 101	0.00	536.87	-9.16
Junc 102	0.00	536.87	-7.86
Junc 103	0.00	536.87	-7.86
Junc 104	0.00	534.42	-6.75
Junc 105	0.00	525.12	11.75
Junc 106	0.00	523.70	19.80
Junc 107	0.00	522.27	18.32
Junc 108	0.00	511.67	-7.94
Junc 109	0.00	511.41	14.48
Junc 110	0.00	510.99	14.29
Junc 111	0.00	510.11	7.41
Junc 112	0.00	509.57	6.75
Junc 113	0.00	509.39	6.23
Junc 114	0.00	509.05	6.09
Junc 115	0.00	508.37	3.63
Junc 116	0.00	536.87	57.14
Junc 117	0.00	536.87	-8.72
Junc 118	0.00	547.58	65.25
Junc 119	0.00	537.41	-6.32
Junc 120	0.00	534.42	62.58
Junc 121	0.00	534.42	-7.18
Junc 122	0.00	525.12	59.85
Junc 123	0.00	525.12	11.32
Junc 124	0.00	508.00	4.77

Backwash pump at IRL-3 operating

Node ID	Demand GPM	Head ft	Pressure psi
Junc 125	0.00	508.00	4.77
Junc 126	0.00	508.00	4.77
Junc 127	0.00	508.00	4.77
Junc 128	0.00	638.00	61.10
Junc 129	0.00	638.00	61.10
Junc 130	0.00	638.00	4.77
Junc 131	0.00	638.00	4.77
Junc 132	0.00	638.00	4.77
Junc 133	0.00	638.00	4.77
Junc 200	0.00	638.00	107.46
Junc 201	0.00	638.00	9.53
Junc 202	0.00	638.00	9.53
Junc 203	0.00	638.00	8.67
Junc 204	0.00	638.00	5.63
Junc 205	0.00	638.00	6.50
Junc 206	0.00	638.00	6.50
Junc 207	0.00	638.00	4.33
Junc 208	0.00	638.00	4.33
Junc 209	0.00	638.00	4.33
Junc 210	0.00	638.00	4.33
Junc 211	0.00	638.00	107.46
Junc 212	0.00	638.00	23.40
Junc 213	0.00	638.00	23.40
Junc 300	0.00	638.00	98.79
Junc 301	0.00	638.00	41.16
Junc 302	0.00	638.00	32.50

Backwash pump at IRL-3 operating

Node ID	Demand GPM	Head ft	Pressure psi
Junc 303	0.00	638.00	13.87
Junc 304	0.00	638.00	13.87
Junc 305	0.00	638.00	13.87
Junc 306	0.00	638.00	5.63
Resvr FW-1	0.00	405.00	0.00
Resvr FW-2	0.00	420.00	0.00
Resvr IRL-1	0.00	405.00	0.00
Resvr IRL-2	0.00	405.00	0.00
Resvr IRL-3	-400.00	405.00	0.00
Resvr IRL-4	0.00	405.00	0.00
Resvr TCS-1	0.00	405.00	0.00
Resvr TCS-2	0.00	405.00	0.00
Tank T721	400.00	508.00	4.33
Tank T201	-0.14	638.00	4.33
Tank T202	-0.05	638.00	4.33
Tank T203	0.05	638.00	4.33
Tank T204	0.14	638.00	4.33

Backwash pump at IRL-3 operating

Network Table - Links

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 101	0.00	0.00	0.00	Open
Pipe 102	0.00	0.00	0.00	Open
Pipe 103	0.00	0.00	0.00	Open
Pipe 104	400.00	5.56	17.09	Open
Pipe 105	400.00	5.56	17.09	Open
Pipe 106	400.00	3.28	4.73	Open
Pipe 107	400.00	2.92	4.64	Open
Pipe 108	400.00	3.28	4.73	Open
Pipe 109	400.00	3.28	4.73	Open
Pipe 110	400.00	3.28	4.73	Open
Pipe 111	400.00	3.28	4.73	Open
Pipe 112	400.00	3.28	4.73	Open
Pipe 113	400.00	3.28	4.73	Open
Pipe 114	400.00	3.28	4.73	Open
Pipe 115	400.00	3.28	4.73	Open
Pipe 116	400.00	2.92	4.64	Open
Pipe 117	0.00	0.00	0.00	Open
Pipe 118	0.00	0.00	0.00	Open
Pipe 119	400.00	4.92	12.71	Open
Pipe 120	400.00	5.56	17.09	Open
Pipe 121	0.00	0.00	0.00	Open
Pipe 122	0.00	0.00	0.00	Open
Pipe 123	0.00	0.00	0.00	Open
Pipe 124	0.00	0.00	0.00	Open
Pipe 125	0.00	0.00	0.00	Open

Backwash pump at IRL-3 operating

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 126	0.00	0.00	0.00	Open
Pipe 127	0.00	0.00	0.00	Open
Pipe 128	0.00	0.00	0.00	Open
Pipe 129	0.00	0.00	0.00	Open
Pipe 130	0.00	0.00	0.00	Open
Pipe 131	0.35	0.01	0.00	Open
Pipe 132	0.46	0.01	0.00	Open
Pipe 133	0.35	0.01	0.00	Open
Pipe 134	-0.35	0.03	0.00	Open
Pipe 135	-0.11	0.01	0.00	Open
Pipe 136	0.11	0.01	0.00	Open
Pipe 137	0.35	0.03	0.00	Open
Pipe 201	0.00	0.00	0.00	Open
Pipe 202	0.00	0.00	0.00	Open
Pipe 203	0.00	0.00	0.00	Open
Pipe 204	0.00	0.00	0.00	Open
Pipe 205	0.00	0.00	0.00	Open
Pipe 206	0.00	0.00	0.00	Open
Pipe 207	0.00	0.00	0.00	Open
Pipe 208	0.48	0.00	0.00	Open
Pipe 209	0.64	0.00	0.00	Open
Pipe 210	0.48	0.00	0.00	Open
Pipe 211	-0.49	0.03	0.00	Open
Pipe 212	-0.16	0.01	0.00	Open
Pipe 213	0.16	0.01	0.00	Open
Pipe 214	0.48	0.03	0.00	Open

Backwash pump at IRL-3 operating

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 215	0.00	0.00	0.00	Open
Pipe 216	0.00	0.00	0.00	Open
Pipe 217	0.00	0.00	0.00	Open
Pipe 301	0.00	0.00	0.00	Open
Pipe 302	0.00	0.00	0.00	Open
Pipe 303	0.00	0.00	0.00	Open
Pipe 304	0.00	0.00	0.00	Open
Pipe 305	0.00	0.00	0.00	Open
Pipe 306	0.00	0.00	0.00	Open
Pipe 307	0.00	0.00	0.00	Open
Pump PMP001	0.00	0.00	0.00	Closed
Pump PMP002	0.00	0.00	0.00	Closed
Pump PMP442	0.00	0.00	0.00	Closed
Pump PMP443	0.00	0.00	0.00	Closed
Pump PMP641	0.00	0.00	0.00	Closed
Pump PMP642	0.00	0.00	0.00	Closed
Pump PMP643	400.00	0.00	-142.58	Open
Pump PMP644	0.00	0.00	0.00	Closed
Pump PMP745	0.00	0.00	0.00	Closed

Backwash pump at IRL-4 operating

Network Table - Nodes

Node ID	Demand GPM	Head ft	Pressure psi
Junc 100	0.00	537.48	62.60
Junc 101	0.00	537.48	-8.89
Junc 102	0.00	537.48	-7.59
Junc 103	0.00	536.87	-7.86
Junc 104	0.00	534.42	-6.75
Junc 105	0.00	525.12	11.75
Junc 106	0.00	523.70	19.80
Junc 107	0.00	522.27	18.32
Junc 108	0.00	511.67	-7.94
Junc 109	0.00	511.41	14.48
Junc 110	0.00	510.99	14.29
Junc 111	0.00	510.11	7.41
Junc 112	0.00	509.57	6.75
Junc 113	0.00	509.39	6.23
Junc 114	0.00	509.05	6.09
Junc 115	0.00	508.37	3.63
Junc 116	0.00	558.82	66.65
Junc 117	0.00	556.13	-0.38
Junc 118	0.00	536.87	60.60
Junc 119	0.00	536.87	-6.56
Junc 120	0.00	534.42	62.58
Junc 121	0.00	534.42	-7.18
Junc 122	0.00	525.12	59.85
Junc 123	0.00	525.12	11.32
Junc 124	0.00	508.00	4.77

Backwash pump at IRL-4 operating

Node ID	Demand GPM	Head ft	Pressure psi
Junc 125	0.00	508.00	4.77
Junc 126	0.00	508.00	4.77
Junc 127	0.00	508.00	4.77
Junc 128	0.00	638.00	61.10
Junc 129	0.00	638.00	61.10
Junc 130	0.00	638.00	4.77
Junc 131	0.00	638.00	4.77
Junc 132	0.00	638.00	4.77
Junc 133	0.00	638.00	4.77
Junc 200	0.00	638.00	107.46
Junc 201	0.00	638.00	9.53
Junc 202	0.00	638.00	9.53
Junc 203	0.00	638.00	8.67
Junc 204	0.00	638.00	5.63
Junc 205	0.00	638.00	6.50
Junc 206	0.00	638.00	6.50
Junc 207	0.00	638.00	4.33
Junc 208	0.00	638.00	4.33
Junc 209	0.00	638.00	4.33
Junc 210	0.00	638.00	4.33
Junc 211	0.00	638.00	107.46
Junc 212	0.00	638.00	23.40
Junc 213	0.00	638.00	23.40
Junc 300	0.00	638.00	98.79
Junc 301	0.00	638.00	41.16
Junc 302	0.00	638.00	32.50

Backwash pump at IRL-4 operating

Node ID	Demand GPM	Head ft	Pressure psi
Junc 303	0.00	638.00	13.87
Junc 304	0.00	638.00	13.87
Junc 305	0.00	638.00	13.87
Junc 306	0.00	638.00	5.63
Resvr FW-1	0.00	405.00	0.00
Resvr FW-2	0.00	420.00	0.00
Resvr IRL-1	0.00	405.00	0.00
Resvr IRL-2	0.00	405.00	0.00
Resvr IRL-3	0.00	405.00	0.00
Resvr IRL-4	-400.00	405.00	0.00
Resvr TCS-1	0.00	405.00	0.00
Resvr TCS-2	0.00	405.00	0.00
Tank T721	400.00	508.00	4.33
Tank T201	-0.14	638.00	4.33
Tank T202	-0.05	638.00	4.33
Tank T203	0.05	638.00	4.33
Tank T204	0.14	638.00	4.33

Backwash pump at IRL-4 operating

Network Table - Links

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 101	0.00	0.00	0.00	Open
Pipe 102	0.00	0.00	0.00	Open
Pipe 103	400.00	5.56	17.09	Open
Pipe 104	400.00	5.56	17.09	Open
Pipe 105	400.00	5.56	17.09	Open
Pipe 106	400.00	3.28	4.73	Open
Pipe 107	400.00	2.92	4.64	Open
Pipe 108	400.00	3.28	4.73	Open
Pipe 109	400.00	3.28	4.73	Open
Pipe 110	400.00	3.28	4.73	Open
Pipe 111	400.00	3.28	4.73	Open
Pipe 112	400.00	3.28	4.73	Open
Pipe 113	400.00	3.28	4.73	Open
Pipe 114	400.00	3.28	4.73	Open
Pipe 115	400.00	3.28	4.73	Open
Pipe 116	400.00	2.92	4.64	Open
Pipe 117	400.00	4.92	12.71	Open
Pipe 118	400.00	5.56	17.09	Open
Pipe 119	0.00	0.00	0.00	Open
Pipe 120	0.00	0.00	0.00	Open
Pipe 121	0.00	0.00	0.00	Open
Pipe 122	0.00	0.00	0.00	Open
Pipe 123	0.00	0.00	0.00	Open
Pipe 124	0.00	0.00	0.00	Open
Pipe 125	0.00	0.00	0.00	Open

Backwash pump at IRL-4 operating

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 126	0.00	0.00	0.00	Open
Pipe 127	0.00	0.00	0.00	Open
Pipe 128	0.00	0.00	0.00	Open
Pipe 129	0.00	0.00	0.00	Open
Pipe 130	0.00	0.00	0.00	Open
Pipe 131	0.35	0.01	0.00	Open
Pipe 132	0.46	0.01	0.00	Open
Pipe 133	0.35	0.01	0.00	Open
Pipe 134	-0.35	0.03	0.00	Open
Pipe 135	-0.11	0.01	0.00	Open
Pipe 136	0.11	0.01	0.00	Open
Pipe 137	0.35	0.03	0.00	Open
Pipe 201	0.00	0.00	0.00	Open
Pipe 202	0.00	0.00	0.00	Open
Pipe 203	0.00	0.00	0.00	Open
Pipe 204	0.00	0.00	0.00	Open
Pipe 205	0.00	0.00	0.00	Open
Pipe 206	0.00	0.00	0.00	Open
Pipe 207	0.00	0.00	0.00	Open
Pipe 208	0.48	0.00	0.00	Open
Pipe 209	0.64	0.00	0.00	Open
Pipe 210	0.48	0.00	0.00	Open
Pipe 211	-0.49	0.03	0.00	Open
Pipe 212	-0.16	0.01	0.00	Open
Pipe 213	0.16	0.01	0.00	Open
Pipe 214	0.48	0.03	0.00	Open

Backwash pump at IRL-4 operating

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 215	0.00	0.00	0.00	Open
Pipe 216	0.00	0.00	0.00	Open
Pipe 217	0.00	0.00	0.00	Open
Pipe 301	0.00	0.00	0.00	Open
Pipe 302	0.00	0.00	0.00	Open
Pipe 303	0.00	0.00	0.00	Open
Pipe 304	0.00	0.00	0.00	Open
Pipe 305	0.00	0.00	0.00	Open
Pipe 306	0.00	0.00	0.00	Open
Pipe 307	0.00	0.00	0.00	Open
Pump PMP001	0.00	0.00	0.00	Closed
Pump PMP002	0.00	0.00	0.00	Closed
Pump PMP442	0.00	0.00	0.00	Closed
Pump PMP443	0.00	0.00	0.00	Closed
Pump PMP641	0.00	0.00	0.00	Closed
Pump PMP642	0.00	0.00	0.00	Closed
Pump PMP643	0.00	0.00	0.00	Closed
Pump PMP644	400.00	0.00	-153.82	Open
Pump PMP745	0.00	0.00	0.00	Closed

Hydraulic Calculations for NTH IRZ, Inner Recirculation Loop, and TCS Recirculation Loop Wells

Header and Branch Distribution Piping Hydraulic Worksheet - IRZ Extraction Header

Site: Pacific Gas & Electric Topock Compressor Station
Location: Topock, California

Created By: CL
Revision No. 0
Revision Date: 7/18/2012

Fluid:	**Water**
Fluid Temperature (deg F):	**50**
Maximum Flowrate	200
Header Length (ft):	1,600
Number of Branches	3
Average Branch Flowrate (gpm):	66.7

◉ DISCHARGE HEADER

○ RETURN HEADER

Header Pipe Material: Smooth Pipes (PE and other thermoplastics/Brass/Glass and

Header Pipe Type: SDR 11 - HDPE

Header Pipe Nominal Diameter (in): 6

Header Pipe, e (ft): **0.00001**
Header Pipe Inner Diameter (in): **5.348**
e / D: 0.00001

Branch Pipe Material: Smooth Pipes (PE and other thermoplastics/Brass/Glass and

Branch Pipe Type: SDR 11 - HDPE

Branch Pipe Nominal Diameter (in): 2 / 2

Branch Pipe, e (ft): **0.00001**
Branch Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Fluid Density (lb/ft^3): **62.36**
Viscosity (cP): **1.12**

Kinematic viscosity, v (ft^2/s): **1.21E-05**
g (ft/s^2): **32.17**
Oriface Coefficient, C_o: **0.62**
Oriface Value, K[1]: **0.5**

Header Pressure Drop, Δp_p (lb$_f$/ft^2): 7.7
Header Pressure Drop, Δp_p (psig): 0.05
Branch Outlet Pressure Drop, Δp_o (lb$_f$/ft^2): 199.4
Branch Outlet Pressure Drop, Δp_o (psig): 1.38
Percent Maldistribution (%)[5]: 1.94%
Average Branch Pipe Pressure Drop (ft w.c.): 7.48
Average Well Head Pressure (ft w.c.): 0.00
Average Branch Pipe Pressure Drop (ft w.c.)[5]: 7.48
Average Branch Pipe Pressure Drop (psig): 3.24
Average Branch Pipe Pressure Drop > 10x Δp_p: Yes

Header Pipe Estimated Conditions

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Description:		IRZ-1 to IRZ-5	IRZ-5 to IRZ-9	IRZ-9 to MW-20		Static Head IRZ-1 to IRZ-9					
Length of Segment (ft):	0	300	300	1000							
Header flow rate (gpm):		40	120	200							
Branch flow rate (gpm):	---	40	80	80							
Header Pipe Velocity (ft/s):	0.00	0.57	1.71	2.86							
Reynolds Number, Re:		2.11E+04	6.33E+04	1.05E+05							
Fanning Friction Factor, f (Eq(6)):		0.00639	0.00497	0.00446							
Pressure Drop (ft w.c.), (Eq.(7)):		0.09	0.61	5.08							
Velocity Head, $v^2/2g_c$ (ft w.c.):	0.000	0.005	0.046	0.127							
Pressure Drop (ft w.c.):	0.00	0.09	0.61	5.08		2.50					

Branch Pipe Estimated Conditions

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Orifice Velocity (ft/s):	---	4.45	8.89	8.89							
Length of Branch Pipe (ft)[2]:	---	67	78	68							
Reynolds Number, Re:	---	5.89E+04	1.18E+05	1.18E+05							
Fanning Friction Factor, f:	---	0.00507	0.00439	0.00439							
Pressure Drop (ft w.c.), (Eq.(7)):	---	2.60	10.61	9.25							
Velocity Head, $v^2/2g_c$ (ft w.c.):	---	0.307	1.229	1.229							
Pressure Drop (ft w.c.)[3]:	---	2.60	10.61	9.25							
Well Head Pressure (ft w.c.)[4]:	---	0	0	0	0	0	0	0	0	0	0

Header Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Length of Segment (ft):											**1,600**	**(Total)**
Header flow rate (gpm):											---	---
Branch flow rate (gpm):											---	---
Header Pipe Velocity (ft/s):											**1.3**	**(Avg.)**
Reynolds Number, Re:											**6.33E+04**	**(Avg.)**
Fanning Friction Factor, f:											**0.00528**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.044**	**(Avg.)**
Pressure Drop (ft w.c.):											**8.28**	**(Total)**

Branch Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Orifice Velocity (ft/s):											**7.41**	**(Avg.)**
Length of Branch Pipe (ft)[2]:											**71.12**	**(Avg.)**
Reynolds Number, Re:											**9.81E+04**	**(Avg.)**
Fanning Friction Factor, f:											**0.00462**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.922**	**(Avg.)**
Pressure Drop (ft w.c.)[3]:											**7.48**	**(Avg.)**
Well Head Pressure (ft w.c.)[4]:											**0.00**	**(Avg.)**

Eq. (1)
Discharge Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} - 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (2)
Return Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} + 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (3)
Branch Outlet Pressure Drop:

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2g_c}$$

Eq. (4)
Reynolds Number:

$$Re = \frac{D \cdot v \cdot \rho}{\mu} = \frac{D \cdot v}{\eta}$$

Eq. (5)
Distribution Equation:

$$\%\,Maldistribution = 100\left(1 - \sqrt{\frac{\Delta p_o - |\Delta p_p|}{\Delta p_o}}\right)$$

Eq. (6)
Fanning Friction Factor:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{[(p_0 - p_L) - \rho g(h_0 - h_L)]}{\frac{1}{2}\rho v^2}\right)$$

Eq. (7)
Darcy Equation:

$$h_L = \left[\left(4f\,\frac{L}{D}\right)\right]\frac{v^2}{2g}$$

Notes:

(1) K = 0.5 when viscous losses are negligible, K = 1.0 for return headers.
(2) Include the equivalent length of valves and fittings.
(3) Pressure drop due to velocity head and friction losses across the length of the branch pipe.
(4) Pressure at the well head taking into consideration frictional losses across the length of the drop pipe, static head associated with water elevation and mounding, and pressure drop required for foot valve or variable area valve.
(5) Maldistribution of 10 percent or less is recommended.
(6) If the branch piping exhibits average pressure losses (due to length, fittings, and/or well head pressures) of at least 10 times higher than the header, pressure losses maldistribution will be less than 10 percent.

Header and Branch Distribution Piping Hydraulic Worksheet - IRZ North Injection Header

Site: Pacific Gas & Electric Topock Compressor Station
Location: Topock, California

Created By: CL
Revision No. 1
Revision Date: 7/18/2012

Fluid:	**Water**
Fluid Temperature (deg F):	**50**
Initial Flowrate	220
Header Length (ft):	820
Number of Branches	8
Average Branch Flowrate (gpm):	24.4

◉ DISCHARGE HEADER

○ RETURN HEADER

Header Pipe Material: Smooth Pipes (PE and other thermoplastics/Brass/Glass and

Header Pipe Type: SDR 11 - HDPE

Header Pipe Nominal Diameter (in): 6

Header Pipe, e (ft): **0.00001**
Header Pipe Inner Diameter (in): **5.348**
e / D: 0.00001

Branch Pipe Material: Smooth Pipes (PE and other thermoplastics/Brass/Glass and

Branch Pipe Type: SDR 11 - HDPE

Branch Pipe Nominal Diameter (in): 2

Branch Pipe, e (ft): **0.00001**
Branch Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Fluid Density (lb/ft^3): **62.36**
Viscosity (cP): **1.12**

Kinematic viscosity, v (ft^2/s): **1.21E-05**
g (ft/s^2): **32.17**
Oriface Coefficient, C_o: **0.62**
Oriface Value, K[1]: **0.5**

Header Pressure Drop, Δp_p (lb$_f$/ft^2): 106.2
Header Pressure Drop, Δp_p (psig): 0.74
Branch Outlet Pressure Drop, Δp_o (lb$_f$/ft^2): 49.9
Branch Outlet Pressure Drop, Δp_o (psig): 0.35
Percent Maldistribution (%)[5]: Unbalanced
Average Branch Pipe Pressure Drop (ft w.c.): 1.91
Average Well Head Pressure (ft w.c.): 23.10
Average Branch Pipe Pressure Drop (ft w.c.)[5]: 25.01
Average Branch Pipe Pressure Drop (psig): 10.83
Average Branch Pipe Pressure Drop > 10x Δp_p: Yes

Header Pipe Estimated Conditions (Continued)

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Description:		MW-20 to IRZ-21	IRZ-21 to IRZ-20	IRZ-20 to IRZ-19	IRZ-19 to IRZ-17	IRZ-17 to IRZ-16	IRZ-16 to IRZ-15	IRZ-21 to IRZ-20	IRZ-15 to IRZ-13	IRZ-13 to IRZ-11		Static Head IRZ -15 to IRZ- 20
Length of Segment (ft):	0	35	30	70	260	70	65	140	150			
Header flow rate (gpm):	**220**	220	200	184	156	128	104	76	40			
Branch flow rate (gpm):	**---**	20	16	28	28	24	28	36	40			
Header Pipe Velocity (ft/s):	3.14	3.14	2.86	2.63	2.23	1.83	1.49	1.09	0.57			
Reynolds Number, Re:	1.16E+05	1.16E+05	1.05E+05	9.71E+04	8.23E+04	6.75E+04	5.49E+04	4.01E+04	2.11E+04			
Fanning Friction Factor, f (Eq(6)):	0.00438	0.00438	0.00446	0.00454	0.00470	0.00490	0.00513	0.00550	0.00639			
Pressure Drop (ft w.c.), (Eq.(7)):	0.00	0.21	0.15	0.31	0.85	0.16	0.10	0.13	0.04			
Velocity Head, $v^2/2g_c$ (ft w.c.):	0.153	0.153	0.127	0.107	0.077	0.052	0.034	0.018	0.005			
Pressure Drop (ft w.c.):	0.00	0.21	0.15	0.31	0.85	0.16	0.10	0.13	0.04		18.00	

Branch Pipe Estimated Conditions (Continued)

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Orifice Velocity (ft/s):	---	2.22	1.78	3.11	3.11	2.67	3.11	4.00	4.45		
Length of Branch Pipe (ft)[2]:	---	148	141	60	140	149	55	62	73		
Reynolds Number, Re:	---	2.94E+04	2.35E+04	4.12E+04	4.12E+04	3.53E+04	4.12E+04	5.30E+04	5.89E+04		
Fanning Friction Factor, f:	---	0.00592	0.00624	0.00548	0.00548	0.00568	0.00548	0.00519	0.00507		
Pressure Drop (ft w.c.), (Eq.(7)):	---	1.68	1.08	1.25	2.90	2.34	1.14	2.02	2.86		
Velocity Head, $v^2/2g_c$ (ft w.c.):	---	0.077	0.049	0.151	0.151	0.111	0.151	0.249	0.307		
Pressure Drop (ft w.c.)[3]:	---	1.68	1.08	1.25	2.90	2.34	1.14	2.02	2.86		
Well Head Pressure (ft w.c.)[4]:	---	23.1	23.1	23.1	23.1	23.1	23.1	23.1	23.1		

Header Pipe Estimated Conditions

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Length of Segment (ft):											**820**	**(Total)**
Header flow rate (gpm):											**---**	**---**
Branch flow rate (gpm):											**---**	**---**
Header Pipe Velocity (ft/s):											**2.1**	**(Avg.)**
Reynolds Number, Re:											**7.78E+04**	**(Avg.)**
Fanning Friction Factor, f:											**0.00493**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.081**	**(Avg.)**
Pressure Drop (ft w.c.):											**19.95**	**(Total)**

Branch Pipe Estimated Conditions

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Orifice Velocity (ft/s):											**3.06**	**(Avg.)**
Length of Branch Pipe (ft)[2]:											**103.73**	**(Avg.)**
Reynolds Number, Re:											**2.02E+04**	**(Avg.)**
Fanning Friction Factor, f:											**0.00557**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.156**	**(Avg.)**
Pressure Drop (ft w.c.)[3]:											**1.91**	**(Avg.)**
Well Head Pressure (ft w.c.)[4]:											**23.10**	**(Avg.)**

Eq. (1)
Discharge Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} - 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (2)
Return Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} + 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (3)
Branch Outlet Pressure Drop:

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2g_c}$$

Eq. (4)
Reynolds Number:

$$Re = \frac{D \cdot v \cdot \rho}{\mu} = \frac{D \cdot v}{\eta}$$

Eq. (5)
Distribution Equation:

$$\%\,Maldistribution = 100\left(1 - \sqrt{\frac{\Delta p_o - |\Delta p_p|}{\Delta p_o}}\right)$$

Eq. (6)
Fanning Friction Factor:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{[(p_0 - p_L) - \rho g(h_0 - h_L)]}{\frac{1}{2}\rho v^2}\right)$$

Eq. (7)
Darcy Equation:

$$h_L = \left[\left(4f\,\frac{L}{D}\right)\right]\frac{v^2}{2g}$$

Notes:

(1) K = 0.5 when viscous losses are negligible, K = 1.0 for return headers.
(2) Include the equivalent length of valves and fittings.
(3) Pressure drop due to velocity head and friction losses across the length of the branch pipe.
(4) Pressure at the well head taking into consideration frictional losses across the length of the drop pipe, static head associated with water elevation and mounding, and pressure drop required for foot valve or variable area valve.
(5) Maldistribution of 10 percent or less is recommended.
(6) If the branch piping exhibits average pressure losses (due to length, fittings, and/or well head pressures) of at least 10 times higher than the header, pressure losses maldistribution will be less than 10 percent.

Header and Branch Distribution Piping Hydraulic Worksheet - IRZ South Injection Header (IRZ-24 to IRZ-28)

Site: Pacific Gas & Electric Topock Compressor Station
Location: Topock, California

Created By: CL
Revision No. 1
Revision Date: 7/18/2012

Fluid:	**Water**
Fluid Temperature (deg F):	**50**
Initial Flowrate:	32
Header Length (ft):	285
Number of Branches:	2
Average Branch Flowrate (gpm):	16.0

◉ DISCHARGE HEADER

○ RETURN HEADER

Header Pipe Material: Smooth Pipes (PE and other thermoplastics/Brass/Glass ar

Header Pipe Type: SDR 11 - HDPE

Header Pipe Nominal Diameter (in): 6

Header Pipe, e (ft):	**0.00001**
Header Pipe Inner Diameter (in):	**5.348**
e / D:	**0.00001**

Branch Pipe Material: Smooth Pipes (PE and other thermoplastics/Brass/Glass ar

Branch Pipe Type: SDR 11 - HDPE

Branch Pipe Nominal Diameter (in): 2

Branch Pipe, e (ft):	**0.00001**
Branch Pipe Inner Diameter (in):	**1.917**
e / D:	**0.00003**

Fluid Density (lb/ft^3):	**62.36**
Viscosity (cP):	**1.12**
Kinematic viscosity, v (ft^2/s):	**1.21E-05**
g (ft/s^2):	**32.17**
Oriface Coefficient, C_o:	**0.62**
Oriface Value, K[1]:	**0.5**

Header Pressure Drop, Δp_p (lb$_f$/ft^2):	1.0
Header Pressure Drop, Δp_p (psig):	**0.01**
Branch Outlet Pressure Drop, Δp_o (lb$_f$/ft^2):	8.0
Branch Outlet Pressure Drop, Δp_o (psig):	**0.06**
Percent Maldistribution (%)[5]:	**6.75%**
Average Branch Pipe Pressure Drop (ft w.c.):	**0.68**
Average Well Head Pressure (ft w.c.):	**23.10**
Average Branch Pipe Pressure Drop (ft w.c.)[5]:	**23.78**
Average Branch Pipe Pressure Drop (psig):	**10.29**
Average Branch Pipe Pressure Drop > 10x Δp_p:	**Yes**

Header Pipe Estimated Conditions (Continued)

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Description:		MW-20 to IRZ-25	MW-20 to IRZ-27								Static Head IRZ-25 to IRZ-27
Length of Segment (ft):	0	115	170								
Header flow rate (gpm):	**32**	32	16								
Branch flow rate (gpm):	---	16	16								
Header Pipe Velocity (ft/s):	0.46	0.46	0.23								
Reynolds Number, Re:	1.69E+04	1.69E+04	8.44E+03								
Fanning Friction Factor, f (Eq(6)):	0.00675	0.00675	0.00808								
Pressure Drop (ft w.c.), (Eq.(7)):	0.00	0.02	0.01								
Velocity Head, $v^2/2g_c$ (ft w.c.):	0.003	0.003	0.001								
Pressure Drop (ft w.c.):	0.00	0.02	0.01								2.50

Branch Pipe Estimated Conditions (Continued)

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Orifice Velocity (ft/s):	---	1.78	1.78								
Length of Branch Pipe (ft)[2]:	---	136	41								
Reynolds Number, Re:	---	2.35E+04	2.35E+04								
Fanning Friction Factor, f:	---	0.00624	0.00624								
Pressure Drop (ft w.c.), (Eq.(7)):	---	1.04	0.32								
Velocity Head, $v^2/2g_c$ (ft w.c.):	---	0.049	0.049								
Pressure Drop (ft w.c.)[3]:	---	1.04	0.32								
Well Head Pressure (ft w.c.)[4]:	---	23.1	23.1								

Header Pipe Estimated Conditions

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Length of Segment (ft):											**285**	**(Total)**
Header flow rate (gpm):											---	---
Branch flow rate (gpm):											---	---
Header Pipe Velocity (ft/s):											**0.4**	**(Avg.)**
Reynolds Number, Re:											**1.41E+04**	**(Avg.)**
Fanning Friction Factor, f:											**0.00720**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.002**	**(Avg.)**
Pressure Drop (ft w.c.):											**2.53**	**(Total)**

Branch Pipe Estimated Conditions

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Orifice Velocity (ft/s):											**1.78**	**(Avg.)**
Length of Branch Pipe (ft)[2]:											**88.52**	**(Avg.)**
Reynolds Number, Re:											**2.35E+04**	**(Avg.)**
Fanning Friction Factor, f:											**0.00624**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.002**	**(Avg.)**
Pressure Drop (ft w.c.)[3]:											**0.68**	**(Avg.)**
Well Head Pressure (ft w.c.)[4]:											**23.10**	**(Avg.)**

Eq. (1)
Discharge Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} - 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (2)
Return Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} + 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (3)
Branch Outlet Pressure Drop:

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2g_c}$$

Eq. (4)
Reynolds Number:

$$Re = \frac{D \cdot v \cdot \rho}{\mu} = \frac{D \cdot v}{\eta}$$

Eq. (5)
Distribution Equation:

$$\%\,Maldistribution = 100\left(1 - \sqrt{\frac{|\Delta p_o| - |\Delta p_p|}{\Delta p_o}}\right)$$

Eq. (6)
Fanning Friction Factor:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{[(p_0 - p_L) - \rho g(h_0 - h_L)]}{\frac{1}{2}\rho v^2}\right)$$

Eq. (7)
Darcy Equation:

$$h_L = \left[\left(4f\,\frac{L}{D}\right)\right]\frac{v^2}{2g}$$

Notes:

(1) K = 0.5 when viscous losses are negligible, K = 1.0 for return headers.
(2) Include the equivalent length of valves and fittings.
(3) Pressure drop due to velocity head and friction losses across the length of the branch pipe.
(4) Pressure at the well head taking into consideration frictional losses across the length of the drop pipe, static head associated with water elevation and mounding, and pressure drop required for foot valve or variable area valve.
(5) Maldistribution of 10 percent or less is recommended.
(6) If the branch piping exhibits average pressure losses (due to length, fittings, and/or well head pressures) of at least 10 times higher than the header, pressure losses maldistribution will be less than 10 percent.

Header and Branch Distribution Piping Hydraulic Worksheet- IRZ South Injection Header (IRZ-29 to IRZ-37)

Site: Pacific Gas & Electric Topock Compressor Station
Location: Topock, California

Created By: CL
Revision No. 1
Revision Date: 6/18/2012

Fluid:	**Water**
Fluid Temperature (deg F):	**50**
Initial Flowrate:	44
Header Length (ft):	1,950
Number of Branches:	5
Average Branch Flowrate (gpm):	8.8

◉ DISCHARGE HEADER

○ RETURN HEADER

Header Pipe Material: Smooth Pipes (PE and other thermoplastics/Brass/Glass and

Header Pipe Type: SDR 11 - HDPE

Header Pipe Nominal Diameter (in): 4

Header Pipe, e (ft): **0.00001**
Header Pipe Inner Diameter (in): **3.633**
e / D: 0.00002

Branch Pipe Material: Smooth Pipes (PE and other thermoplastics/Brass/Glass and

Branch Pipe Type: SDR 11 - HDPE

Branch Pipe Nominal Diameter (in): 2

Branch Pipe, e (ft): **0.00001**
Branch Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Fluid Density (lb/ft^3): **62.36**
Viscosity (cP): **1.12**

Kinematic viscosity, v (ft^2/s): **1.21E-05**
g (ft/s^2): **32.17**
Oriface Coefficient, C_o: **0.62**
Oriface Value, K[1]: **0.5**

Header Pressure Drop, Δp_p (lb$_f$/ft^2): 111.5
Header Pressure Drop, Δp_p (psig): 0.77
Branch Outlet Pressure Drop, Δp_o (lb$_f$/ft^2): 2.0
Branch Outlet Pressure Drop, Δp_o (psig): 0.01
Percent Maldistribution (%)[5]: Unbalanced
Average Branch Pipe Pressure Drop (ft w.c.): 0.21
Average Well Head Pressure (ft w.c.): 23.10
Average Branch Pipe Pressure Drop (ft w.c.)[6]: 23.31
Average Branch Pipe Pressure Drop (psig): 10.09
Average Branch Pipe Pressure Drop > 10x Δp_p: Yes

Header Pipe Estimated Conditions (Continued)

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
		MW-20 to Tee	Tee to IRZ-31	Tee to IRZ-33	IRZ-33 to IRZ-35	IRZ-35 to IRZ-37		Static Head IRZ-30 to IRZ-37			
Length of Segment (ft):	1360	55	135	100	150	150					
Header flow rate (gpm):	**44**	40	28	18	10	4					
Branch flow rate (gpm):	---	12	14	8	6	4					
Header Pipe Velocity (ft/s):	1.36	1.24	0.87	0.56	0.31	0.12					
Reynolds Number, Re:	3.42E+04	3.11E+04	2.17E+04	1.40E+04	7.76E+03	3.11E+03					
Fanning Friction Factor, f (Eq(6)):	0.00571	0.00583	0.00635	0.00709	0.00827	0.01077					
Pressure Drop (ft w.c.), (Eq.(7)):	2.96	0.10	0.13	0.05	0.02	0.01					
Velocity Head, $v^2/2g_c$ (ft w.c.):	0.029	0.024	0.012	0.005	0.001	0.000					
Pressure Drop (ft w.c.):	2.96	0.10	0.13	0.05	0.02	0.01		2.50			

Branch Pipe Estimated Conditions (Continued)

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Orifice Velocity (ft/s):	---	1.33	1.56	0.89	0.67	0.44					
Length of Branch Pipe (ft)[2]:	---	49	50	46	44	37					
Reynolds Number, Re:	---	1.77E+04	2.06E+04	1.18E+04	8.83E+03	5.89E+03					
Fanning Friction Factor, f:	---	0.00669	0.00644	0.00741	0.00799	0.00893					
Pressure Drop (ft w.c.), (Eq.(7)):	---	0.23	0.30	0.10	0.06	0.03					
Velocity Head, $v^2/2g_c$ (ft w.c.):	---	0.028	0.038	0.012	0.007	0.003					
Pressure Drop (ft w.c.)[3]:	---	0.23	0.30	0.10	0.06	0.03					
Well Head Pressure (ft w.c.)[4]:	---	23.1	23.1	23.1	23.1	23.1					

Header Pipe Estimated Conditions

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Length of Segment (ft):											**1,950**	**(Total)**
Header flow rate (gpm):											---	---
Branch flow rate (gpm):											---	---
Header Pipe Velocity (ft/s):											**0.7**	**(Avg.)**
Reynolds Number, Re:											**1.86E+04**	**(Avg.)**
Fanning Friction Factor, f:											**0.00734**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.012**	**(Avg.)**
Pressure Drop (ft w.c.):											**5.76**	**(Total)**

Branch Pipe Estimated Conditions

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Orifice Velocity (ft/s):											**0.98**	**(Avg.)**
Length of Branch Pipe (ft)[2]:											**45.11**	**(Avg.)**
Reynolds Number, Re:											**1.29E+04**	**(Avg.)**
Fanning Friction Factor, f:											**0.00749**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.018**	**(Avg.)**
Pressure Drop (ft w.c.)[3]:											**0.21**	**(Avg.)**
Well Head Pressure (ft w.c.)[4]:											**23.10**	**(Avg.)**

Eq. (1)
Discharge Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} - 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (2)
Return Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} + 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (3)
Branch Outlet Pressure Drop:

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2g_c}$$

Eq. (4)
Reynolds Number:

$$Re = \frac{D \cdot v \cdot \rho}{\mu} = \frac{D \cdot v}{\eta}$$

Eq. (5)
Distribution Equation:

$$\%\,Maldistribution = 100\left(1 - \sqrt{\frac{\Delta p_o - |\Delta p_p|}{\Delta p_o}}\right)$$

Eq. (6)
Fanning Friction Factor:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{[(p_0 - p_L) - \rho g(h_0 - h_L)]}{\frac{1}{2}\rho v^2}\right)$$

Eq. (7)
Darcy Equation:

$$h_L = \left[\left(4f\,\frac{L}{D}\right)\right]\frac{v^2}{2g}$$

Notes:

(1) K = 0.5 when viscous losses are negligible, K = 1.0 for return headers.
(2) Include the equivalent length of valves and fittings.
(3) Pressure drop due to velocity head and friction losses across the length of the branch pipe.
(4) Pressure at the well head taking into consideration frictional losses across the length of the drop pipe, static head associated with water elevation and mounding, and pressure drop required for foot valve or variable area valve.
(5) Maldistribution of 10 percent or less is recommended.
(6) If the branch piping exhibits average pressure losses (due to length, fittings, and/or well head pressures) of at least 10 times higher than the header, pressure losses maldistribution will be less than 10 percent.

Header and Branch Distribution Piping Hydraulic Worksheet- IRZ South Injection Header (IRZ-38 to IRZ-40)

Site: Pacific Gas & Electric Topock Compressor Station
Location: Topock, California

Created By: CL
Revision No. 1
Revision Date: 7/18/2012

Fluid:	**Water**
Fluid Temperature (deg F):	**50**
Initial Flowrate:	4
Header Length (ft):	996
Number of Branches:	1
Average Branch Flowrate (gpm):	4.0

◉ DISCHARGE HEADER

○ RETURN HEADER

Header Pipe Material: Smooth Pipes (PE and other thermoplastics/Brass/Glass ar

Header Pipe Type: SDR 11 - HDPE

Header Pipe Nominal Diameter (in): 4

Header Pipe, e (ft): **0.00001**
Header Pipe Inner Diameter (in): **3.633**
e / D: 0.00002

Branch Pipe Material: Smooth Pipes (PE and other thermoplastics/Brass/Glass ar

Branch Pipe Type: SDR 11 - HDPE

Branch Pipe Nominal Diameter (in): 2

Branch Pipe, e (ft): **0.00001**
Branch Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Fluid Density (lb/ft^3): **62.36**
Viscosity (cP): **1.12**

Kinematic viscosity, v (ft^2/s): **1.21E-05**
g (ft/s^2): **32.17**
Oriface Coefficient, C_o: **0.62**
Oriface Value, K[1]: **0.5**

Header Pressure Drop, Δp_p (lb$_f$/ft^2): 0.7
Header Pressure Drop, Δp_p (psig): 0.005
Branch Outlet Pressure Drop, Δp_o (lb$_f$/ft^2): 0.5
Branch Outlet Pressure Drop, Δp_o (psig): 0.003
Percent Maldistribution (%)[5]: Unbalanced
Average Branch Pipe Pressure Drop (ft w.c.): 0.01
Average Well Head Pressure (ft w.c.): 23.10
Average Branch Pipe Pressure Drop (ft w.c.)[5]: 23.11
Average Branch Pipe Pressure Drop (psig): 10.01
Average Branch Pipe Pressure Drop > 10x Δp_p: Yes

Header Pipe Estimated Conditions (Continued)

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Description:	MW-20 to Tee	Tee to IRZ-39		Static Head IRZ-39 to lowest point							
Length of Segment (ft):	856	140									
Header flow rate (gpm):	**4**	4									
Branch flow rate (gpm):	---	4									
Header Pipe Velocity (ft/s):	0.12	0.12									
Reynolds Number, Re:	3.11E+03	3.11E+03									
Fanning Friction Factor, f (Eq(6)):	0.01077	0.01077									
Pressure Drop (ft w.c.), (Eq.(7)):	0.03	0.00									
Velocity Head, $v^2/2g_c$ (ft w.c.):	0.0002	0.0002									
Pressure Drop (ft w.c.):	0.03	0.00		27.50							

Branch Pipe Estimated Conditions (Continued)

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Orifice Velocity (ft/s):	---	0.44									
Length of Branch Pipe (ft)[2]:	---	20									
Reynolds Number, Re:	---	5.89E+03									
Fanning Friction Factor, f:	---	0.00893									
Pressure Drop (ft w.c.), (Eq.(7)):	---	0.01									
Velocity Head, $v^2/2g_c$ (ft w.c.):	---	0.003									
Pressure Drop (ft w.c.)[3]:	---	0.01									
Well Head Pressure (ft w.c.)[4]:	---	23.1									

Header Pipe Estimated Conditions

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Length of Segment (ft):											**996**	**(Total)**
Header flow rate (gpm):											**---**	**---**
Branch flow rate (gpm):											**---**	**---**
Header Pipe Velocity (ft/s):											**0.1**	**(Avg.)**
Reynolds Number, Re:											**3.11E+03**	**(Avg.)**
Fanning Friction Factor, f:											**0.01077**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.000**	**(Avg.)**
Pressure Drop (ft w.c.):											**27.53**	**(Total)**

Branch Pipe Estimated Conditions

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Orifice Velocity (ft/s):											**0.44**	**(Avg.)**
Length of Branch Pipe (ft)[2]:											**20.00**	**(Avg.)**
Reynolds Number, Re:											**5.89E+03**	**(Avg.)**
Fanning Friction Factor, f:											**0.00893**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.003**	**(Avg.)**
Pressure Drop (ft w.c.)[3]:											**0.01**	**(Avg.)**
Well Head Pressure (ft w.c.)[4]:											**23.10**	**(Avg.)**

Eq. (1)
Discharge Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} - 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (2)
Return Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} + 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (3)
Branch Outlet Pressure Drop:

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2g_c}$$

Eq. (4)
Reynolds Number:

$$Re = \frac{D \cdot v \cdot \rho}{\mu} = \frac{D \cdot v}{\eta}$$

Eq. (5)
Distribution Equation:

$$\%\,Maldistribution = 100\left(1 - \sqrt{\frac{|\Delta p_o| - |\Delta p_p|}{\Delta p_o}}\right)$$

Eq. (6)
Fanning Friction Factor:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{[(p_0 - p_L) - \rho g(h_0 - h_L)]}{\frac{1}{2}\rho v^2}\right)$$

Eq. (7)
Darcy Equation:

$$h_L = \left[\left(4f\,\frac{L}{D}\right)\right]\frac{v^2}{2g}$$

Notes:

(1) K = 0.5 when viscous losses are negligible, K = 1.0 for return headers.
(2) Include the equivalent length of valves and fittings.
(3) Pressure drop due to velocity head and friction losses across the length of the branch pipe.
(4) Pressure at the well head taking into consideration frictional losses across the length of the drop pipe, static head associated with water elevation and mounding, and pressure drop required for foot valve or variable area valve.
(5) Maldistribution of 10 percent or less is recommended.
(6) If the branch piping exhibits average pressure losses (due to length, fittings, and/or well head pressures) of at least 10 times higher than the header, pressure losses maldistribution will be less than 10 percent.

Header and Branch Distribution Piping Hydraulic Worksheet - IRL

Site: Pacific Gas & Electric Topock Compressor Station
Location: Topock, California

Created By: YS
Revision No. 1
Revision Date: 7/20/2012

Fluid:	**Water**
Fluid Temperature (deg F):	**50**
Initial Flowrate	450
Header Length (ft):	4,000
Number of Branches	4
Average Branch Flowrate (gpm):	112.5

(●) DISCHARGE HEADER

( ) RETURN HEADER

Header Pipe Material: Smooth Pipes (PE and other thermoplastics/Brass/Glass a

Header Pipe Type: SDR 11 - HDPE

Header Pipe Nominal Diameter (in): 8

Header Pipe, e (ft): **0.00001**
Header Pipe Inner Diameter (in): **6.963**
e / D: 0.00001

Branch Pipe Material: Smooth Pipes (PE and other thermoplastics/Brass/Glass a

Branch Pipe Type: SDR 11 - HDPE

Branch Pipe Nominal Diameter (in): 3

Branch Pipe, e (ft): **0.00001**
Branch Pipe Inner Diameter (in): **2.825**
e / D: 0.00002

Fluid Density (lb/ft^3): **62.36**
Viscosity (cP): **1.12**

Kinematic viscosity, v (ft^2/s): **1.21E-05**
g (ft/s^2): **32.17**
Oriface Coefficient, C_o: **0.62**
Oriface Value, K[1]: **0.5**

Header Pressure Drop, Δp_p (lb$_f$/ft^2):	329.0
Header Pressure Drop, Δp_p (psig):	**2.29**
Branch Outlet Pressure Drop, Δp_o (lb$_f$/ft^2):	264.3
Branch Outlet Pressure Drop, Δp_o (psig):	**1.84**
Percent Maldistribution (%)[5]:	**Unbalanced**
Average Branch Pipe Pressure Drop (ft w.c.):	**12.22**
Average Well Head Pressure (ft w.c.):	**198.09**
Average Branch Pipe Pressure Drop (ft w.c.)[5]:	**210.31**
Average Branch Pipe Pressure Drop (psig):	**91.04**

Header Pipe Estimated Conditions

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Description:		MW-20 to IRL-1	IRL-1 to IRL-2	IRL-2 to IRL-3	IRL-3 to IRL-4		Static Head IRL-4 to IRL-1				
Length of Segment (ft):	0	3000	350	350	300						
Header flow rate (gpm):	**450**	450	375	300	200						
Branch flow rate (gpm):	**---**	75	75	100	200						
Header Pipe Velocity (ft/s):	3.79	3.79	3.16	2.53	1.69						
Reynolds Number, Re:	1.82E+05	1.82E+05	1.52E+05	1.22E+05	8.10E+04						
Fanning Friction Factor, f:	0.00400	0.00400	0.00414	0.00433	0.00471						
Fanning Friction Factor, f (Eq(6)):	0.00400	0.00400	0.00414	0.00433	0.00471						
Pressure Drop (ft w.c.), (Eq.(7)):	0.00	18.48	1.55	1.04	0.43						
Velocity Head, $v^2/2g_c$ (ft w.c.):	0.223	0.223	0.155	0.099	0.044						
Pressure Drop (ft w.c.):	0.00	18.48	1.55	1.04	0.43		TBD				

Branch Pipe Estimated Conditions

Location:	**Entrance**	1	2	3	4	5	6	7	8	9	10
Orifice Velocity (ft/s):	---	3.84	3.84	5.12	10.24						
Length of Branch Pipe (ft)[2]:	---	93	77	98	389						
Reynolds Number, Re:	---	7.49E+04	7.49E+04	9.99E+04	2.00E+05						
Fanning Friction Factor, f:	---	0.00481	0.00481	0.00453	0.00395						
Pressure Drop (ft w.c.), (Eq.(7)):	---	1.75	1.44	3.07	42.62						
Velocity Head, $v^2/2g_c$ (ft w.c.):	---	0.229	0.229	0.407	1.629						
Pressure Drop (ft w.c.)[3]:	---	1.75	1.44	3.07	42.62						
Well Head Pressure (ft w.c.)[4]:	---	80.32	56.72	155.17	500.15						

Header Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Length of Segment (ft):											**4,000**	**(Total)**
Header flow rate (gpm):											**---**	**---**
Branch flow rate (gpm):											**---**	**---**
Header Pipe Velocity (ft/s):											**3.0**	**(Avg.)**
Reynolds Number, Re:											**1.44E+05**	**(Avg.)**
Fanning Friction Factor, f:											**0.00424**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.149**	**(Avg.)**
Pressure Drop (ft w.c.):											**21.50**	**(Total)**

Branch Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Orifice Velocity (ft/s):											**5.76**	**(Avg.)**
Length of Branch Pipe (ft)[2]:											**164**	**(Avg.)**
Reynolds Number, Re:											**1.12E+05**	**(Avg.)**
Fanning Friction Factor, f:											**0.00452**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.624**	**(Avg.)**
Pressure Drop (ft w.c.)[3]:											**12.22**	**(Avg.)**
Well Head Pressure (ft w.c.)[4]:											**198.1**	**(Avg.)**

Eq. (1)
Discharge Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} - 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (2)
Return Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} + 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (3)
Branch Outlet Pressure Drop:

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2g_c}$$

Eq. (4)
Reynolds Number:

$$Re = \frac{D \cdot v \cdot \rho}{\mu} = \frac{D \cdot v}{\eta}$$

Eq. (5)
Distribution Equation:

$$\%\,Maldistribution = 100\left(1 - \sqrt{\frac{\Delta p_o - |\Delta p_p|}{\Delta p_o}}\right)$$

Eq. (6)
Fanning Friction Factor:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{[(p_0 - p_L) - \rho g(h_0 - h_L)]}{\frac{1}{2}\rho v^2}\right)$$

Eq. (7)
Darcy Equation:

$$h_L = \left[\left(4f\,\frac{L}{D}\right)\right]\frac{v^2}{2g}$$

Notes:

(1) K = 0.5 when viscous losses are negligible, K = 1.0 for return headers.
(2) Include the equivalent length of valves and fittings.
(3) Pressure drop due to velocity head and friction losses across the length of the branch pipe.
(4) Pressure at the well head taking into consideration frictional losses across the length of the drop pipe, static head associated with water elevation and mounding, and pressure drop required for foot valve or variable area valve.
(5) Maldistribution of 10 percent or less is recommended.
(6) If the branch piping exhibits average pressure losses (due to length, fittings, and/or well head pressures) of at least 10 times higher than the header, pressure losses maldistribution will be less than 10 percent.

Header and Branch Distribution Piping Hydraulic Worksheet - ER

Site: Pacific Gas & Electric Topock Compressor Station
Location: Topock, California

Created By: YS
Revision No. 0
Revision Date: 7/23/2012

Fluid:	**Water**
Fluid Temperature (deg F):	**50**
Maximum Flowrate	2
Header Length (ft):	1,130
Number of Branches	4
Average Branch Flowrate (gpm):	0.4

○ DISCHARGE HEADER

◉ RETURN HEADER

Header Pipe Material: Smooth Pipes (PE and other thermoplastics/Brass/Glass a

Header Pipe Type: SDR 11 - HDPE

Header Pipe Nominal Diameter (in): 2

Header Pipe, e (ft): **0.00001**
Header Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Branch Pipe Material: Smooth Pipes (PE and other thermoplastics/Brass/Glass a

Branch Pipe Type: SDR 11 - HDPE

Branch Pipe Nominal Diameter (in): 2

Branch Pipe, e (ft): **0.00001**
Branch Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Fluid Density (lb/ft^3): **62.36**
Viscosity (cP): **1.12**

Kinematic viscosity, v (ft^2/s): **1.21E-05**
g (ft/s^2): **32.17**
Oriface Coefficient, C_o: **0.62**
Oriface Value, K[1]: **1.0**

Header Pressure Drop, Δp_p (lb$_f$/ft^2): 2.5
Header Pressure Drop, Δp_p (psig): 0.02
Branch Outlet Pressure Drop, Δp_o (lb$_f$/ft^2): 0.008
Branch Outlet Pressure Drop, Δp_o (psig): 0.0001
Percent Maldistribution (%)[5]: Unbalanced
Average Branch Pipe Pressure Drop (ft w.c.): 0.00
Average Well Head Pressure (ft w.c.): 23.10
Average Branch Pipe Pressure Drop (ft w.c.)[5]: 23.10
Average Branch Pipe Pressure Drop (psig): 10.00
Average Branch Pipe Pressure Drop > 10x Δp_p: Yes

Header Pipe Estimated Conditions

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
		ER-4 to ER-3	ER-3 to ER-2	ER-2 to ER-1	ER-1 to TWB		Static Head ER-4 to ER-1				
Length of Segment (ft):	0	575	175	230	150						
Header flow rate (gpm):		0.5	1	1.5	2						
Branch flow rate (gpm):		0.5	0.5	0.5	0.5						
Header Pipe Velocity (ft/s):		0.06	0.11	0.17	0.22						
Reynolds Number, Re:		7.36E+02	1.47E+03	2.21E+03	2.94E+03						
Fanning Friction Factor, f (Eq(6)):		0.02175	0.01087	0.01198	0.01095						
Pressure Drop (ft w.c.), (Eq.(7)):		0.02	0.01	0.03	0.03						
Velocity Head, $v^2/2g_c$ (ft w.c.):		0.0000	0.0002	0.0004	0.0008						
Pressure Drop (ft w.c.):		0.02	0.01	0.03	0.03		17.50				

Branch Pipe Estimated Conditions

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Orifice Velocity (ft/s):	---	0.06	0.06	0.06	0.06						
Length of Branch Pipe (ft)[2]:	---	27	27	37	47						
Reynolds Number, Re:	---	7.36E+02	7.36E+02	7.36E+02	7.36E+02						
Fanning Friction Factor, f:	---	0.02175	0.02175	0.02175	0.02175						
Pressure Drop (ft w.c.), (Eq.(7)):	---	0.001	0.001	0.001	0.001						
Velocity Head, $v^2/2g_c$ (ft w.c.):	---	0.00005	0.00005	0.00005	0.00005						
Pressure Drop (ft w.c.)[3]:	---	0.001	0.001	0.001	0.001						
Well Head Pressure (ft w.c.)[4]:	---	23.1	23.1	23.1	23.1						

Header Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Length of Segment (ft):											**1,130**	**(Total)**
Header flow rate (gpm):											---	---
Branch flow rate (gpm):											---	---
Header Pipe Velocity (ft/s):											**0.1**	**(Avg.)**
Reynolds Number, Re:											**1.84E+03**	**(Avg.)**
Fanning Friction Factor, f:											**0.01389**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.000**	**(Avg.)**
Pressure Drop (ft w.c.):											**17.59**	**(Total)**

Branch Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Orifice Velocity (ft/s):											**0.06**	**(Avg.)**
Length of Branch Pipe (ft)[2]:											**34.14**	**(Avg.)**
Reynolds Number, Re:											**7.36E+02**	**(Avg.)**
Fanning Friction Factor, f:											**0.02175**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.000**	**(Avg.)**
Pressure Drop (ft w.c.)[3]:											**0.00**	**(Avg.)**
Well Head Pressure (ft w.c.)[4]:											**23.10**	**(Avg.)**

Eq. (1)
Discharge Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} - 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (2)
Return Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} + 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (3)
Branch Outlet Pressure Drop:

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2g_c}$$

Eq. (4)
Reynolds Number:

$$Re = \frac{D \cdot v \cdot \rho}{\mu} = \frac{D \cdot v}{\eta}$$

Eq. (5)
Distribution Equation:

$$\%\,Maldistribution = 100\left(1 - \sqrt{\frac{\left|\Delta p_o - |\Delta p_p|\right|}{\Delta p_o}}\right)$$

Eq. (6)
Fanning Friction Factor:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{[(p_o - p_L) - \rho g(h_o - h_L)]}{\frac{1}{2}\rho v^2}\right)$$

Eq. (7)
Darcy Equation:

$$h_L = \left[\left(4f\,\frac{L}{D}\right)\right]\frac{v^2}{2g}$$

Notes:

(1) K = 0.5 when viscous losses are negligible, K = 1.0 for return headers.
(2) Include the equivalent length of valves and fittings.
(3) Pressure drop due to velocity head and friction losses across the length of the branch pipe.
(4) Pressure at the well head taking into consideration frictional losses across the length of the drop pipe, static head associated with water elevation and mounding, and pressure drop required for foot valve or variable area valve.
(5) Maldistribution of 10 percent or less is recommended.
(6) If the branch piping exhibits average pressure losses (due to length, fittings, and/or well head pressures) of at least 10 times higher than the header, pressure losses maldistribution will be less than 10 percent.

Header and Branch Distribution Piping Hydraulic Worksheet - TWB

Site: Pacific Gas & Electric Topock Compressor Station
Location: Topock, California

Created By: YS
Revision No. 1
Revision Date: 7/20/2012

Fluid:	**Water**
Fluid Temperature (deg F):	**50**
Maximum Flowrate:	13
Header Length (ft):	320
Number of Branches:	2
Average Branch Flowrate (gpm):	4.3

○ DISCHARGE HEADER

◉ RETURN HEADER

Header Pipe Material: Smooth Pipes (PE and other thermoplastics/Brass/Glass and

Header Pipe Type: SDR 11 - HDPE

Header Pipe Nominal Diameter (in): 4

Header Pipe, e (ft): **0.00001**
Header Pipe Inner Diameter (in): **3.633**
e / D: 0.00002

Branch Pipe Material: Smooth Pipes (PE and other thermoplastics/Brass/Glass and

Branch Pipe Type: SDR 11 - HDPE

Branch Pipe Nominal Diameter (in): 2

Branch Pipe, e (ft): **0.00001**
Branch Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Fluid Density (lb/ft^3): **62.36**
Viscosity (cP): **1.12**

Kinematic viscosity, v (ft^2/s): **1.21E-05**
g (ft/s^2): **32.17**
Oriface Coefficient, C_o: **0.62**
Oriface Value, K[1]: **1.0**

Header Pressure Drop, Δp_p (lb$_f$/ft^2): 3.5
Header Pressure Drop, Δp_p (psig): 0.02
Branch Outlet Pressure Drop, Δp_o (lb$_f$/ft^2): 3.8
Branch Outlet Pressure Drop, Δp_o (psig): 0.03
Percent Maldistribution (%)[5]: 71.46%
Average Branch Pipe Pressure Drop (ft w.c.): 0.25
Average Well Head Pressure (ft w.c.): 38.92
Average Branch Pipe Pressure Drop (ft w.c.)[5]: 39.17
Average Branch Pipe Pressure Drop (psig): 16.96
Average Branch Pipe Pressure Drop > 10x Δp_p: Yes

Header Pipe Estimated Conditions

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Description		TWB-1 to TWB-2	TWB-2 to TWB		Static Head						
Length of Segment (ft):	0	140	180								
Header flow rate (gpm):		13	22								
Branch flow rate (gpm):		13	9								
Header Pipe Velocity (ft/s):		0.40	0.68								
Reynolds Number, Re:		1.01E+04	1.71E+04								
Fanning Friction Factor, f (Eq(6)):		0.0077	0.0067								
Pressure Drop (ft w.c.), (Eq.(7)):		0.04	0.12								
Velocity Head, $v^2/2g_c$ (ft w.c.):		0.003	0.007								
Pressure Drop (ft w.c.):		0.04	0.12		TBD						

Branch Pipe Estimated Conditions

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Orifice Velocity (ft/s):	---	1.45	1.00								
Length of Branch Pipe (ft)[2]:	---	62	59								
Reynolds Number, Re:	---	1.91E+04	1.32E+04								
Fanning Friction Factor, f:	---	0.00656	0.00719								
Pressure Drop (ft w.c.), (Eq.(7)):	---	0.33	0.16								
Velocity Head, $v^2/2g_c$ (ft w.c.):	---	0.032	0.016								
Pressure Drop (ft w.c.)[3]:	---	0.33	0.16								
Well Head Pressure (ft w.c.)[4]:	---	198.42	190.80	0	0	0	0	0	0	0	0

Header Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Length of Segment (ft):											**320**	**(Total)**
Header flow rate (gpm):											---	---
Branch flow rate (gpm):											---	---
Header Pipe Velocity (ft/s):											**0.5**	**(Avg.)**
Reynolds Number, Re:											**1.36E+04**	**(Avg.)**
Fanning Friction Factor, f:											**0.00722**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.005**	**(Avg.)**
Pressure Drop (ft w.c.):											**0.15**	**(Total)**

Branch Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Orifice Velocity (ft/s):											**1.22**	**(Avg.)**
Length of Branch Pipe (ft)[2]:											**60.29**	**(Avg.)**
Reynolds Number, Re:											**1.62E+04**	**(Avg.)**
Fanning Friction Factor, f:											**0.00687**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.024**	**(Avg.)**
Pressure Drop (ft w.c.)[3]:											**0.25**	**(Avg.)**
Well Head Pressure (ft w.c.)[4]:											**38.92**	**(Avg.)**

Eq. (1)
Discharge Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} - 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (2)
Return Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} + 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (3)
Branch Outlet Pressure Drop:

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2g_c}$$

Eq. (4)
Reynolds Number:

$$Re = \frac{D \cdot v \cdot \rho}{\mu} = \frac{D \cdot v}{\eta}$$

Eq. (5)
Distribution Equation:

$$\%\,Maldistribution = 100\left(1 - \sqrt{\frac{\Delta p_o - |\Delta p_p|}{\Delta p_o}}\right)$$

Eq. (6)
Fanning Friction Factor:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{[(p_0 - p_L) - \rho g(h_0 - h_L)]}{\frac{1}{2}\rho v^2}\right)$$

Eq. (7)
Darcy Equation:

$$h_L = \left[\left(4f\,\frac{L}{D}\right)\right]\frac{v^2}{2g}$$

Notes:

(1) K = 0.5 when viscous losses are negligible, K = 1.0 for return headers.
(2) Include the equivalent length of valves and fittings.
(3) Pressure drop due to velocity head and friction losses across the length of the branch pipe.
(4) Pressure at the well head taking into consideration frictional losses across the length of the drop pipe, static head associated with water elevation and mounding, and pressure drop required for foot valve or variable area valve.
(5) Maldistribution of 10 percent or less is recommended.
(6) If the branch piping exhibits average pressure losses (due to length, fittings, and/or well head pressures) of at least 10 times higher than the header, pressure losses maldistribution will be less than 10 percent.

Header and Branch Distribution Piping Hydraulic Worksheet - TCS

Site: Pacific Gas & Electric Topock Compressor Station
Location: Topock, California

Created By: YS
Revision No. 1
Revision Date: 7/20/2012

Fluid:	**Water**
Fluid Temperature (deg F):	**50**
Initial Flowrate	24
Header Length (ft):	3,550
Number of Branches	2
Average Branch Flowrate (gpm):	12.0

(●) DISCHARGE HEADER

( ) RETURN HEADER

Header Pipe Material: Smooth Pipes (PE and other thermoplastics/Brass/Glass a

Header Pipe Type: SDR 11 - HDPE

Header Pipe Nominal Diameter (in): 2

Header Pipe, e (ft): **0.00001**
Header Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Branch Pipe Material: Smooth Pipes (PE and other thermoplastics/Brass/Glass a

Branch Pipe Type: SDR 11 - HDPE

Branch Pipe Nominal Diameter (in): 2

Branch Pipe, e (ft): **0.00001**
Branch Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Fluid Density (lb/ft^3): **62.36**
Viscosity (cP): **1.12**

Kinematic viscosity, v (ft^2/s): **1.21E-05**
g (ft/s^2): **32.17**
Oriface Coefficient, C_o: **0.62**
Oriface Value, K[1]: **0.5**

Header Pressure Drop, Δp_p (lb$_f$/ft^2): 848.8
Header Pressure Drop, Δp_p (psig): 5.89
Branch Outlet Pressure Drop, Δp_o (lb$_f$/ft^2): 4.5
Branch Outlet Pressure Drop, Δp_o (psig): 0.03
Percent Maldistribution (%)[5]: Unbalanced
Average Branch Pipe Pressure Drop (ft w.c.): 1.26
Average Well Head Pressure (ft w.c.): 48.59
Average Branch Pipe Pressure Drop (ft w.c.)[5]: 49.86
Average Branch Pipe Pressure Drop (psig): 21.58
Average Branch Pipe Pressure Drop > 10x Δp_p: No

Header Pipe Estimated Conditions

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Description		TWB to TCS-2	TCS-2 to TCS-1		Static Head						
Length of Segment (ft):	0	3500	50								
Header flow rate (gpm):	**24**	24	12								
Branch flow rate (gpm):	**---**	12	12								
Header Pipe Velocity (ft/s):	2.67	2.67	1.33								
Reynolds Number, Re:	3.53E+04	3.53E+04	1.77E+04								
Fanning Friction Factor, f (Eq(6)):	0.00568	0.00568	0.00669								
Pressure Drop (ft w.c.), (Eq.(7)):	0.00	55.03	0.23								
Velocity Head, $v^2/2g_c$ (ft w.c.):	0.111	0.111	0.028								
Pressure Drop (ft w.c.):	0.00	55.03	0.23		TBD						

Branch Pipe Estimated Conditions

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Orifice Velocity (ft/s):	---	1.33	1.33								
Length of Branch Pipe (ft)[2]:	---	68	68								
Reynolds Number, Re:	---	1.77E+04	1.77E+04								
Fanning Friction Factor, f:	---	0.02700	0.02700								
Pressure Drop (ft w.c.), (Eq.(7)):	---	1.26	1.26								
Velocity Head, $v^2/2g_c$ (ft w.c.):	---	0.028	0.028								
Pressure Drop (ft w.c.)[3]:	---	1.26	1.26								
Well Head Pressure (ft w.c.)[4]:	---	48.74	48.44								

Header Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Length of Segment (ft):											**3,550**	**(Total)**
Header flow rate (gpm):											**---**	**---**
Branch flow rate (gpm):											**---**	**---**
Header Pipe Velocity (ft/s):											**2.2**	**(Avg.)**
Reynolds Number, Re:											**2.94E+04**	**(Avg.)**
Fanning Friction Factor, f:											**0.00601**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.083**	**(Avg.)**
Pressure Drop (ft w.c.):											**55.26**	**(Total)**

Branch Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Orifice Velocity (ft/s):											**1.33**	**(Avg.)**
Length of Branch Pipe (ft)[2]:											**68**	**(Avg.)**
Reynolds Number, Re:											**1.77E+04**	**(Avg.)**
Fanning Friction Factor, f:											**0.02700**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.028**	**(Avg.)**
Pressure Drop (ft w.c.)[3]:											**1.26**	**(Avg.)**
Well Head Pressure (ft w.c.)[4]:											**48.6**	**(Avg.)**

Eq. (1)
Discharge Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} - 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (2)
Return Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} + 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (3)
Branch Outlet Pressure Drop:

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2g_c}$$

Eq. (4)
Reynolds Number:

$$Re = \frac{D \cdot v \cdot \rho}{\mu} = \frac{D \cdot v}{\eta}$$

Eq. (5)
Distribution Equation:

$$\%\,Maldistribution = 100\left(1 - \sqrt{\frac{|\Delta p_o| - |\Delta p_p|}{\Delta p_o}}\right)$$

Eq. (6)
Fanning Friction Factor:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{[(p_0 - p_L) - \rho g(h_0 - h_L)]}{\frac{1}{2}\rho v^2}\right)$$

Eq. (7)
Darcy Equation:

$$h_L = \left[\left(4f\,\frac{L}{D}\right)\right]\frac{v^2}{2g}$$

Notes:

(1) K = 0.5 when viscous losses are negligible, K = 1.0 for return headers.
(2) Include the equivalent length of valves and fittings.
(3) Pressure drop due to velocity head and friction losses across the length of the branch pipe.
(4) Pressure at the well head taking into consideration frictional losses across the length of the drop pipe, static head associated with water elevation and mounding, and pressure drop required for foot valve or variable area valve.
(5) Maldistribution of 10 percent or less is recommended.
(6) If the branch piping exhibits average pressure losses (due to length, fittings, and/or well head pressures) of at least 10 times higher than the header, pressure losses maldistribution will be less than 10 percent.

Header and Branch Distribution Piping Hydraulic Worksheet - North IRZ BW Extraction Header

Site: Pacific Gas & Electric Topock Compressor Station
Location: Topock, California

Created By: BAS
Revision No. 2
Revision Date: 2/20/2013

Fluid: **Water**
Fluid Temperature (deg F): **50**

Maximum Flowrate: 40
Header Length (ft): 755
Number of Branches: 1
Average Branch Flowrate (gpm): 40.0

(●) DISCHARGE HEADER

( ) RETURN HEADER

Header Pipe Material:
13

Header Pipe Type:
SDR 11 - HDPE

Header Pipe Nominal Diameter (in):
2 — **9**

Header Pipe, e (ft): **0.00001**
Header Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Branch Pipe Material:
13

Branch Pipe Type:
SDR 11 - HDPE

Branch Pipe Nominal Diameter (in):
2
2

Branch Pipe, e (ft): **0.00001**
Branch Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Fluid Density (lb/ft^3): **62.36**
Viscosity (cP): **1.12**

Kinematic viscosity, v (ft^2/s): **1.21E-05**
g (ft/s^2): **32.17**
Oriface Coefficient, C_o: **0.62**
Oriface Value, K[1]: **0.5**

Header Pressure Drop, Δp_p (lb$_f$/ft^2): 593.0
Header Pressure Drop, Δp_p (psig): 4.12
Branch Outlet Pressure Drop, Δp_o (lb$_f$/ft^2): 49.9
Branch Outlet Pressure Drop, Δp_o (psig): 0.35
Percent Maldistribution (%)[5]: Unbalanced
Average Branch Pipe Pressure Drop (ft w.c.): 2.85
Average Well Head Pressure (ft w.c.): 0.00
Average Branch Pipe Pressure Drop (ft w.c.)[5]: 2.85
Average Branch Pipe Pressure Drop (psig): 1.23
Average Branch Pipe Pressure Drop > 10x Δp_p: No

Header Pipe Estimated Conditions

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Description:		EXIRZ-11 to MW-20									Static Head EXIRZ-11 to MW-20
Length of Segment (ft):	0	755	0	0	0	0	0	0	0		
Header flow rate (gpm):		40									
Branch flow rate (gpm):	---	40									
Header Pipe Velocity (ft/s):	0.00	4.45									
Reynolds Number, Re:		5.89E+04									
Fanning Friction Factor, f (Eq(6)):		0.00507									
Pressure Drop (ft w.c.), (Eq.(7)):		29.45									
Velocity Head, $v^2/2g_c$ (ft w.c.):	0.000	0.307									
Pressure Drop (ft w.c.):	0.00	29.45									15.0

Branch Pipe Estimated Conditions

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Orifice Velocity (ft/s):	---	4.45									
Length of Branch Pipe (ft)[2]:	---	73									
Reynolds Number, Re:	---	5.89E+04									
Fanning Friction Factor, f:	---	0.00507									
Pressure Drop (ft w.c.), (Eq.(7)):	---	2.85									
Velocity Head, $v^2/2g_c$ (ft w.c.):	---	0.307									
Pressure Drop (ft w.c.)[3]:	---	2.85									
Well Head Pressure (ft w.c.)[4]:	---	0	0	0	0	0	0	0	0	0	0

Header Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Length of Segment (ft):											755	(Total)
Header flow rate (gpm):											---	---
Branch flow rate (gpm):											---	---
Header Pipe Velocity (ft/s):											2.2	(Avg.)
Reynolds Number, Re:											5.89E+04	(Avg.)
Fanning Friction Factor, f:											0.00507	(Avg.)
Velocity Head, $v^2/2g_c$ (ft w.c.):											0.154	(Avg.)
Pressure Drop (ft w.c.):											44.45	(Total)

Branch Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Orifice Velocity (ft/s):											4.45	(Avg.)
Length of Branch Pipe (ft)[2]:											73.00	(Avg.)
Reynolds Number, Re:											5.89E+04	(Avg.)
Fanning Friction Factor, f:											0.00507	(Avg.)
Velocity Head, $v^2/2g_c$ (ft w.c.):											0.307	(Avg.)
Pressure Drop (ft w.c.)[3]:											2.85	(Avg.)
Well Head Pressure (ft w.c.)[4]:											0.00	(Avg.)

Eq. (1)
Discharge Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} - 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (2)
Return Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} + 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (3)
Branch Outlet Pressure Drop:

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2g_c}$$

Eq. (4)
Reynolds Number:

$$Re = \frac{D \cdot v \cdot \rho}{\mu} = \frac{D \cdot v}{\eta}$$

Eq. (5)
Distribution Equation:

$$\%\,Maldistribution = 100\left(1 - \sqrt{\frac{\Delta p_o - |\Delta p_p|}{\Delta p_o}}\right)$$

Eq. (6)
Fanning Friction Factor:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{[(p_0 - p_L) - \rho g(h_0 - h_L)]}{\frac{1}{2}\rho v^2}\right)$$

Eq. (7)
Darcy Equation:

$$h_L = \left[\left(4f\,\frac{L}{D}\right)\right]\frac{v^2}{2g}$$

Notes:

(1) K = 0.5 when viscous losses are negligible, K = 1.0 for return headers.
(2) Include the equivalent length of valves and fittings.
(3) Pressure drop due to velocity head and friction losses across the length of the branch pipe.
(4) Pressure at the well head taking into consideration frictional losses across the length of the drop pipe, static head associated with water elevation and mounding, and pressure drop required for foot valve or variable area valve.
(5) Maldistribution of 10 percent or less is recommended.
(6) If the branch piping exhibits average pressure losses (due to length, fittings, and/or well head pressures) of at least 10 times higher than the header, pressure losses maldistribution will be less than 10 percent.

4.45

Header and Branch Distribution Piping Hydraulic Worksheet - IRZ Backwash Header

Site: Pacific Gas & Electric Topock Compressor Station
Location: Topock, California

Created By: BAS
Revision No. 2
Revision Date: 2/20/2013

Fluid: **Water**
Fluid Temperature (deg F): **50**

Maximum Flowrate: 14
Header Length (ft): 290
Number of Branches: 1
Average Branch Flowrate (gpm): 14.0

(●) DISCHARGE HEADER

( ) RETURN HEADER

Header Pipe Material:

Header Pipe Type: SDR 11 - HDPE

Header Pipe Nominal Diameter (in): 2

Header Pipe, e (ft): **0.00001**
Header Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Branch Pipe Material:

Branch Pipe Type: SDR 11 - HDPE

Branch Pipe Nominal Diameter (in): 2

Branch Pipe, e (ft): **0.00001**
Branch Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Fluid Density (lb/ft^3): **62.36**
Viscosity (cP): **1.12**

Kinematic viscosity, v (ft^2/s): **1.21E-05**
g (ft/s^2): **32.17**
Oriface Coefficient, C_o: **0.62**
Oriface Value, K[1]: **0.5**

Header Pressure Drop, Δp_p (lb$_f$/ft^2): 34.3
Header Pressure Drop, Δp_p (psig): 0.24
Branch Outlet Pressure Drop, Δp_o (lb$_f$/ft^2): 6.1
Branch Outlet Pressure Drop, Δp_o (psig): 0.04
Percent Maldistribution (%)[5]: Unbalanced
Average Branch Pipe Pressure Drop (ft w.c.): 1.03
Average Well Head Pressure (ft w.c.): 0.00
Average Branch Pipe Pressure Drop (ft w.c.)[5]: 1.03
Average Branch Pipe Pressure Drop (psig): 0.45
Average Branch Pipe Pressure Drop > 10x Δp_p: No

	Header Pipe Estimated Conditions											
Location:	**Entrance**	1	2	3	4	5	6	7	8	9	10	
Description:		EXIRZ-27 to MW-20									Static Head IRZ-27 to MW-20	
Length of Segment (ft):	0	290										
Header flow rate (gpm):		14										
Branch flow rate (gpm):	---	14										
Header Pipe Velocity (ft/s):	0.00	1.56										
Reynolds Number, Re:		2.06E+04										
Fanning Friction Factor, f (Eq(6)):		0.00644										
Pressure Drop (ft w.c.), (Eq.(7)):		1.76										
Velocity Head, $v^2/2g_c$ (ft w.c.):	0.000	0.038										
Pressure Drop (ft w.c.):	0.00	1.76									-3.00	
	Branch Pipe Estimated Conditions											
Location:	**Entrance**	1	2	3	4	5	6	7	8	9	10	
Orifice Velocity (ft/s):	---	1.56										
Length of Branch Pipe (ft)[2]:	---	170										
Reynolds Number, Re:	---	2.06E+04										
Fanning Friction Factor, f:	---	0.00644										
Pressure Drop (ft w.c.), (Eq.(7)):	---	1.03										
Velocity Head, $v^2/2g_c$ (ft w.c.):	---	0.038										
Pressure Drop (ft w.c.)[3]:	---	1.03										
Well Head Pressure (ft w.c.)[4]:	---	0	0	0	0	0	0	0	0	0	0	

	Header Pipe Estimated Conditions (Continued)											
Location:	11	12	13	14	15	16	17	18	19	20	**Summary**	
Length of Segment (ft):											**290**	**(Total)**
Header flow rate (gpm):											---	---
Branch flow rate (gpm):											---	---
Header Pipe Velocity (ft/s):											**0.8**	**(Avg.)**
Reynolds Number, Re:											**2.06E+04**	**(Avg.)**
Fanning Friction Factor, f:											**0.00644**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.019**	**(Avg.)**
Pressure Drop (ft w.c.):											**-1.24**	**(Total)**
	Branch Pipe Estimated Conditions (Continued)											
Location:	11	12	13	14	15	16	17	18	19	20	**Summary**	
Orifice Velocity (ft/s):											**1.56**	**(Avg.)**
Length of Branch Pipe (ft)[2]:											**170.00**	**(Avg.)**
Reynolds Number, Re:											**2.06E+04**	**(Avg.)**
Fanning Friction Factor, f:											**0.00644**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.038**	**(Avg.)**
Pressure Drop (ft w.c.)[3]:											**1.03**	**(Avg.)**
Well Head Pressure (ft w.c.)[4]:											**0.00**	**(Avg.)**

Eq. (1)
Discharge Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} - 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (2)
Return Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} + 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (3)
Branch Outlet Pressure Drop:

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2g_c}$$

Eq. (4)
Reynolds Number:

$$Re = \frac{D \cdot v \cdot \rho}{\mu} = \frac{D \cdot v}{\eta}$$

Eq. (5)
Distribution Equation:

$$\%\ Maldistribution = 100\left(1 - \sqrt{\frac{\Delta p_o - |\Delta p_p|}{\Delta p_o}}\right)$$

Eq. (6)
Fanning Friction Factor:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{[(p_0 - p_L) - \rho g(h_0 - h_L)]}{\frac{1}{2}\rho v^2}\right)$$

Eq. (7)
Darcy Equation:

$$h_L = \left[\left(4f\ \frac{L}{D}\right)\right]\frac{v^2}{2g}$$

Notes:

(1) K = 0.5 when viscous losses are negligible, K = 1.0 for return headers.
(2) Include the equivalent length of valves and fittings.
(3) Pressure drop due to velocity head and friction losses across the length of the branch pipe.
(4) Pressure at the well head taking into consideration frictional losses across the length of the drop pipe, static head associated with water elevation and mounding, and pressure drop required for foot valve or variable area valve.
(5) Maldistribution of 10 percent or less is recommended.
(6) If the branch piping exhibits average pressure losses (due to length, fittings, and/or well head pressures) of at least 10 times higher than the header, pressure losses maldistribution will be less than 10 percent.

1.56

Header and Branch Distribution Piping Hydraulic Worksheet - IRZ Backwash Header

Site: Pacific Gas & Electric Topock Compressor Station
Location: Topock, California

Created By: BAS
Revision No. 2
Revision Date: 2/15/2013

Fluid:	**Water**
Fluid Temperature (deg F):	**50**
Maximum Flowrate:	28
Header Length (ft):	1,540
Number of Branches:	1
Average Branch Flowrate (gpm):	28.0

○ DISCHARGE HEADER

◉ RETURN HEADER

Header Pipe Material:

Header Pipe Type: SDR 11 - HDPE

Header Pipe Nominal Diameter (in): 2

Header Pipe, e (ft): **0.00001**
Header Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Branch Pipe Material:

Branch Pipe Type: SDR 11 - HDPE

Branch Pipe Nominal Diameter (in): 2 / 2

Branch Pipe, e (ft): **0.00001**
Branch Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Fluid Density (lb/ft^3): **62.36**
Viscosity (cP): **1.12**

Kinematic viscosity, v (ft^2/s): **1.21E-05**
g (ft/s^2): **32.17**
Oriface Coefficient, C_o: **0.62**
Oriface Value, K[1]: **1.0**

Header Pressure Drop, Δp_p (lb$_f$/ft^2): #VALUE!
Header Pressure Drop, Δp_p (psig): #VALUE!
Branch Outlet Pressure Drop, Δp_o (lb$_f$/ft^2): #VALUE!
Branch Outlet Pressure Drop, Δp_o (psig): #VALUE!
Percent Maldistribution (%)[5]: Unbalanced
Average Branch Pipe Pressure Drop (ft w.c.): 1.03
Average Well Head Pressure (ft w.c.): 0.00
Average Branch Pipe Pressure Drop (ft w.c.)[5]: 1.03
Average Branch Pipe Pressure Drop (psig): 0.45
Average Branch Pipe Pressure Drop > 10x Δp_p: #VALUE!

Header Pipe Estimated Conditions

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Description:		EXIRZ-29 to Tee	EXIRZ-35 to EXIRZ-33	EXIRZ-33 to Tee	EXIRZ-31 to Tee						Static Head IRZ-29 to Tee
Length of Segment (ft):	1360	180	0	0	0			0			
Header flow rate (gpm):	**0**	28									
Branch flow rate (gpm):	--	28	0	0	0			0			
Header Pipe Velocity (ft/s):	0.00	3.11									
Reynolds Number, Re:		4.12E+04									
Fanning Friction Factor, f (Eq(6)):		0.00548									
Pressure Drop (ft w.c.), (Eq.(7)):		3.72									
Velocity Head, $v^2/2g_c$ (ft w.c.):	0.000	0.151									
Pressure Drop (ft w.c.):	0.00	3.72									-2.50

Branch Pipe Estimated Conditions

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Orifice Velocity (ft/s):	---	3.11									
Length of Branch Pipe (ft)[2]:	---	50									
Reynolds Number, Re:	---	4.12E+04									
Fanning Friction Factor, f:	---	0.00548									
Pressure Drop (ft w.c.), (Eq.(7)):	---	1.03									
Velocity Head, $v^2/2g_c$ (ft w.c.):	---	0.151									
Pressure Drop (ft w.c.)[3]:	---	1.03									
Well Head Pressure (ft w.c.)[4]:	---	0	0	0	0	0	0	0	0	0	0

Header Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Length of Segment (ft):											**1,540**	**(Total)**
Header flow rate (gpm):											---	---
Branch flow rate (gpm):											---	---
Header Pipe Velocity (ft/s):											**1.6**	**(Avg.)**
Reynolds Number, Re:											**4.12E+04**	**(Avg.)**
Fanning Friction Factor, f:											**0.00548**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.075**	**(Avg.)**
Pressure Drop (ft w.c.):											**1.22**	**(Total)**

Branch Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Orifice Velocity (ft/s):											**3.11**	**(Avg.)**
Length of Branch Pipe (ft)[2]:											**50.00**	**(Avg.)**
Reynolds Number, Re:											**4.12E+04**	**(Avg.)**
Fanning Friction Factor, f:											**0.00548**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.151**	**(Avg.)**
Pressure Drop (ft w.c.)[3]:											**1.03**	**(Avg.)**
Well Head Pressure (ft w.c.)[4]:											**0.00**	**(Avg.)**

Eq. (1)
Discharge Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} - 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (2)
Return Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} + 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (3)
Branch Outlet Pressure Drop:

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2g_c}$$

Eq. (4)
Reynolds Number:

$$Re = \frac{D \cdot v \cdot \rho}{\mu} = \frac{D \cdot v}{\eta}$$

Eq. (5)
Distribution Equation:

$$\%\,Maldistribution = 100\left(1 - \sqrt{\frac{\Delta p_o - |\Delta p_p|}{\Delta p_o}}\right)$$

Eq. (6)
Fanning Friction Factor:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{[(p_0 - p_L) - \rho g(h_0 - h_L)]}{\frac{1}{2}\rho v^2}\right)$$

Eq. (7)
Darcy Equation:

$$h_L = \left[\left(4f\ \frac{L}{D}\right)\right]\frac{v^2}{2g}$$

Notes:

(1) K = 0.5 when viscous losses are negligible, K = 1.0 for return headers.
(2) Include the equivalent length of valves and fittings.
(3) Pressure drop due to velocity head and friction losses across the length of the branch pipe.
(4) Pressure at the well head taking into consideration frictional losses across the length of the drop pipe, static head associated with water elevation and mounding, and pressure drop required for foot valve or variable area valve.
(5) Maldistribution of 10 percent or less is recommended.
(6) If the branch piping exhibits average pressure losses (due to length, fittings, and/or well head pressures) of at least 10 times higher than the header, pressure losses maldistribution will be less than 10 percent.

3.11

Header and Branch Distribution Piping Hydraulic Worksheet - IRZ Backwash Header

Site: Pacific Gas & Electric Topock Compressor Station
Location: Topock, California

Created By: BAS
Revision No. 2
Revision Date: 2/15/2013

Fluid: **Water**
Fluid Temperature (deg F): **50**

Maximum Flowrate: 16
Header Length (ft): 996
Number of Branches: 1
Average Branch Flowrate (gpm): 16.0

○ DISCHARGE HEADER

◉ RETURN HEADER

Header Pipe Material:

Header Pipe Type: SDR 11 - HDPE

Header Pipe Nominal Diameter (in): 2

Header Pipe, e (ft): **0.00001**
Header Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Branch Pipe Material:

Branch Pipe Type: SDR 11 - HDPE

Branch Pipe Nominal Diameter (in): 2 / 2

Branch Pipe, e (ft): **0.00001**
Branch Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Fluid Density (lb/ft^3): **62.36**
Viscosity (cP): **1.12**

Kinematic viscosity, v (ft^2/s): **1.21E-05**
g (ft/s^2): **32.17**
Oriface Coefficient, C_o: **0.62**
Oriface Value, K[1]: **1.0**

Header Pressure Drop, Δp_p (lb$_f$/ft^2): **0.0**
Header Pressure Drop, Δp_p (psig): 0.00
Branch Outlet Pressure Drop, Δp_o (lb$_f$/ft^2): 0.0
Branch Outlet Pressure Drop, Δp_o (psig): 0.00
Percent Maldistribution (%)[5]: Unbalanced
Average Branch Pipe Pressure Drop (ft w.c.): 0.05
Average Well Head Pressure (ft w.c.): 0.00
Average Branch Pipe Pressure Drop (ft w.c.)[5]: 0.05
Average Branch Pipe Pressure Drop (psig): 0.02
Average Branch Pipe Pressure Drop > 10x Δp_o: #DIV/0!

Header Pipe Estimated Conditions

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Description:		EXIRZ-39 to Tee									Static Head EXIRZ-39 to Tee
Length of Segment (ft):	856	140		0	0	0	0	0	0		
Header flow rate (gpm):	**0**	16									
Branch flow rate (gpm):	---	8									
Header Pipe Velocity (ft/s):	0.00	1.78									
Reynolds Number, Re:		2.35E+04									
Fanning Friction Factor, f (Eq(6)):		0.00624									
Pressure Drop (ft w.c.), (Eq.(7)):		1.08									
Velocity Head, $v^2/2g_c$ (ft w.c.):	0.000	0.049									
Pressure Drop (ft w.c.):	0.00	1.08									2.00

Branch Pipe Estimated Conditions

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Orifice Velocity (ft/s):	---	0.89									
Length of Branch Pipe (ft)[2]:	---	20									
Reynolds Number, Re:	---	1.18E+04									
Fanning Friction Factor, f:	---	0.00741									
Pressure Drop (ft w.c.), (Eq.(7)):	---	0.05									
Velocity Head, $v^2/2g_c$ (ft w.c.):	---	0.012									
Pressure Drop (ft w.c.)[3]:	---	0.05									
Well Head Pressure (ft w.c.)[4]:	---	0	0	0	0	0	0	0	0	0	0

Header Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Length of Segment (ft):											**996**	**(Total)**
Header flow rate (gpm):											---	---
Branch flow rate (gpm):											---	---
Header Pipe Velocity (ft/s):											**0.9**	**(Avg.)**
Reynolds Number, Re:											**2.35E+04**	**(Avg.)**
Fanning Friction Factor, f:											**0.00624**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.025**	**(Avg.)**
Pressure Drop (ft w.c.):											**3.08**	**(Total)**

Branch Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Orifice Velocity (ft/s):											**0.89**	**(Avg.)**
Length of Branch Pipe (ft)[2]:											**20.00**	**(Avg.)**
Reynolds Number, Re:											**1.18E+04**	**(Avg.)**
Fanning Friction Factor, f:											**0.00741**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.012**	**(Avg.)**
Pressure Drop (ft w.c.)[3]:											**0.05**	**(Avg.)**
Well Head Pressure (ft w.c.)[4]:											**0.00**	**(Avg.)**

Eq. (1)
Discharge Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} - 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (2)
Return Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} + 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (3)
Branch Outlet Pressure Drop:

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2g_c}$$

Eq. (4)
Reynolds Number:

$$Re = \frac{D \cdot v \cdot \rho}{\mu} = \frac{D \cdot v}{\eta}$$

Eq. (5)
Distribution Equation:

$$\%\,Maldistribution = 100\left(1 - \sqrt{\frac{\Delta p_o - |\Delta p_p|}{\Delta p_o}}\right)$$

Eq. (6)
Fanning Friction Factor:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{[(p_0 - p_L) - \rho g(h_0 - h_L)]}{\frac{1}{2}\rho v^2}\right)$$

Eq. (7)
Darcy Equation:

$$h_L = \left[\left(4f\,\frac{L}{D}\right)\right]\frac{v^2}{2g}$$

Notes:

(1) K = 0.5 when viscous losses are negligible, K = 1.0 for return headers.
(2) Include the equivalent length of valves and fittings.
(3) Pressure drop due to velocity head and friction losses across the length of the branch pipe.
(4) Pressure at the well head taking into consideration frictional losses across the length of the drop pipe, static head associated with water elevation and mounding, and pressure drop required for foot valve or variable area valve.
(5) Maldistribution of 10 percent or less is recommended.
(6) If the branch piping exhibits average pressure losses (due to length, fittings, and/or well head pressures) of at least 10 times higher than the header, pressure losses maldistribution will be less than 10 percent.

1.78

Header and Branch Distribution Piping Hydraulic Worksheet - TCS Backwash Header

Site: Pacific Gas & Electric Topock Compressor Station
Location: Topock, California

Created By: BAS
Revision No. 2
Revision Date: 2/15/2013

Fluid: **Water**
Fluid Temperature (deg F): **50**

Maximum Flowrate: 48
Header Length (ft): 3,550
Number of Branches: 1
Average Branch Flowrate (gpm): 48.0

○ DISCHARGE HEADER

◉ RETURN HEADER

Header Pipe Material:

Header Pipe Type: SDR 11 - HDPE

Header Pipe Nominal Diameter (in): 2

Header Pipe, e (ft): **0.00001**
Header Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Branch Pipe Material:

Branch Pipe Type: SDR 11 - HDPE

Branch Pipe Nominal Diameter (in): 2 / 2

Branch Pipe, e (ft): **0.00001**
Branch Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Fluid Density (lb/ft^3): **62.36**
Viscosity (cP): **1.12**

Kinematic viscosity, v (ft^2/s): **1.21E-05**
g (ft/s^2): **32.17**
Oriface Coefficient, C_o: **0.62**
Oriface Value, K[1]: **1.0**

Header Pressure Drop, Δp_p (lb$_f$/ft^2): **0.0**
Header Pressure Drop, Δp_p (psig): 0.00
Branch Outlet Pressure Drop, Δp_o (lb$_f$/ft^2): 71.8
Branch Outlet Pressure Drop, Δp_o (psig): 0.50
Percent Maldistribution (%)[5]: 0.00%
Average Branch Pipe Pressure Drop (ft w.c.): 3.67
Average Well Head Pressure (ft w.c.): 0.00
Average Branch Pipe Pressure Drop (ft w.c.)[5]: 3.67
Average Branch Pipe Pressure Drop (psig): 1.59
Average Branch Pipe Pressure Drop > 10x Δp_p: #DIV/0!

Header Pipe Estimated Conditions

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Description:		TCS-2 to TWB									Static Head
Length of Segment (ft):	0	3550		0	0	0	0	0	0		
Header flow rate (gpm):		48	0								
Branch flow rate (gpm):	---	48									
Header Pipe Velocity (ft/s):	0.00	5.34	0.00								
Reynolds Number, Re:		7.06E+04	0.00E+00								
Fanning Friction Factor, f (Eq(6)):		0.00488									
Pressure Drop (ft w.c.), (Eq.(7)):		191.82	#VALUE!								
Velocity Head, $v^2/2g_c$ (ft w.c.):	0.000	0.443	0.000								
Pressure Drop (ft w.c.):	0.00	191.82			-27.50						TBD

Branch Pipe Estimated Conditions

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Orifice Velocity (ft/s):	---	5.34	0.00								
Length of Branch Pipe (ft)[2]:	---	68									
Reynolds Number, Re:	---	7.06E+04	0.00E+00								
Fanning Friction Factor, f:	---	0.00488									
Pressure Drop (ft w.c.), (Eq.(7)):	---	3.67	#VALUE!								
Velocity Head, $v^2/2g_c$ (ft w.c.):	---	0.443	0.000								
Pressure Drop (ft w.c.)[3]:	---	3.67									
Well Head Pressure (ft w.c.)[4]:	---	0	0	0	0	0	0	0	0	0	0

Header Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Length of Segment (ft):											3,550	(Total)
Header flow rate (gpm):											---	---
Branch flow rate (gpm):											---	---
Header Pipe Velocity (ft/s):											1.8	(Avg.)
Reynolds Number, Re:											3.53E+04	(Avg.)
Fanning Friction Factor, f:											0.00488	(Avg.)
Velocity Head, $v^2/2g_c$ (ft w.c.):											0.148	(Avg.)
Pressure Drop (ft w.c.):											164.32	(Total)

Branch Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Orifice Velocity (ft/s):											2.67	(Avg.)
Length of Branch Pipe (ft)[2]:											68.00	(Avg.)
Reynolds Number, Re:											3.53E+04	(Avg.)
Fanning Friction Factor, f:											0.00488	(Avg.)
Velocity Head, $v^2/2g_c$ (ft w.c.):											0.221	(Avg.)
Pressure Drop (ft w.c.)[3]:											3.67	(Avg.)
Well Head Pressure (ft w.c.)[4]:											0.00	(Avg.)

Eq. (1)
Discharge Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} - 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (2)
Return Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} + 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (3)
Branch Outlet Pressure Drop:

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2g_c}$$

Eq. (4)
Reynolds Number:

$$Re = \frac{D \cdot v \cdot \rho}{\mu} = \frac{D \cdot v}{\eta}$$

Eq. (5)
Distribution Equation:

$$\%\ Maldistribution = 100\left(1 - \sqrt{\frac{\Delta p_o - |\Delta p_p|}{\Delta p_o}}\right)$$

Eq. (6)
Fanning Friction Factor:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{[(p_0 - p_L) - \rho g(h_0 - h_L)]}{\frac{1}{2}\rho v^2}\right)$$

Eq. (7)
Darcy Equation:

$$h_L = \left[\left(4f\ \frac{L}{D}\right)\right]\frac{v^2}{2g}$$

Notes:

(1) K = 0.5 when viscous losses are negligible, K = 1.0 for return headers.
(2) Include the equivalent length of valves and fittings.
(3) Pressure drop due to velocity head and friction losses across the length of the branch pipe.
(4) Pressure at the well head taking into consideration frictional losses across the length of the drop pipe, static head associated with water elevation and mounding, and pressure drop required for foot valve or variable area valve.
(5) Maldistribution of 10 percent or less is recommended.
(6) If the branch piping exhibits average pressure losses (due to length, fittings, and/or well head pressures) of at least 10 times higher than the header, pressure losses maldistribution will be less than 10 percent.

2.67

North IRZ CIP (using Injection line)

Site: Pacific Gas & Electric Topock Compressor Station
Location: Topock, California

Created By: BAS
Revision No. 1
Revision Date: 2/26/2013

Fluid:	**Water**
Fluid Temperature (deg F):	**50**
Maximum Flowrate:	420.0628601
Header Length (ft):	755
Number of Branches:	1
Average Branch Flowrate (gpm):	420.1

(●) DISCHARGE HEADER

( ) RETURN HEADER

Header Pipe Material: 13

Header Pipe Type: SDR 11 - HDPE

Header Pipe Nominal Diameter (in): 6 **15**

Header Pipe, e (ft): **0.00001**
Header Pipe Inner Diameter (in): **5.348**
e / D: 0.00001

Branch Pipe Material: 13

Branch Pipe Type: SDR 11 - HDPE

Branch Pipe Nominal Diameter (in): 2 / 2

Branch Pipe, e (ft): **0.00001**
Branch Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Fluid Density (lb/ft^3):	**62.36**
Viscosity (cP):	**1.12**
Kinematic viscosity, v (ft^2/s):	**1.21E-05**
g (ft/s^2):	**32.17**
Oriface Coefficient, C_o:	**0.62**
Oriface Value, K[1]:	**0.5**

Header Pressure Drop, Δp_p (lb$_f$/ft^2):	269.1
Header Pressure Drop, Δp_p (psig):	**1.87**
Branch Outlet Pressure Drop, Δp_o (lb$_f$/ft^2):	0.0
Branch Outlet Pressure Drop, Δp_o (psig):	**0.00**
Percent Maldistribution (%)[5]:	
Average Branch Pipe Pressure Drop (ft w.c.):	
Average Well Head Pressure (ft w.c.):	
Average Branch Pipe Pressure Drop (ft w.c.)[5]:	
Average Branch Pipe Pressure Drop (psig):	
Average Branch Pipe Pressure Drop > 10x Δp_p:	

Header Pipe Estimated Conditions

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Description:		MW-20 to IRZ-11							Static Head EXIRZ-11 to MW-20		
Length of Segment (ft):	0	755	0	0	0	0	0	0			
Header flow rate (gpm):		420.0628601									
Branch flow rate (gpm):	---	420.0628601									
Header Pipe Velocity (ft/s):	0.00	6.00									
Reynolds Number, Re:		2.22E+05									
Fanning Friction Factor, f (Eq(6)):		0.00386									
Pressure Drop (ft w.c.), (Eq.(7)):		14.62									
Velocity Head, $v^2/2g_c$ (ft w.c.):	0.000	0.560									
Pressure Drop (ft w.c.):	0.00	14.62							15.0		

Branch Pipe Estimated Conditions

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Orifice Velocity (ft/s):	---	0.00									0.00
Length of Branch Pipe (ft)[2]:	---	73									
Reynolds Number, Re:	---	0.00E+00									0.00E+00
Fanning Friction Factor, f:	---										
Pressure Drop (ft w.c.), (Eq.(7)):	---										
Velocity Head, $v^2/2g_c$ (ft w.c.):	---	0.000									0.000
Pressure Drop (ft w.c.)[3]:	---	0.00									0.00
Well Head Pressure (ft w.c.)[4]:	---	0	0	0	0	0	0	0	0	0	0

Header Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Length of Segment (ft):											**755**	**(Total)**
Header flow rate (gpm):											---	---
Branch flow rate (gpm):											---	---
Header Pipe Velocity (ft/s):											**3.0**	**(Avg.)**
Reynolds Number, Re:											**2.22E+05**	**(Avg.)**
Fanning Friction Factor, f:											**0.00386**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.280**	**(Avg.)**
Pressure Drop (ft w.c.):											**29.62**	**(Total)**

Branch Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Orifice Velocity (ft/s):											**0.00**	**(Avg.)**
Length of Branch Pipe (ft)[2]:											**73.00**	**(Avg.)**
Reynolds Number, Re:											**0.00E+00**	**(Avg.)**
Fanning Friction Factor, f:											**#DIV/0!**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.000**	**(Avg.)**
Pressure Drop (ft w.c.)[3]:											**0.00**	**(Avg.)**
Well Head Pressure (ft w.c.)[4]:											**0.00**	**(Avg.)**

Eq. (1)
Discharge Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} - 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (2)
Return Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} + 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (3)
Branch Outlet Pressure Drop:

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2g_c}$$

Eq. (4)
Reynolds Number:

$$Re = \frac{D \cdot v \cdot \rho}{\mu} = \frac{D \cdot v}{\eta}$$

Eq. (5)
Distribution Equation:

$$\%\ Maldistribution = 100\left(1 - \sqrt{\frac{\Delta p_o - |\Delta p_p|}{\Delta p_o}}\right)$$

Eq. (6)
Fanning Friction Factor:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{[(p_0 - p_L) - \rho g(h_0 - h_L)]}{\frac{1}{2}\rho v^2}\right)$$

Eq. (7)
Darcy Equation:

$$h_L = \left[\left(4f\ \frac{L}{D}\right)\right]\frac{v^2}{2g}$$

Notes:

(1) K = 0.5 when viscous losses are negligible, K = 1.0 for return headers.
(2) Include the equivalent length of valves and fittings.
(3) Pressure drop due to velocity head and friction losses across the length of the branch pipe.
(4) Pressure at the well head taking into consideration frictional losses across the length of the drop pipe, static head associated with water elevation and mounding, and pressure drop required for foot valve or variable area valve.
(5) Maldistribution of 10 percent or less is recommended.
(6) If the branch piping exhibits average pressure losses (due to length, fittings, and/or well head pressures) of at least 10 times higher than the header, pressure losses maldistribution will be less than 10 percent.

6.00

North IRZ CIP line back (using Extraction line)
Site: Pacific Gas & Electric Topock Compressor Station
Location: Topock, California

Created By: BAS
Revision No. 1
Revision Date: 2/26/2013

Fluid:	**Water**
Fluid Temperature (deg F):	**50**
Maximum Flowrate:	420.0628601
Header Length (ft):	755
Number of Branches:	1
Average Branch Flowrate (gpm):	420.1

◉ DISCHARGE HEADER

○ RETURN HEADER

Header Pipe Material: 13

Header Pipe Type: SDR 11 - HDPE

Header Pipe Nominal Diameter (in): 6 **15**

Header Pipe, e (ft): **0.00001**
Header Pipe Inner Diameter (in): **5.348**
e / D: 0.00001

Branch Pipe Material: 13

Branch Pipe Type: SDR 11 - HDPE

Branch Pipe Nominal Diameter (in): 2 / 2

Branch Pipe, e (ft): **0.00001**
Branch Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Fluid Density (lb/ft^3):	**62.36**
Viscosity (cP):	**1.12**
Kinematic viscosity, v (ft^2/s):	**1.21E-05**
g (ft/s^2):	**32.17**
Oriface Coefficient, C_o:	**0.62**
Oriface Value, K[1]:	**0.5**

Header Pressure Drop, Δp_p (lb$_f$/ft^2):	269.1
Header Pressure Drop, Δp_p (psig):	**1.87**
Branch Outlet Pressure Drop, Δp_o (lb$_f$/ft^2):	5498.2
Branch Outlet Pressure Drop, Δp_o (psig):	**38.18**
Percent Maldistribution (%)[5]:	**2.48%**
Average Branch Pipe Pressure Drop (ft w.c.):	**203.88**
Average Well Head Pressure (ft w.c.):	**0.00**
Average Branch Pipe Pressure Drop (ft w.c.)[5]:	**203.88**
Average Branch Pipe Pressure Drop (psig):	**88.26**
Average Branch Pipe Pressure Drop > 10x Δp_p:	**Yes**

Header Pipe Estimated Conditions

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Description:		EXIRZ-11 to MW-20							Static Head EXIRZ-11 to MW-20		
Length of Segment (ft):	0	755	0	0	0	0	0	0			
Header flow rate (gpm):		420.0628601									
Branch flow rate (gpm):	---	420.0628601									
Header Pipe Velocity (ft/s):	0.00	6.00									
Reynolds Number, Re:		2.22E+05									
Fanning Friction Factor, f (Eq(6)):		0.00386									
Pressure Drop (ft w.c.), (Eq.(7)):		14.62									
Velocity Head, $v^2/2g_c$ (ft w.c.):	0.000	0.560									
Pressure Drop (ft w.c.):	0.00	14.62							-15.0		

Branch Pipe Estimated Conditions

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Orifice Velocity (ft/s):	---	46.70									0.00
Length of Branch Pipe (ft)[2]:	---	73									
Reynolds Number, Re:	---	6.18E+05									0.00E+00
Fanning Friction Factor, f:	---	0.00329									
Pressure Drop (ft w.c.), (Eq.(7)):	---	203.88									#VALUE!
Velocity Head, $v^2/2g_c$ (ft w.c.):	---	33.892									0.000
Pressure Drop (ft w.c.)[3]:	---	203.88									
Well Head Pressure (ft w.c.)[4]:	---	0	0	0	0	0	0	0	0	0	0

Header Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Length of Segment (ft):											**755**	**(Total)**
Header flow rate (gpm):											---	---
Branch flow rate (gpm):											---	---
Header Pipe Velocity (ft/s):											**3.0**	**(Avg.)**
Reynolds Number, Re:											**2.22E+05**	**(Avg.)**
Fanning Friction Factor, f:											**0.00386**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.280**	**(Avg.)**
Pressure Drop (ft w.c.):											**-0.38**	**(Total)**

Branch Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Orifice Velocity (ft/s):											**23.35**	**(Avg.)**
Length of Branch Pipe (ft)[2]:											**73.00**	**(Avg.)**
Reynolds Number, Re:											**3.09E+05**	**(Avg.)**
Fanning Friction Factor, f:											**0.00329**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**16.946**	**(Avg.)**
Pressure Drop (ft w.c.)[3]:											**203.88**	**(Avg.)**
Well Head Pressure (ft w.c.)[4]:											**0.00**	**(Avg.)**

Eq. (1)
Discharge Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} - 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (2)
Return Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} + 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (3)
Branch Outlet Pressure Drop:

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2g_c}$$

Eq. (4)
Reynolds Number:

$$Re = \frac{D \cdot v \cdot \rho}{\mu} = \frac{D \cdot v}{\eta}$$

Eq. (5)
Distribution Equation:

$$\%\,Maldistribution = 100\left(1 - \sqrt{\frac{\Delta p_o - |\Delta p_p|}{\Delta p_o}}\right)$$

Eq. (6)
Fanning Friction Factor:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{[(p_0 - p_L) - \rho g(h_0 - h_L)]}{\frac{1}{2}\rho v^2}\right)$$

Eq. (7)
Darcy Equation:

$$h_L = \left[\left(4f\,\frac{L}{D}\right)\right]\frac{v^2}{2g}$$

Notes:

(1) K = 0.5 when viscous losses are negligible, K = 1.0 for return headers.
(2) Include the equivalent length of valves and fittings.
(3) Pressure drop due to velocity head and friction losses across the length of the branch pipe.
(4) Pressure at the well head taking into consideration frictional losses across the length of the drop pipe, static head associated with water elevation and mounding, and pressure drop required for foot valve or variable area valve.
(5) Maldistribution of 10 percent or less is recommended.
(6) If the branch piping exhibits average pressure losses (due to length, fittings, and/or well head pressures) of at least 10 times higher than the header, pressure losses maldistribution will be less than 10 percent.

6.00

South CIP line MW20 to 27 (using injection line)
Site: Pacific Gas & Electric Topock Compressor Station
Location: Topock, California

Created By: BAS
Revision No. 1
Revision Date: 2/26/2013

Fluid: **Water**
Fluid Temperature (deg F): **50**
Maximum Flowrate: 150
Header Length (ft): 290
Number of Branches: 1
Average Branch Flowrate (gpm): 150.0

(●) DISCHARGE HEADER
( ) RETURN HEADER

Header Pipe Material:
Header Pipe Type: SDR 11 - HDPE
Header Pipe Nominal Diameter (in): 6

Header Pipe, e (ft): **0.00001**
Header Pipe Inner Diameter (in): **5.348**
e / D: 0.00001

Branch Pipe Material:
Branch Pipe Type: SDR 11 - HDPE
Branch Pipe Nominal Diameter (in): 2 / 2

Branch Pipe, e (ft): **0.00001**
Branch Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Fluid Density (lb/ft^3): **62.36**
Viscosity (cP): **1.12**

Kinematic viscosity, v (ft^2/s): **1.21E-05**
g (ft/s^2): **32.17**
Oriface Coefficient, C_o: **0.62**
Oriface Value, K[1]: **0.5**

Header Pressure Drop, Δp_p (lb$_f$/ft^2): 13.8
Header Pressure Drop, Δp_p (psig): 0.10
Branch Outlet Pressure Drop, Δp_o (lb$_f$/ft^2): 0.0
Branch Outlet Pressure Drop, Δp_o (psig): 0.00
Percent Maldistribution (%)[5]: Unbalanced
Average Branch Pipe Pressure Drop (ft w.c.):
Average Well Head Pressure (ft w.c.):
Average Branch Pipe Pressure Drop (ft w.c.)[5]:
Average Branch Pipe Pressure Drop (psig):
Average Branch Pipe Pressure Drop > 10x Δp_p:

	Header Pipe Estimated Conditions											
Location:	**Entrance**	1	2	3	4	5	6	7	8	9	10	
Description:		MW-20 to EXIRZ-27								Equip Losses	Static Head MW-20 to EXIRZ-27	
Length of Segment (ft):	0	290										
Header flow rate (gpm):		150										
Branch flow rate (gpm):	---	150										
Header Pipe Velocity (ft/s):	0.00	2.14										
Reynolds Number, Re:		7.91E+04										
Fanning Friction Factor, f (Eq(6)):		0.00474										
Pressure Drop (ft w.c.), (Eq.(7)):		0.88										
Velocity Head, $v^2/2g_c$ (ft w.c.):	0.000	0.071										
Pressure Drop (ft w.c.):	0.00	0.88								1.76	3.00	
	Branch Pipe Estimated Conditions											
Location:	**Entrance**	1	2	3	4	5	6	7	8	9	10	
Orifice Velocity (ft/s):	---	0.00										
Length of Branch Pipe (ft)[2]:	---	170										
Reynolds Number, Re:	---	0.00E+00										
Fanning Friction Factor, f:	---											
Pressure Drop (ft w.c.), (Eq.(7)):	---	#VALUE!										
Velocity Head, $v^2/2g_c$ (ft w.c.):	---	0.000										
Pressure Drop (ft w.c.)[3]:	---											
Well Head Pressure (ft w.c.)[4]:	---	0	0	0	0	0	0	0	0	0	0	

	Header Pipe Estimated Conditions (Continued)											
Location:	11	12	13	14	15	16	17	18	19	20	**Summary**	
Length of Segment (ft):											**290**	**(Total)**
Header flow rate (gpm):											**---**	**---**
Branch flow rate (gpm):											**---**	**---**
Header Pipe Velocity (ft/s):											**1.1**	**(Avg.)**
Reynolds Number, Re:											**7.91E+04**	**(Avg.)**
Fanning Friction Factor, f:											**0.00474**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.036**	**(Avg.)**
Pressure Drop (ft w.c.):											**5.64**	**(Total)**
	Branch Pipe Estimated Conditions (Continued)											
Location:	11	12	13	14	15	16	17	18	19	20	**Summary**	
Orifice Velocity (ft/s):											**0.00**	**(Avg.)**
Length of Branch Pipe (ft)[2]:											**170.00**	**(Avg.)**
Reynolds Number, Re:											**0.00E+00**	**(Avg.)**
Fanning Friction Factor, f:											**#DIV/0!**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.000**	**(Avg.)**
Pressure Drop (ft w.c.)[3]:											**#DIV/0!**	**(Avg.)**
Well Head Pressure (ft w.c.)[4]:											**0.00**	**(Avg.)**

Eq. (1)
Discharge Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} - 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (2)
Return Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} + 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (3)
Branch Outlet Pressure Drop:

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2g_c}$$

Eq. (4)
Reynolds Number:

$$Re = \frac{D \cdot v \cdot \rho}{\mu} = \frac{D \cdot v}{\eta}$$

Eq. (5)
Distribution Equation:

$$\%\ Maldistribution = 100\left(1 - \sqrt{\frac{\Delta p_o - |\Delta p_p|}{\Delta p_o}}\right)$$

Eq. (6)
Fanning Friction Factor:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{[(p_0 - p_L) - \rho g(h_0 - h_L)]}{\frac{1}{2}\rho v^2}\right)$$

Eq. (7)
Darcy Equation:

$$h_L = \left[\left(4f\ \frac{L}{D}\right)\right]\frac{v^2}{2g}$$

Notes:
(1) K = 0.5 when viscous losses are negligible, K = 1.0 for return headers.
(2) Include the equivalent length of valves and fittings.
(3) Pressure drop due to velocity head and friction losses across the length of the branch pipe.
(4) Pressure at the well head taking into consideration frictional losses across the length of the drop pipe, static head associated with water elevation and mounding, and pressure drop required for foot valve or variable area valve.
(5) Maldistribution of 10 percent or less is recommended.
(6) If the branch piping exhibits average pressure losses (due to length, fittings, and/or well head pressures) of at least 10 times higher than the header, pressure losses maldistribution will be less than 10 percent.

2.14

South CIP line MW20 to 27 (using BW line)

Site: Pacific Gas & Electric Topock Compressor Station
Location: Topock, California

Created By: BAS
Revision No. 2
Revision Date: 2/20/2013

Fluid:	**Water**
Fluid Temperature (deg F):	**50**
Maximum Flowrate:	150
Header Length (ft):	290
Number of Branches:	1
Average Branch Flowrate (gpm):	150.0

◉ DISCHARGE HEADER

○ RETURN HEADER

Header Pipe Material:

Header Pipe Type: SDR 11 - HDPE

Header Pipe Nominal Diameter (in): 2

Header Pipe, e (ft): **0.00001**
Header Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Branch Pipe Material:

Branch Pipe Type: SDR 11 - HDPE

Branch Pipe Nominal Diameter (in): 2 / 2

Branch Pipe, e (ft): **0.00001**
Branch Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Fluid Density (lb/ft^3): **62.36**
Viscosity (cP): **1.12**

Kinematic viscosity, v (ft^2/s): **1.21E-05**
g (ft/s^2): **32.17**
Oriface Coefficient, C_o: **0.62**
Oriface Value, K[1]: **0.5**

Header Pressure Drop, Δp_p (lb$_f$/ft^2): 2275.8
Header Pressure Drop, Δp_p (psig): 15.80
Branch Outlet Pressure Drop, Δp_o (lb$_f$/ft^2): 0.0
Branch Outlet Pressure Drop, Δp_o (psig): 0.00
Percent Maldistribution (%)[5]:
Average Branch Pipe Pressure Drop (ft w.c.):
Average Well Head Pressure (ft w.c.):
Average Branch Pipe Pressure Drop (ft w.c.)[5]:
Average Branch Pipe Pressure Drop (psig):
Average Branch Pipe Pressure Drop > 10x Δp_p:

	Header Pipe Estimated Conditions											
Location:	**Entrance**	1	2	3	4	5	6	7	8	9	10	
Description:		EXIRZ-27 to MW-20								Equip Losses	Static Head MW-20 to IRZ-27	
Length of Segment (ft):	0	290										
Header flow rate (gpm):		150										
Branch flow rate (gpm):	---	150										
Header Pipe Velocity (ft/s):	0.00	16.68										
Reynolds Number, Re:		2.21E+05										
Fanning Friction Factor, f (Eq(6)):		0.00390										
Pressure Drop (ft w.c.), (Eq.(7)):		122.45										
Velocity Head, $v^2/2g_c$ (ft w.c.):	0.000	4.322										
Pressure Drop (ft w.c.):	0.00	122.45								158.09	-3.00	
	Branch Pipe Estimated Conditions											
Location:	**Entrance**	1	2	3	4	5	6	7	8	9	10	
Orifice Velocity (ft/s):	---	0.00										
Length of Branch Pipe (ft)[2]:	---	115										
Reynolds Number, Re:	---	0.00E+00										
Fanning Friction Factor, f:	---											
Pressure Drop (ft w.c.), (Eq.(7)):	---											
Velocity Head, $v^2/2g_c$ (ft w.c.):	---	0.000										
Pressure Drop (ft w.c.)[3]:	---	0.00										
Well Head Pressure (ft w.c.)[4]:	---	0	0	0	0	0	0	0	0	0	0	

	Header Pipe Estimated Conditions (Continued)											
Location:	11	12	13	14	15	16	17	18	19	20	**Summary**	
Length of Segment (ft):											**290**	**(Total)**
Header flow rate (gpm):											---	---
Branch flow rate (gpm):											---	---
Header Pipe Velocity (ft/s):											**8.3**	**(Avg.)**
Reynolds Number, Re:											**2.21E+05**	**(Avg.)**
Fanning Friction Factor, f:											**0.00390**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**2.161**	**(Avg.)**
Pressure Drop (ft w.c.):											**277.54**	**(Total)**
	Branch Pipe Estimated Conditions (Continued)											
Location:	11	12	13	14	15	16	17	18	19	20	**Summary**	
Orifice Velocity (ft/s):											**0.00**	**(Avg.)**
Length of Branch Pipe (ft)[2]:											**115.00**	**(Avg.)**
Reynolds Number, Re:											**0.00E+00**	**(Avg.)**
Fanning Friction Factor, f:											**#DIV/0!**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.000**	**(Avg.)**
Pressure Drop (ft w.c.)[3]:											**0.00**	**(Avg.)**
Well Head Pressure (ft w.c.)[4]:											**0.00**	**(Avg.)**

Eq. (1)
Discharge Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} - 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (2)
Return Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} + 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (3)
Branch Outlet Pressure Drop:

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2g_c}$$

Eq. (4)
Reynolds Number:

$$Re = \frac{D \cdot v \cdot \rho}{\mu} = \frac{D \cdot v}{\eta}$$

Eq. (5)
Distribution Equation:

$$\%\ Maldistribution = 100\left(1 - \sqrt{\frac{\Delta p_o - |\Delta p_p|}{\Delta p_o}}\right)$$

Eq. (6)
Fanning Friction Factor:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{[(p_0 - p_L) - \rho g(h_0 - h_L)]}{\frac{1}{2}\rho v^2}\right)$$

Eq. (7)
Darcy Equation:

$$h_L = \left[\left(4f\ \frac{L}{D}\right)\right]\frac{v^2}{2g}$$

Notes:

(1) K = 0.5 when viscous losses are negligible, K = 1.0 for return headers.
(2) Include the equivalent length of valves and fittings.
(3) Pressure drop due to velocity head and friction losses across the length of the branch pipe.
(4) Pressure at the well head taking into consideration frictional losses across the length of the drop pipe, static head associated with water elevation and mounding, and pressure drop required for foot valve or variable area valve.
(5) Maldistribution of 10 percent or less is recommended.
(6) If the branch piping exhibits average pressure losses (due to length, fittings, and/or well head pressures) of at least 10 times higher than the header, pressure losses maldistribution will be less than 10 percent.

16.68

South CIP line MW20 to 37 (using injection line)
Site: Pacific Gas & Electric Topock Compressor Station
Location: Topock, California

Created By: BAS
Revision No. 2
Revision Date: 2/20/2013

Fluid:	**Water**
Fluid Temperature (deg F):	**50**
Maximum Flowrate	150
Header Length (ft):	1,760
Number of Branches	1
Average Branch Flowrate (gpm):	150.0

○ DISCHARGE HEADER

◉ RETURN HEADER

Header Pipe Material:

Header Pipe Type: SDR 11 - HDPE

Header Pipe Nominal Diameter (in): 4

Header Pipe, e (ft): **0.00001**
Header Pipe Inner Diameter (in): **3.633**
e / D: 0.00002

Branch Pipe Material:

Branch Pipe Type: SDR 11 - HDPE

Branch Pipe Nominal Diameter (in): 2 / 2

Branch Pipe, e (ft): **0.00001**
Branch Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Fluid Density (lb/ft^3): **62.36**
Viscosity (cP): **1.12**

Kinematic viscosity, v (ft^2/s): **1.21E-05**
g (ft/s^2): **32.17**
Oriface Coefficient, C_o: **0.62**
Oriface Value, K[1]: **1.0**

Header Pressure Drop, Δp_p (lb$_f$/ft^2): 0.0
Header Pressure Drop, Δp_p (psig): 0.00
Branch Outlet Pressure Drop, Δp_o (lb$_f$/ft^2): 0.0
Branch Outlet Pressure Drop, Δp_o (psig): 0.00
Percent Maldistribution (%)[5]:
Average Branch Pipe Pressure Drop (ft w.c.):
Average Well Head Pressure (ft w.c.):
Average Branch Pipe Pressure Drop (ft w.c.)[5]:
Average Branch Pipe Pressure Drop (psig):
Average Branch Pipe Pressure Drop > 10x Δp_p:

	Header Pipe Estimated Conditions											
Location:	**Entrance**	1	2	3	4	5	6	7	8	9	10	
Description:		MW-20 to EXIRZ-37						Equip	Static Head MW-20 to EXIRZ-37			
Length of Segment (ft):	0	1760										
Header flow rate (gpm):	**0**	150	0									
Branch flow rate (gpm):	--	150										
Header Pipe Velocity (ft/s):	0.00	4.64	0.00									
Reynolds Number, Re:		1.16E+05	0.00E+00									
Fanning Friction Factor, f (Eq(6)):		0.00438										
Pressure Drop (ft w.c.), (Eq.(7)):		34.14	#VALUE!									
Velocity Head, $v^2/2g_c$ (ft w.c.):	0.000	0.335	0.000									
Pressure Drop (ft w.c.):	0.00	34.14						40.53	2.00			
	Branch Pipe Estimated Conditions											
Location:	**Entrance**	1	2	3	4	5	6	7	8	9	10	
Orifice Velocity (ft/s):	---	0.00	0.00									
Length of Branch Pipe (ft)[2]:	---	37										
Reynolds Number, Re:	---	0.00E+00	0.00E+00									
Fanning Friction Factor, f:	---											
Pressure Drop (ft w.c.), (Eq.(7)):	---	#VALUE!	#VALUE!									
Velocity Head, $v^2/2g_c$ (ft w.c.):	---	0.000	0.000									
Pressure Drop (ft w.c.)[3]:	---											
Well Head Pressure (ft w.c.)[4]:	---	0	0	0	0	0	0	0	0	0	0	

	Header Pipe Estimated Conditions (Continued)											
Location:	11	12	13	14	15	16	17	18	19	20	**Summary**	
Length of Segment (ft):											**1,760**	**(Total)**
Header flow rate (gpm):											---	---
Branch flow rate (gpm):											---	---
Header Pipe Velocity (ft/s):											**1.5**	**(Avg.)**
Reynolds Number, Re:											**5.82E+04**	**(Avg.)**
Fanning Friction Factor, f:											**0.00438**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.112**	**(Avg.)**
Pressure Drop (ft w.c.):											**76.67**	**(Total)**
	Branch Pipe Estimated Conditions (Continued)											
Location:	11	12	13	14	15	16	17	18	19	20	**Summary**	
Orifice Velocity (ft/s):											**0.00**	**(Avg.)**
Length of Branch Pipe (ft)[2]:											**37.00**	**(Avg.)**
Reynolds Number, Re:											**0.00E+00**	**(Avg.)**
Fanning Friction Factor, f:											**#DIV/0!**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.000**	**(Avg.)**
Pressure Drop (ft w.c.)[3]:											**#DIV/0!**	**(Avg.)**
Well Head Pressure (ft w.c.)[4]:											**0.00**	**(Avg.)**

Eq. (1)
Discharge Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} - 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (2)
Return Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} + 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (3)
Branch Outlet Pressure Drop:

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2g_c}$$

Eq. (4)
Reynolds Number:

$$Re = \frac{D \cdot v \cdot \rho}{\mu} = \frac{D \cdot v}{\eta}$$

Eq. (5)
Distribution Equation:

$$\%\,Maldistribution = 100\left(1 - \sqrt{\frac{|\Delta p_o| - |\Delta p_p|}{\Delta p_o}}\right)$$

Eq. (6)
Fanning Friction Factor:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{[(p_0 - p_L) - \rho g(h_0 - h_L)]}{\frac{1}{2}\rho v^2}\right)$$

Eq. (7)
Darcy Equation:

$$h_L = \left[\left(4f\,\frac{L}{D}\right)\right]\frac{v^2}{2g}$$

Notes:

(1) K = 0.5 when viscous losses are negligible, K = 1.0 for return headers.
(2) Include the equivalent length of valves and fittings.
(3) Pressure drop due to velocity head and friction losses across the length of the branch pipe.
(4) Pressure at the well head taking into consideration frictional losses across the length of the drop pipe, static head associated with water elevation and mounding, and pressure drop required for foot valve or variable area valve.
(5) Maldistribution of 10 percent or less is recommended.
(6) If the branch piping exhibits average pressure losses (due to length, fittings, and/or well head pressures) of at least 10 times higher than the header, pressure losses maldistribution will be less than 10 percent.

2.32

South CIP line 37 to MW20 (using extraction line)
Site: Pacific Gas & Electric Topock Compressor Station
Location: Topock, California

Created By: BAS
Revision No. 1
Revision Date: 2/26/2013

Fluid:	**Water**
Fluid Temperature (deg F):	**50**
Maximum Flowrate:	150
Header Length (ft):	1,760
Number of Branches:	1
Average Branch Flowrate (gpm):	150.0

○ DISCHARGE HEADER

◉ RETURN HEADER

Header Pipe Material:

Header Pipe Type: SDR 11 - HDPE

Header Pipe Nominal Diameter (in): 2

Header Pipe, e (ft): **0.00001**
Header Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Branch Pipe Material:

Branch Pipe Type: SDR 11 - HDPE

Branch Pipe Nominal Diameter (in): 2 / 2

Branch Pipe, e (ft): **0.00001**
Branch Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Fluid Density (lb/ft^3): **62.36**
Viscosity (cP): **1.12**

Kinematic viscosity, v (ft^2/s): **1.21E-05**
g (ft/s^2): **32.17**
Oriface Coefficient, C_o: **0.62**
Oriface Value, K[1]: **1.0**

Header Pressure Drop, Δp_p (lb$_f$/ft^2): 0.0
Header Pressure Drop, Δp_p (psig): 0.00
Branch Outlet Pressure Drop, Δp_o (lb$_f$/ft^2): 0.0
Branch Outlet Pressure Drop, Δp_o (psig): 0.00
Percent Maldistribution (%)[5]:
Average Branch Pipe Pressure Drop (ft w.c.):
Average Well Head Pressure (ft w.c.):
Average Branch Pipe Pressure Drop (ft w.c.)[5]:
Average Branch Pipe Pressure Drop (psig):
Average Branch Pipe Pressure Drop > 10x Δp_p:

	Header Pipe Estimated Conditions											
Location:	**Entrance**	1	2	3	4	5	6	7	8	9	10	
Description:		EXIRZ-37 to MW20								Equip	Static Head IRZ-37 to Tee	
Length of Segment (ft):	0	1760										
Header flow rate (gpm):	**0**	150	0									
Branch flow rate (gpm):	--	150										
Header Pipe Velocity (ft/s):	0.00	16.68	0.00									
Reynolds Number, Re:		2.21E+05	0.00E+00									
Fanning Friction Factor, f (Eq(6)):		0.00390										
Pressure Drop (ft w.c.), (Eq.(7)):		743.14	#VALUE!									
Velocity Head, $v^2/2g_c$ (ft w.c.):	0.000	4.322	0.000									
Pressure Drop (ft w.c.):	0.00	743.14								807.92	-2.00	
	Branch Pipe Estimated Conditions											
Location:	**Entrance**	1	2	3	4	5	6	7	8	9	10	
Orifice Velocity (ft/s):	---	0.00	0.00									
Length of Branch Pipe (ft)[2]:	---	37										
Reynolds Number, Re:	---	0.00E+00	0.00E+00									
Fanning Friction Factor, f:	---											
Pressure Drop (ft w.c.), (Eq.(7)):	---	#VALUE!	#VALUE!									
Velocity Head, $v^2/2g_c$ (ft w.c.):	---	0.000	0.000									
Pressure Drop (ft w.c.)[3]:	---											
Well Head Pressure (ft w.c.)[4]:	---	0	0	0	0	0	0	0	0	0	0	

	Header Pipe Estimated Conditions (Continued)											
Location:	11	12	13	14	15	16	17	18	19	20	**Summary**	
Length of Segment (ft):											**1,760**	**(Total)**
Header flow rate (gpm):											---	---
Branch flow rate (gpm):											---	---
Header Pipe Velocity (ft/s):											**5.6**	**(Avg.)**
Reynolds Number, Re:											**1.10E+05**	**(Avg.)**
Fanning Friction Factor, f:											**0.00390**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**1.441**	**(Avg.)**
Pressure Drop (ft w.c.):											**1549.06**	**(Total)**
	Branch Pipe Estimated Conditions (Continued)											
Location:	11	12	13	14	15	16	17	18	19	20	**Summary**	
Orifice Velocity (ft/s):											**0.00**	**(Avg.)**
Length of Branch Pipe (ft)[2]:											**37.00**	**(Avg.)**
Reynolds Number, Re:											**0.00E+00**	**(Avg.)**
Fanning Friction Factor, f:											**#DIV/0!**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.000**	**(Avg.)**
Pressure Drop (ft w.c.)[3]:											**#DIV/0!**	**(Avg.)**
Well Head Pressure (ft w.c.)[4]:											**0.00**	**(Avg.)**

Eq. (1)
Discharge Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} - 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (2)
Return Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} + 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (3)
Branch Outlet Pressure Drop:

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2g_c}$$

Eq. (4)
Reynolds Number:

$$Re = \frac{D \cdot v \cdot \rho}{\mu} = \frac{D \cdot v}{\eta}$$

Eq. (5)
Distribution Equation:

$$\%\,Maldistribution = 100\left(1 - \sqrt{\frac{|\Delta p_o| - |\Delta p_p|}{\Delta p_o}}\right)$$

Eq. (6)
Fanning Friction Factor:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{[(p_0 - p_L) - \rho g(h_0 - h_L)]}{\frac{1}{2}\rho v^2}\right)$$

Eq. (7)
Darcy Equation:

$$h_L = \left[\left(4f\,\frac{L}{D}\right)\right]\frac{v^2}{2g}$$

Notes:

(1) K = 0.5 when viscous losses are negligible, K = 1.0 for return headers.
(2) Include the equivalent length of valves and fittings.
(3) Pressure drop due to velocity head and friction losses across the length of the branch pipe.
(4) Pressure at the well head taking into consideration frictional losses across the length of the drop pipe, static head associated with water elevation and mounding, and pressure drop required for foot valve or variable area valve.
(5) Maldistribution of 10 percent or less is recommended.
(6) If the branch piping exhibits average pressure losses (due to length, fittings, and/or well head pressures) of at least 10 times higher than the header, pressure losses maldistribution will be less than 10 percent.

8.34

South CIP line MW20 to 39 (using injection line)

Site: Pacific Gas & Electric Topock Compressor Station
Location: Topock, California

Created By: BAS
Revision No. 1
Revision Date: 2/26/2013

Fluid: **Water**
Fluid Temperature (deg F): **50**

Maximum Flowrate: 150
Header Length (ft): 996
Number of Branches: 1
Average Branch Flowrate (gpm): 150.0

○ DISCHARGE HEADER

◉ RETURN HEADER

Header Pipe Material:

Header Pipe Type: SDR 11 - HDPE

Header Pipe Nominal Diameter (in): 4

Header Pipe, e (ft): **0.00001**
Header Pipe Inner Diameter (in): **3.633**
e / D: 0.00002

Branch Pipe Material:

Branch Pipe Type: SDR 11 - HDPE

Branch Pipe Nominal Diameter (in): 2

Branch Pipe, e (ft): **0.00001**
Branch Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Fluid Density (lb/ft^3): **62.36**
Viscosity (cP): **1.12**

Kinematic viscosity, v (ft^2/s): **1.21E-05**
g (ft/s^2): **32.17**
Oriface Coefficient, C_o: **0.62**
Oriface Value, K[1]: **1.0**

Header Pressure Drop, Δp_p (lb$_f$/ft^2): **0.0**
Header Pressure Drop, Δp_p (psig): 0.00
Branch Outlet Pressure Drop, Δp_o (lb$_f$/ft^2): 0.0
Branch Outlet Pressure Drop, Δp_o (psig): 0.00
Percent Maldistribution (%)[5]:
Average Branch Pipe Pressure Drop (ft w.c.):
Average Well Head Pressure (ft w.c.):
Average Branch Pipe Pressure Drop (ft w.c.)[5]:
Average Branch Pipe Pressure Drop (psig):
Average Branch Pipe Pressure Drop > 10x Δp_p:

	Header Pipe Estimated Conditions											
Location:	**Entrance**	1	2	3	4	5	6	7	8	9	10	
Description:		MW20 to IRZ-39								Equip	Static Head MW20 to IRZ-39	
Length of Segment (ft):	0	996		0	0	0	0	0	0			
Header flow rate (gpm):	**0**	150										
Branch flow rate (gpm):	---	150										
Header Pipe Velocity (ft/s):	0.00	4.64										
Reynolds Number, Re:		1.16E+05										
Fanning Friction Factor, f (Eq(6)):		0.00438										
Pressure Drop (ft w.c.), (Eq.(7)):		19.32										
Velocity Head, $v^2/2g_c$ (ft w.c.):	0.000	0.335										
Pressure Drop (ft w.c.):	0.00	19.32								25.19	-17.00	
	Branch Pipe Estimated Conditions											
Location:	**Entrance**	1	2	3	4	5	6	7	8	9	10	
Orifice Velocity (ft/s):	---	0.00										
Length of Branch Pipe (ft)[2]:	---	20										
Reynolds Number, Re:	---	0.00E+00										
Fanning Friction Factor, f:	---											
Pressure Drop (ft w.c.), (Eq.(7)):	---	#VALUE!										
Velocity Head, $v^2/2g_c$ (ft w.c.):	---	0.000										
Pressure Drop (ft w.c.)[3]:	---											
Well Head Pressure (ft w.c.)[4]:	---	0	0	0	0	0	0	0	0	0	0	

	Header Pipe Estimated Conditions (Continued)											
Location:	11	12	13	14	15	16	17	18	19	20	**Summary**	
Length of Segment (ft):											**996**	**(Total)**
Header flow rate (gpm):											---	---
Branch flow rate (gpm):											---	---
Header Pipe Velocity (ft/s):											**2.3**	**(Avg.)**
Reynolds Number, Re:											**1.16E+05**	**(Avg.)**
Fanning Friction Factor, f:											**0.00438**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.168**	**(Avg.)**
Pressure Drop (ft w.c.):											**27.51**	**(Total)**
	Branch Pipe Estimated Conditions (Continued)											
Location:	11	12	13	14	15	16	17	18	19	20	**Summary**	
Orifice Velocity (ft/s):											**0.00**	**(Avg.)**
Length of Branch Pipe (ft)[2]:											**20.00**	**(Avg.)**
Reynolds Number, Re:											**0.00E+00**	**(Avg.)**
Fanning Friction Factor, f:											**#DIV/0!**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.000**	**(Avg.)**
Pressure Drop (ft w.c.)[3]:											**#DIV/0!**	**(Avg.)**
Well Head Pressure (ft w.c.)[4]:											**0.00**	**(Avg.)**

Eq. (1)
Discharge Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} - 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (2)
Return Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} + 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (3)
Branch Outlet Pressure Drop:

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2g_c}$$

Eq. (4)
Reynolds Number:

$$Re = \frac{D \cdot v \cdot \rho}{\mu} = \frac{D \cdot v}{\eta}$$

Eq. (5)
Distribution Equation:

$$\%\ Maldistribution = 100\left(1 - \sqrt{\frac{\Delta p_o - |\Delta p_p|}{\Delta p_o}}\right)$$

Eq. (6)
Fanning Friction Factor:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{[(p_0 - p_L) - \rho g(h_0 - h_L)]}{\frac{1}{2}\rho v^2}\right)$$

Eq. (7)
Darcy Equation:

$$h_L = \left[\left(4f\ \frac{L}{D}\right)\right]\frac{v^2}{2g}$$

Notes:

(1) K = 0.5 when viscous losses are negligible, K = 1.0 for return headers.
(2) Include the equivalent length of valves and fittings.
(3) Pressure drop due to velocity head and friction losses across the length of the branch pipe.
(4) Pressure at the well head taking into consideration frictional losses across the length of the drop pipe, static head associated with water elevation and mounding, and pressure drop required for foot valve or variable area valve.
(5) Maldistribution of 10 percent or less is recommended.
(6) If the branch piping exhibits average pressure losses (due to length, fittings, and/or well head pressures) of at least 10 times higher than the header, pressure losses maldistribution will be less than 10 percent.

4.64

South CIP line MW20 to 39 (using extraction line)
Site: Pacific Gas & Electric Topock Compressor Station
Location: Topock, California

Created By: BAS
Revision No. 1
Revision Date: 2/26/2013

Fluid: **Water**
Fluid Temperature (deg F): **50**

Maximum Flowrate: 150
Header Length (ft): 996
Number of Branches: 1
Average Branch Flowrate (gpm): 150.0

○ DISCHARGE HEADER

◉ RETURN HEADER

Header Pipe Material:

Header Pipe Type: SDR 11 - HDPE

Header Pipe Nominal Diameter (in): 2

Header Pipe, e (ft): **0.00001**
Header Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Branch Pipe Material:

Branch Pipe Type: SDR 11 - HDPE

Branch Pipe Nominal Diameter (in): 2 / 2

Branch Pipe, e (ft): **0.00001**
Branch Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Fluid Density (lb/ft^3): **62.36**
Viscosity (cP): **1.12**

Kinematic viscosity, v (ft^2/s): **1.21E-05**
g (ft/s^2): **32.17**
Oriface Coefficient, C_o: **0.62**
Oriface Value, K[1]: **1.0**

Header Pressure Drop, Δp_p (lb$_f$/ft^2): **0.0**
Header Pressure Drop, Δp_p (psig): 0.00
Branch Outlet Pressure Drop, Δp_o (lb$_f$/ft^2): 0.0
Branch Outlet Pressure Drop, Δp_o (psig): 0.00
Percent Maldistribution (%)[5]:
Average Branch Pipe Pressure Drop (ft w.c.):
Average Well Head Pressure (ft w.c.):
Average Branch Pipe Pressure Drop (ft w.c.)[5]:
Average Branch Pipe Pressure Drop (psig):
Average Branch Pipe Pressure Drop > 10x Δp_o:

	Header Pipe Estimated Conditions											
Location:	**Entrance**	1	2	3	4	5	6	7	8	9	10	
Description:		IRZ-39 to MW-20								Equip	Static Head IRZ-39 to MW20	
Length of Segment (ft):	0	996		0	0	0	0	0	0			
Header flow rate (gpm):	**0**	150										
Branch flow rate (gpm):	---	150										
Header Pipe Velocity (ft/s):	0.00	16.68										
Reynolds Number, Re:		2.21E+05										
Fanning Friction Factor, f (Eq(6)):		0.00390										
Pressure Drop (ft w.c.), (Eq.(7)):		420.55										
Velocity Head, $v^2/2g_c$ (ft w.c.):	0.000	4.322										
Pressure Drop (ft w.c.):	0.00	420.55								475.34	17.00	
	Branch Pipe Estimated Conditions											
Location:	**Entrance**	1	2	3	4	5	6	7	8	9	10	
Orifice Velocity (ft/s):	---	0.00										
Length of Branch Pipe (ft)[2]:	---	20										
Reynolds Number, Re:	---	0.00E+00										
Fanning Friction Factor, f:	---											
Pressure Drop (ft w.c.), (Eq.(7)):	---	#VALUE!										
Velocity Head, $v^2/2g_c$ (ft w.c.):	---	0.000										
Pressure Drop (ft w.c.)[3]:	---											
Well Head Pressure (ft w.c.)[4]:	---	0	0	0	0	0	0	0	0	0	0	

	Header Pipe Estimated Conditions (Continued)											
Location:	11	12	13	14	15	16	17	18	19	20	**Summary**	
Length of Segment (ft):											**996**	**(Total)**
Header flow rate (gpm):											---	---
Branch flow rate (gpm):											---	---
Header Pipe Velocity (ft/s):											**8.3**	**(Avg.)**
Reynolds Number, Re:											**2.21E+05**	**(Avg.)**
Fanning Friction Factor, f:											**0.00390**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**2.161**	**(Avg.)**
Pressure Drop (ft w.c.):											**912.89**	**(Total)**
	Branch Pipe Estimated Conditions (Continued)											
Location:	11	12	13	14	15	16	17	18	19	20	**Summary**	
Orifice Velocity (ft/s):											**0.00**	**(Avg.)**
Length of Branch Pipe (ft)[2]:											**20.00**	**(Avg.)**
Reynolds Number, Re:											**0.00E+00**	**(Avg.)**
Fanning Friction Factor, f:											**#DIV/0!**	**(Avg.)**
Velocity Head, $v^2/2g_c$ (ft w.c.):											**0.000**	**(Avg.)**
Pressure Drop (ft w.c.)[3]:											**#DIV/0!**	**(Avg.)**
Well Head Pressure (ft w.c.)[4]:											**0.00**	**(Avg.)**

Eq. (1)
Discharge Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} - 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (2)
Return Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} + 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (3)
Branch Outlet Pressure Drop:

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2g_c}$$

Eq. (4)
Reynolds Number:

$$Re = \frac{D \cdot v \cdot \rho}{\mu} = \frac{D \cdot v}{\eta}$$

Eq. (5)
Distribution Equation:

$$\%\ Maldistribution = 100\left(1 - \sqrt{\frac{\Delta p_o - |\Delta p_p|}{\Delta p_o}}\right)$$

Eq. (6)
Fanning Friction Factor:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{[(p_0 - p_L) - \rho g(h_0 - h_L)]}{\frac{1}{2}\rho v^2}\right)$$

Eq. (7)
Darcy Equation:

$$h_L = \left[\left(4f\ \frac{L}{D}\right)\right]\frac{v^2}{2g}$$

Notes:

(1) K = 0.5 when viscous losses are negligible, K = 1.0 for return headers.
(2) Include the equivalent length of valves and fittings.
(3) Pressure drop due to velocity head and friction losses across the length of the branch pipe.
(4) Pressure at the well head taking into consideration frictional losses across the length of the drop pipe, static head associated with water elevation and mounding, and pressure drop required for foot valve or variable area valve.
(5) Maldistribution of 10 percent or less is recommended.
(6) If the branch piping exhibits average pressure losses (due to length, fittings, and/or well head pressures) of at least 10 times higher than the header, pressure losses maldistribution will be less than 10 percent.

16.68

Conditioned Water Line

Site: Pacific Gas & Electric Topock Compressor Station
Location: Topock, California

Created By: BAS
Revision No. 1
Revision Date: 3/14/2013

Fluid:	**Water**
Fluid Temperature (deg F):	**50**
Maximum Flowrate:	100
Header Length (ft):	2,025
Number of Branches:	1
Average Branch Flowrate (gpm):	100.0

◉ DISCHARGE HEADER

○ RETURN HEADER

Header Pipe Material: 13

Header Pipe Type: SDR 11 - HDPE

Header Pipe Nominal Diameter (in): 4 **13**

Header Pipe, e (ft): **0.00001**
Header Pipe Inner Diameter (in): **3.633**
e / D: 0.00002

Branch Pipe Material: 13

Branch Pipe Type: SDR 11 - HDPE

Branch Pipe Nominal Diameter (in): 2 / 2

Branch Pipe, e (ft): **0.00001**
Branch Pipe Inner Diameter (in): **1.917**
e / D: 0.00003

Fluid Density (lb/ft^3): **62.36**
Viscosity (cP): **1.12**

Kinematic viscosity, v (ft^2/s): **1.21E-05**
g (ft/s^2): **32.17**
Oriface Coefficient, C_o: **0.62**
Oriface Value, K[1]: **0.5**

Header Pressure Drop, Δp_p (lb$_f$/ft^2): 385.2
Header Pressure Drop, Δp_p (psig): 2.68
Branch Outlet Pressure Drop, Δp_o (lb$_f$/ft^2): 0.0
Branch Outlet Pressure Drop, Δp_o (psig): 0.00
Percent Maldistribution (%)[5]:
Average Branch Pipe Pressure Drop (ft w.c.):
Average Well Head Pressure (ft w.c.):
Average Branch Pipe Pressure Drop (ft w.c.)[5]:
Average Branch Pipe Pressure Drop (psig):
Average Branch Pipe Pressure Drop > 10x Δp_p:

Header Pipe Estimated Conditions

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Description:		HH1-13 junction to TCS							HH1-13 to TCS		
Length of Segment (ft):	0	2,025	0	0	0	0	0	0			
Header flow rate (gpm):		100									
Branch flow rate (gpm):	---	100									
Header Pipe Velocity (ft/s):	0.00	3.10									
Reynolds Number, Re:		7.76E+04									
Fanning Friction Factor, f (Eq(6)):		0.00476									
Pressure Drop (ft w.c.), (Eq.(7)):		18.98									
Velocity Head, $v^2/2g_c$ (ft w.c.):	0.000	0.149									
Pressure Drop (ft w.c.):	0.00	18.98							138.5		

Branch Pipe Estimated Conditions

Location:	Entrance	1	2	3	4	5	6	7	8	9	10
Orifice Velocity (ft/s):	---	0.00									0.00
Length of Branch Pipe (ft)[2]:	---	73									
Reynolds Number, Re:	---	0.00E+00									0.00E+00
Fanning Friction Factor, f:	---										
Pressure Drop (ft w.c.), (Eq.(7)):	---										#VALUE!
Velocity Head, $v^2/2g_c$ (ft w.c.):	---	0.000									0.000
Pressure Drop (ft w.c.)[3]:	---	0.00									
Well Head Pressure (ft w.c.)[4]:	---	0	0	0	0	0	0	0	0	0	0

Header Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Length of Segment (ft):											2,025	(Total)
Header flow rate (gpm):											---	---
Branch flow rate (gpm):											---	---
Header Pipe Velocity (ft/s):											1.5	(Avg.)
Reynolds Number, Re:											7.76E+04	(Avg.)
Fanning Friction Factor, f:											0.00476	(Avg.)
Velocity Head, $v^2/2g_c$ (ft w.c.):											0.074	(Avg.)
Pressure Drop (ft w.c.):											157.48	(Total)

Branch Pipe Estimated Conditions (Continued)

Location:	11	12	13	14	15	16	17	18	19	20	Summary	
Orifice Velocity (ft/s):											0.00	(Avg.)
Length of Branch Pipe (ft)[2]:											73.00	(Avg.)
Reynolds Number, Re:											0.00E+00	(Avg.)
Fanning Friction Factor, f:											#DIV/0!	(Avg.)
Velocity Head, $v^2/2g_c$ (ft w.c.):											0.000	(Avg.)
Pressure Drop (ft w.c.)[3]:											0.00	(Avg.)
Well Head Pressure (ft w.c.)[4]:											0.00	(Avg.)

Eq. (1)
Discharge Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} - 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (2)
Return Header Pressure Drop:

$$\Delta p_p = \left(\frac{4f_{avg}L_p}{3D_p} + 2K\right)\frac{\rho V_p^2}{2g_c}$$

Eq. (3)
Branch Outlet Pressure Drop:

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2g_c}$$

Eq. (4)
Reynolds Number:

$$Re = \frac{D \cdot v \cdot \rho}{\mu} = \frac{D \cdot v}{\eta}$$

Eq. (5)
Distribution Equation:

$$\%\ Maldistribution = 100\left(1 - \sqrt{\frac{\Delta p_o - |\Delta p_p|}{\Delta p_o}}\right)$$

Eq. (6)
Fanning Friction Factor:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{[(p_0 - p_L) - \rho g(h_0 - h_L)]}{\frac{1}{2}\rho v^2}\right)$$

Eq. (7)
Darcy Equation:

$$h_L = \left[\left(4f\ \frac{L}{D}\right)\right]\frac{v^2}{2g}$$

Notes:

(1) K = 0.5 when viscous losses are negligible, K = 1.0 for return headers.
(2) Include the equivalent length of valves and fittings.
(3) Pressure drop due to velocity head and friction losses across the length of the branch pipe.
(4) Pressure at the well head taking into consideration frictional losses across the length of the drop pipe, static head associated with water elevation and mounding, and pressure drop required for foot valve or variable area valve.
(5) Maldistribution of 10 percent or less is recommended.
(6) If the branch piping exhibits average pressure losses (due to length, fittings, and/or well head pressures) of at least 10 times higher than the header, pressure losses maldistribution will be less than 10 percent.

3.10

MW-20 Bench Structural Calculations

ARCADIS

SUBJECT: TOPOCK - MW 20 BENCH

JOB NO: RC000753.0008

BY: [illegible] DATE: 3-14-13

CHKD: DATE:

PAGE

SHEET 1

DEAD LOADS

ROOF PANEL	1.5 PSF
LINER	1.5
INSUL BATT	1
PURLINS 4#/ft/12"	2
	6 PSF

WALL LOADS

WALL PANEL	1.5
LINER	1.5
INSUL	1
GIRTS	2
	6 PSF

COLLATERAL DL 5 PSF

LOADS ON INTERIOR FRAME SPACING = 16'-8

$w_D = 6\,psf(16.67) + 50\,plf$

$w_D = 0.15\ k/ft$

$w_L = 5\,psf(16.67)$

$w_L = 0.083$

COLUMN LOAD (WALL LOADS)

$P_D = 6\,psf(16.67)\,12ft$

$P_D = 1.2k$

LOADS ON END FRAME

$w_D = 6\,psf(16.67/2)_{ft} + 50$

$w_D = 0.1\ k/ft$

$w_L = 5(16.67/2)$

$w_L = 0.04\ k/ft$

COLUMN LOAD

$P_D = [6(16.67/2) + 6(25/4)]\,12$

$P_D = 1.1\ k$ @ END WALL

(CENTER COL SUPPORTS 1/2 END WALL DL)

ARCADIS

SUBJECT:

JOB NO:

BY: [illegible] DATE: 3-14-13

CHKD: DATE:

PAGE

SHEET 1

LIVE LOADS

ROOF LIVE 20 PSF

LOADS ON INTERIOR FRAME

w_L = 20 PSF (16.67)
w_L = 0.33 K/FT

LOADS ON END FRAME

w_L = 20 (16.67/2)
w_L = 0.17 K/FT

FLOOR LIVE - SLAB ON GRADE 500 PSF
WHEEL LOAD 16 K

ARCADIS

SUBJECT: TOWER
WIND LOADS

JOB NO:

BY: EL DATE: 3-14-13

CHKD: DATE:

PAGE

SHEET 1

IBC 2009 1609.6

$h = 15$ m MEAN ROOF HEIGHT $V = 90$ MPH

PARTIALLY ENCLOSED ASCE 7-05 EXPOSURE C

$K_z = 0.85$ ASCE TBL 6-3 $I = 1$ CATAGORY II TBL 6-1

$q_s = 20.7$ psf IBC TBL 1609.6.2(1) $K_{zt} = 1.0$

$P_{NET} = q_s K_z C_{NET} I K_{zt}$

$= 20.7 (0.85)(1)(1)$

$P_{NET} = 17.6 C_{NET}$

MIN WIND LOAD = 20 psf
(PG+E DESIGN CRITERIA)

USE $P_{NET} = 29_{psf} C_{NET}$

IBC TBL 1609.6.2(2)

MWFRS
PARTIALLY ENCLOSED

	C_{NET} CASE 1	C_{NET} CASE 2	P_{NET} (psf) CASE 1	P_{NET} (psf) CASE 2
WINDWARD WALL	+0.11	+1.05	+2.2	+21
LEEWARD WALL	-0.83	+0.11	-16.6	+2.2
SIDE WALL	-0.97	-0.04	-19.4	-0.8
WINDWARD ROOF	-1.41	-0.47	-28.2	-9.4
LEEWARD ROOF	-0.97	-0.04	-19.4	-0.8

ARCADIS

SUBJECT: WIND LOADS

JOB NO:

BY: [illegible] DATE: 3-14-13

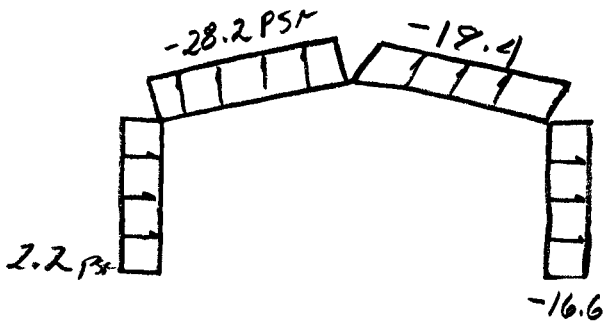
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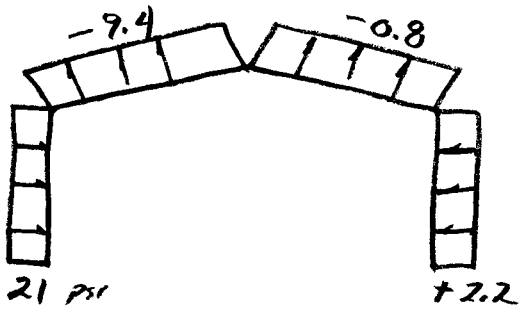
SHEET 1

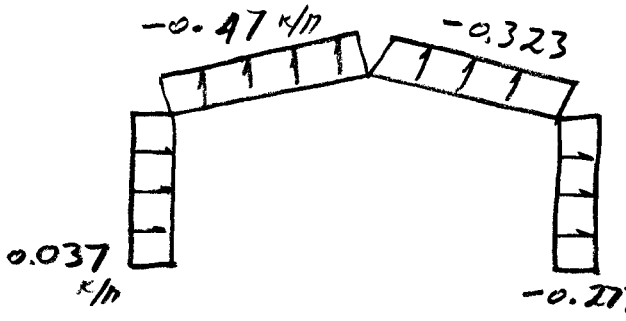
TRANSVERSE WIND

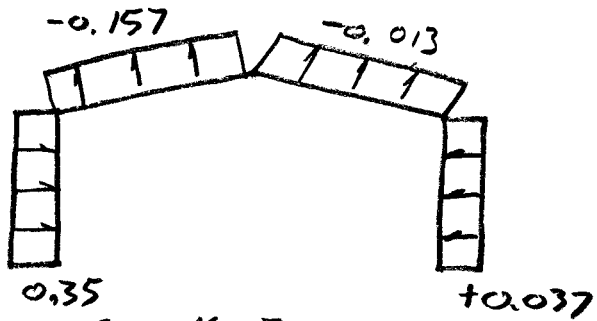
CASE 1



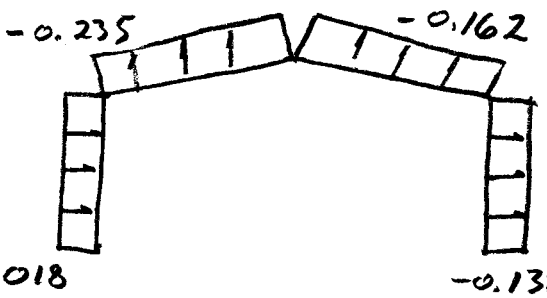
CASE 2

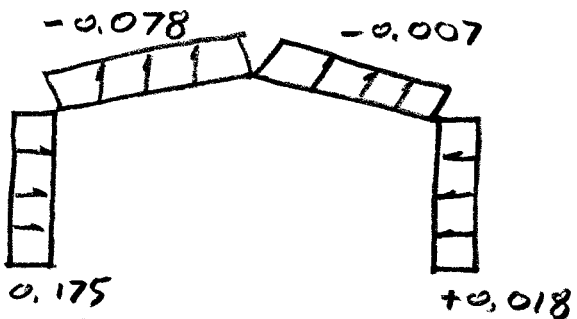






INTERIOR FRAME - TRIB AREA = 16.67 ft





END FRAME - TRIB AREA = 8.3 ft

ARCADIS

SUBJECT: WIND LOADS

JOB NO:

BY: [illegible] DATE: 3/14/13

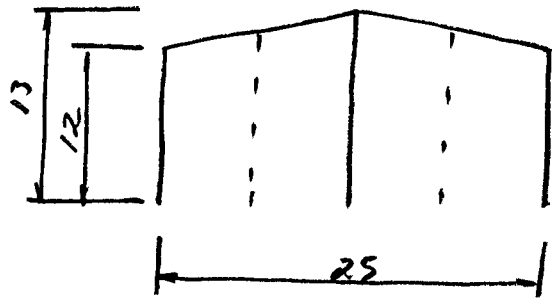
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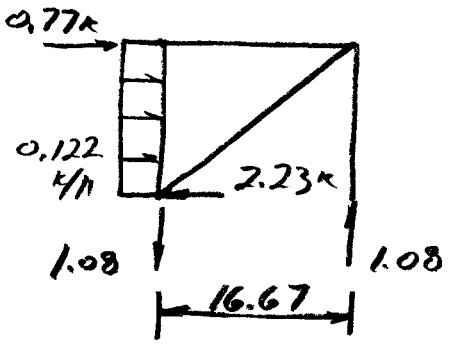
PAGE

SHEET 1

LONGITUDINAL WIND

BRACED FRAME





16.6+2.2 = 18.8 psf

LOAD ON END WALL COLUMN

$18.8\ psf\ (25\ ft/2) = 0.235\ k/ft$

$R_1 = 0.235\ k/ft\ (13\ ft/2) = 1.53\ k$

$R_2 = 1.53\ k$

LOAD ON FRAME COLUMN

$18.8\ psf \left(\frac{25\ ft}{4}\right)\left(\frac{13\ ft + 12\ ft}{2}\right) / 12\ ft = 0.122\ k/ft$

$P = \frac{R_2}{2} = \frac{1.53}{2}$ CONCENTRATED DIAPHRAGM LOAD AT TOP

$P = 0.77\ k$

ARCADIS

SUBJECT: WIND LOADS

JOB NO:

BY: KD DATE: 3-14-13

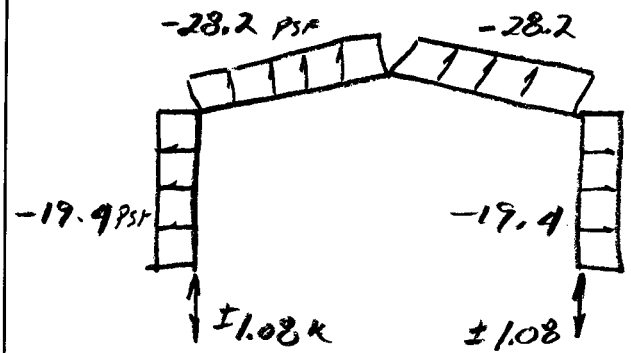
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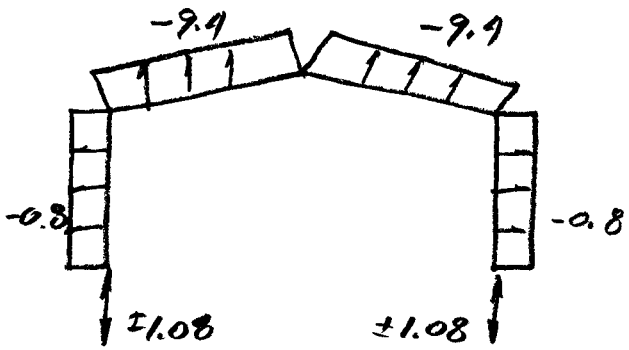
SHEET 1

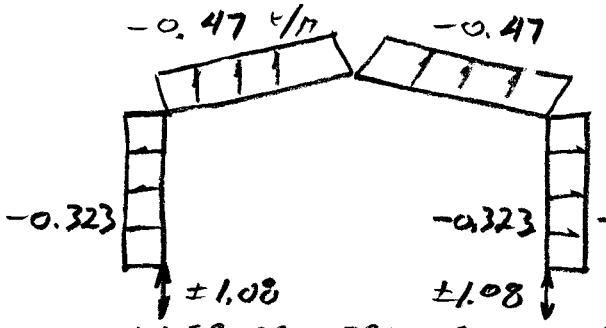
LONGITUDINAL WIND

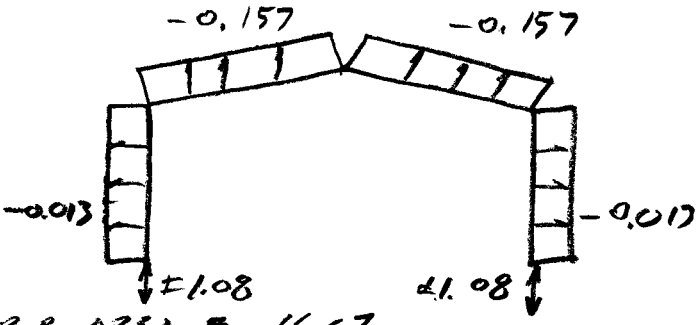
CASE 1



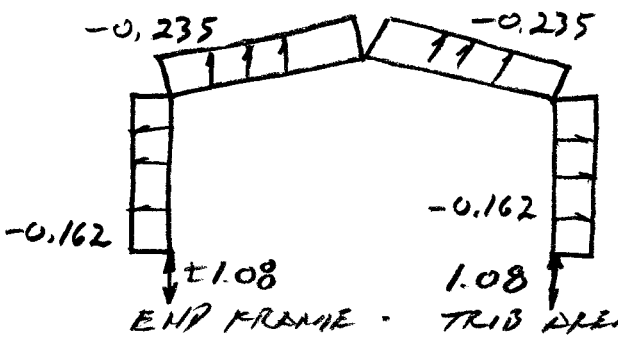
CASE 2

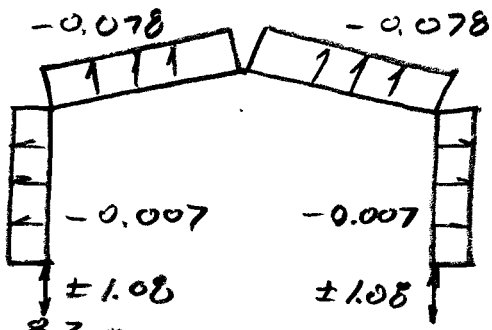






INTERIOR FRAME - TRIB AREA = 16.67 M





END FRAME - TRIB AREA = 8.3 M

Seismic Design Equivalent Lateral Force Procedure per IBC 2009 and ASCE 7-2005

ASCE 7-20.2

Reference:H:\MATHCAD WORKSHEETS\Units.xmcd

Site Class $Class := D$ - per geotechnical engineer

Spectral Response Accelerations

$S_S := 43.4\%$ - mapped spectral acceleration for the short period, see CD rom output

$S_1 := 13.5\%$ - mapped spectral acceleration for a 1-second period, see CD rom output

Adjusted Spectral Response Accelerations (ASCE 7-11.4.3) Design Spectral Response Accelerations

$F_a = 1.45$ $S_{MS} := F_a \cdot S_S$ $S_{MS} = 63.1\%$ $S_{DS} := \frac{2}{3} \cdot S_{MS}$ $S_{DS} = 42.0\%$

$F_v = 2.26$ $S_{M1} := F_v \cdot S_1$ $S_{M1} = 30.5\%$ $S_{D1} := \frac{2}{3} \cdot S_{M1}$ $S_{D1} = 20.3\%$

Building Category

$OccupancyCategory := "II"$ - IBC Table 1604.5 , Enter a Category I, II, III or IV.

$Seimic\_Design\_Category_{sds.} = "C"$ - ASCE 7 Table 11.6-1

$Seimic\_Design\_Category_{sd1.} = "D"$ - ASCE 7 Table 11.6-2

$Seismic\_Design\_Category := \max(Seimic\_Design\_Category_{sds}, Seimic\_Design\_Category_{sd1})$

$Seismic\_Design\_Category = "D"$

ASCE Table 12.2-1 Design Coefficients and Factors for Seismic Force-Resisting Systems

Select Seismic Force-Resisting System:

4. Ordinary steel moment frames

DETAILING REFERENCE SECTION	Refer to IBC
RESPONSE MODIFICATION COEFFICIENT, R[a]	3.5
SYSTEM OVER-STRENGTH FACTOR, Ω_0[g]	3
DEFLECTION AMPLIFICATION FACTOR, C_D[b]	3
BASIC SEISMIC-FORCE-RESISTING SYSTEM	C - 4

Str. System Limitions and Building Height				
Seismic Design Category				
B	C	D	E	F
NL	NL	NPh	NPh	NPi

Equivalent Lateral Force Procedure (ASCE 7-12.8)

$V := C_s \cdot W$ W = effective seismic weight per ASCE 7 section 12.7.2
C_s = seismic response coefficient

$R = 3.5$ - Response Modification Coef. (ASCE 7 - Table 12.2-1)

$I_E = 1$ - Seismic Importance Factor (ASCE 7 - Table 11.5-1)

ASCE 7-12.8.1

$$C_{s\_2} := \frac{S_{DS}}{\frac{R}{I_E}}$$ $C_{s\_2} = 12.01\ \%$ - ASCE 7 equation 12.8-2

ASCE 7-12.8.2.1 $T_L := 6$ - ASCE 7 figure 22-15

Structure Type (ASCE 7 Table 12.8-2)	Ct	x
Steel moment-resisting frames	0.028	0.8

$h_n := 12$ - height in ft above the base to the highest level of th structure

$T_a := C_T \cdot h_n^{\ x}$ $T_a = 0.204$ - ASCE 7 equation 12.8-7

$$C_{s\_3} := \frac{S_{D1}}{T_a \cdot \frac{R}{I_E}}$$ $C_{s\_3} = 28.43\ \%$ - ASCE 7 equation 12.8-3

$$C_{s\_4} := \frac{S_{D1} \cdot T_L}{T_a^{\ 2} \cdot \frac{R}{I_E}}$$ $C_{s\_4} = 834.50\ \%$ - ASCE 7 equation 12.8-4

$$C_{s\_3\_4} := \begin{cases} C_{s\_3} & \text{if } T_a \le T_L \\ C_{s\_4} & \text{if } T_a > T_L \end{cases}$$ $C_{s\_3\_4} = 28.43\ \%$

$C_{s\_5} := 0.01$ $C_{s\_5} = 1.00\ \%$ - ASCE 7 equation 12.8-5

$$C_{s\_6} := \frac{0.5 \cdot S_1}{\frac{R}{I_E}}$$ $C_{s\_6} = 1.93\ \%$ - ASCE 7 equation 12.8-6

Seismic Response Coefficient in accordance with ASCE 7 section 12.8.1.1

$$C_s := \begin{cases} \max\left(\min\left(C_{s\_2}, C_{s\_3\_4}\right), C_{s\_5}\right) & \text{if } S_1 < 0.06 \\ \max\left(\max\left(\min\left(C_{s\_2}, C_{s\_3\_4}\right), C_{s\_5}\right), C_{s\_6}\right) & \text{if } S_1 \ge 0.06 \end{cases}$$

$C_s = 12.01\ \%$

$0.7C_s = 8.41\ \%$

Seismic Load Effects and Combinations (ASCE 7-12.4)

$E := E_h + E_v$ - ASCE 7 equation 12.4-1

$E := E_h - E_v$ - ASCE 7 equation 12.4-2

$E_h := \rho \cdot Q_E$ - ASCE 7 equation 12.4-2

$\rho := 1.3$

$Q_E := C_s$

	Factored	Service
$E_h := \rho \cdot Q_E$	$E_h = 0.156 \cdot W$	$0.7 \cdot E_h = 0.109 \cdot W$
$E_v := \begin{cases} 0 & \text{if } S_{DS} \le 0.125 \\ (0.2 \cdot S_{DS} \cdot D) & \text{otherwise} \end{cases}$	$E_v = 0.084 \cdot D$	$0.7E_v = 0.059 \cdot D$

Determining Dynamic Soil Pressure Coefficient

$K_h := \frac{S_{DS}}{2.5}$ $K_h = 16.814 \cdot \%$ - 2003 NEHRP Commentary, Chapter 7, pg 156

Seismic Design Equivalent Lateral Force Procedure per IBC 2009 and ASCE 7-2005

ASCE 7-20.2

Reference:H:\MATHCAD WORKSHEETS\Units.xmcd

Site Class $Class := D$ - per geotechnical engineer

Spectral Response Accelerations

$S_S := 43.4\%$ - mapped spectral acceleration for the short period, see CD rom output

$S_1 := 13.5\%$ - mapped spectral acceleration for a 1-second period, see CD rom output

Adjusted Spectral Response Accelerations (ASCE 7-11.4.3) Design Spectral Response Accelerations

$F_a = 1.45$ $S_{MS} := F_a \cdot S_S$ $S_{MS} = 63.1\%$ $S_{DS} := \frac{2}{3} \cdot S_{MS}$ $S_{DS} = 42.0\%$

$F_v = 2.26$ $S_{M1} := F_v \cdot S_1$ $S_{M1} = 30.5\%$ $S_{D1} := \frac{2}{3} \cdot S_{M1}$ $S_{D1} = 20.3\%$

Building Category

$OccupancyCategory := "II"$ - IBC Table 1604.5 , Enter a Category I, II, III or IV.

$Seimic\_Design\_Category_{sds} = "C"$ - ASCE 7 Table 11.6-1

$Seimic\_Design\_Category_{sd1} = "D"$ - ASCE 7 Table 11.6-2

$Seismic\_Design\_Category := \max(Seimic\_Design\_Category_{sds}, Seimic\_Design\_Category_{sd1})$

$Seismic\_Design\_Category = "D"$

ASCE Table 12.2-1 Design Coefficients and Factors for Seismic Force-Resisting Systems

Select Seismic Force-Resisting System:

4. Ordinary steel concentrically braced frames

DETAILING REFERENCE SECTION	Refer to IBC
RESPONSE MODIFICATION COEFFICIENT, R[a]	3.25
SYSTEM OVER-STRENGTH FACTOR, Ω[g]	2
DEFLECTION AMPLIFICATION FACTOR, C_D[b]	3.25
BASIC SEISMIC-FORCE-RESISTING SYSTEM	B - 4

Str. System Limitions and Building Height				
Seismic Design Category				
B	C	D	E	F
NL	NL	35j	35j	NPj

Equivalent Lateral Force Procedure (ASCE 7-12.8)

$V := C_S \cdot W$ — W = effective seismic weight per ASCE 7 section 12.7.2; C_S = seismic response coefficient

$R = 3.25$ — Response Modification Coef. (ASCE 7 - Table 12.2-1)

$I_E = 1$ — Seismic Importance Factor (ASCE 7 - Table 11.5-1)

ASCE 7-12.8.1

$$C_{S\_2} := \frac{S_{DS}}{\frac{R}{I_E}}$$ $C_{S\_2} = 12.93\%$ — ASCE 7 equation 12.8-2

ASCE 7-12.8.2.1

$T_L := 6$ — ASCE 7 figure 22-15

Structure Type (ASCE 7 Table 12.8-2)	Ct	x
All other structural systems	0.02	0.75

$h_n := 12$ — height in ft above the base to the highest level of the structure

$T_a := C_T \cdot h_n^{\,x}$ $T_a = 0.129$ — ASCE 7 equation 12.8-7

$$C_{S\_3} := \frac{S_{D1}}{T_a \cdot \frac{R}{I_E}}$$ $C_{S\_3} = 48.53\%$ — ASCE 7 equation 12.8-3

$$C_{S\_4} := \frac{S_{D1} \cdot T_L}{T_a^{\,2} \cdot \frac{R}{I_E}}$$ $C_{S\_4} = 2258.33\%$ — ASCE 7 equation 12.8-4

$$C_{S\_3\_4} := \begin{cases} C_{S\_3} & \text{if } T_a \le T_L \\ C_{S\_4} & \text{if } T_a > T_L \end{cases}$$ $C_{S\_3\_4} = 48.53\%$

$C_{S\_5} := 0.01$ $C_{S\_5} = 1.00\%$ — ASCE 7 equation 12.8-5

$$C_{S\_6} := \frac{0.5 \cdot S_1}{\frac{R}{I_E}}$$ $C_{S\_6} = 2.08\%$ — ASCE 7 equation 12.8-6

Seismic Response Coefficient in accordance with ASCE 7 section 12.8.1.1

$$C_S := \begin{cases} \max\left(\min\left(C_{S\_2}, C_{S\_3\_4}\right), C_{S\_5}\right) & \text{if } S_1 < 0.06 \\ \max\left(\max\left(\min\left(C_{S\_2}, C_{S\_3\_4}\right), C_{S\_5}\right), C_{S\_6}\right) & \text{if } S_1 \ge 0.06 \end{cases}$$

$C_S = 12.93\%$

$0.7C_S = 9.05\%$

Seismic Load Effects and Combinations (ASCE 7-12.4)

$E := E_h + E_v$ - ASCE 7 equation 12.4-1

$E := E_h - E_v$ - ASCE 7 equation 12.4-2

$E_h := \rho \cdot Q_E$ - ASCE 7 equation 12.4-2

$\rho := 1.3$

$Q_E := C_s$

	Factored	Service
$E_h := \rho \cdot Q_E$	$E_h = 0.168 \cdot W$	$0.7 \cdot E_h = 0.118 \cdot W$
$E_v := \begin{cases} 0 & \text{if } S_{DS} \le 0.125 \\ (0.2 \cdot S_{DS} \cdot D) & \text{otherwise} \end{cases}$	$E_v = 0.084 \cdot D$	$0.7E_v = 0.059 \cdot D$

ARCADIS

SUBJECT: SEISMIC LOAD COMBINATIONS

JOB NO:

BY: DATE: 3-14-13

CHKD: DATE:

PAGE

SHEET 1

STRENGTH COMBINATIONS

$1.2D + 1.0E$

$E = \rho Q_E + 0.2 S_{DS} D$

$\rho = 1.3 \quad S_{DS} = 0.42$

$1.2D + \rho Q_E + 0.2 S_{DS} D$

$1.2D + 1.3 Q_E + 0.2 (0.42) D$

$(1.2 + 0.084) D + 1.3 Q_E$

$1.284D + 1.3 Q_E$

$0.9D + 1.0E$

$0.9D - 0.2 S_{DS} D + \rho Q_E$

$0.9D - 0.2 (0.42) D + 1.3 Q_E$

$(0.9 - 0.084) D + 1.3 Q_E$

$0.816D + 1.3 Q_E$

ARCADIS

SUBJECT: SEISMIC LOAD COMBINATIONS

JOB NO:

BY: [illegible] DATE: 3-14-13

CHKD: DATE:

PAGE

SHEET 1

SERVICE LOAD COMBINATIONS

$(1.0 + 0.14 S_{DS}) D + 0.7 \rho Q_L$

$(1 + 0.14(0.42)) D + 0.7(1.3) Q_L$

$1.06 D + 0.91 Q_L$

$(0.6 - 0.14 S_{DS}) D + 0.7 \rho Q_L$

$(0.6 - 0.14(0.42)) D + 0.7(1.3) Q_L$

$0.541 D + 0.91 Q_L$

ARCADIS

SUBJECT: SEISMIC COMBINATIONS

JOB NO:

BY: DATE:

CHKD: DATE:

PAGE

SHEET 1

ORTHOGONAL COMBINATIONS AS PER 12.5.4

FOR SDC D STRENGTH COMBINATIONS

COMBINE 100% Q BRACED FRAME Q_2

30% Q MOMENT FRAME Q_1

$1.2D + 1.0L$

$1.2D + 0.3\rho Q_1 + \rho Q_2 + 0.2 S_{DS} D$

$1.284D + 0.39 Q_1 + 1.3 Q_2$

$0.9D + 1.0E$

$0.9D - 0.2 S_{DS} + 0.3\rho Q_1 + \rho Q_2$

$0.816D + 0.39 Q_1 + 1.3 Q_2$

ARCADIS

SUBJECT: SEISMIC COMBINATIONS

JOB NO:

BY: RD DATE: 3-14-13

CHKD: DATE:

PAGE

SHEET 1

ORTHOGONAL COMBINATIONS

SERVICE LOAD COMBINATIONS

$(1.0 + 0.14S_{DS})D + 0.3(0.7)\rho Q_1 + 0.7\rho Q_2$

$1.06D + 0.273Q_1 + 0.91Q_2$

$(0.6 - 0.14S_{DS})D + 0.3(0.7)\rho Q_1 + 0.7\rho Q_2$

$0.541D + 0.273Q_1 + 0.91Q_2$

ARCADIS

SUBJECT: SEISMIC

JOB NO:

BY: [illegible] DATE: 3-14-13

CHKD: DATE:

PAGE

SHEET 1

MOMENT FRAMES

INTERIOR MOMENT FRAME

$C_s = 0.12$

$q_E = C_s W$

W = EFFECTIVE SEISMIC WEIGHT
= DL + COLLATERAL

W: 0.15 k/ft (25ft)	=	3.8
2 (1.2)	=	2.4
0.083 k/ft (25ft)	=	2.1
W:		8.3k

$q_E = 0.12(8.3)$

$q_E = 1$ k

END MOMENT FRAME

W: 0.1 k/ft (25)ft	=	2.5
2 (1.5)	=	3
0.04 k/ft (25)	=	1
W:		6.5k

$q_E = 0.12(6.5)$

$q_E = 0.8$ k

ARCADIS

SUBJECT: SEISMIC

JOB NO:

BY: [illegible] DATE: 3-14-13

CHKD: DATE:

PAGE

SHEET 1

BRACED FRAMES

$C_s = 0.13$

$Q_E = C_s W$

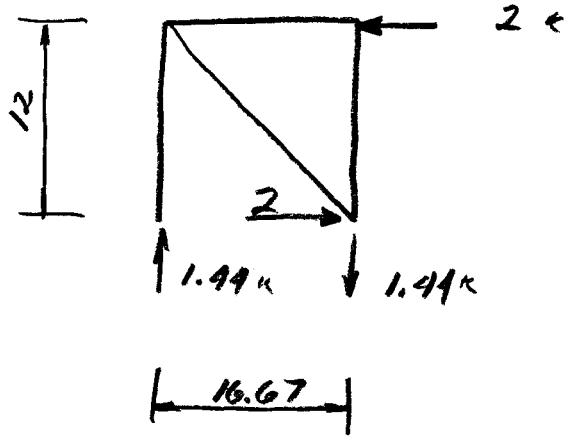
$W = \underbrace{8.3(2)}_{2\ \text{SIDES}} + \underbrace{6.5\text{k}\ 2}_{2\ \text{ENDS}}$

2 INT FRAMES, 2 END FRAMES

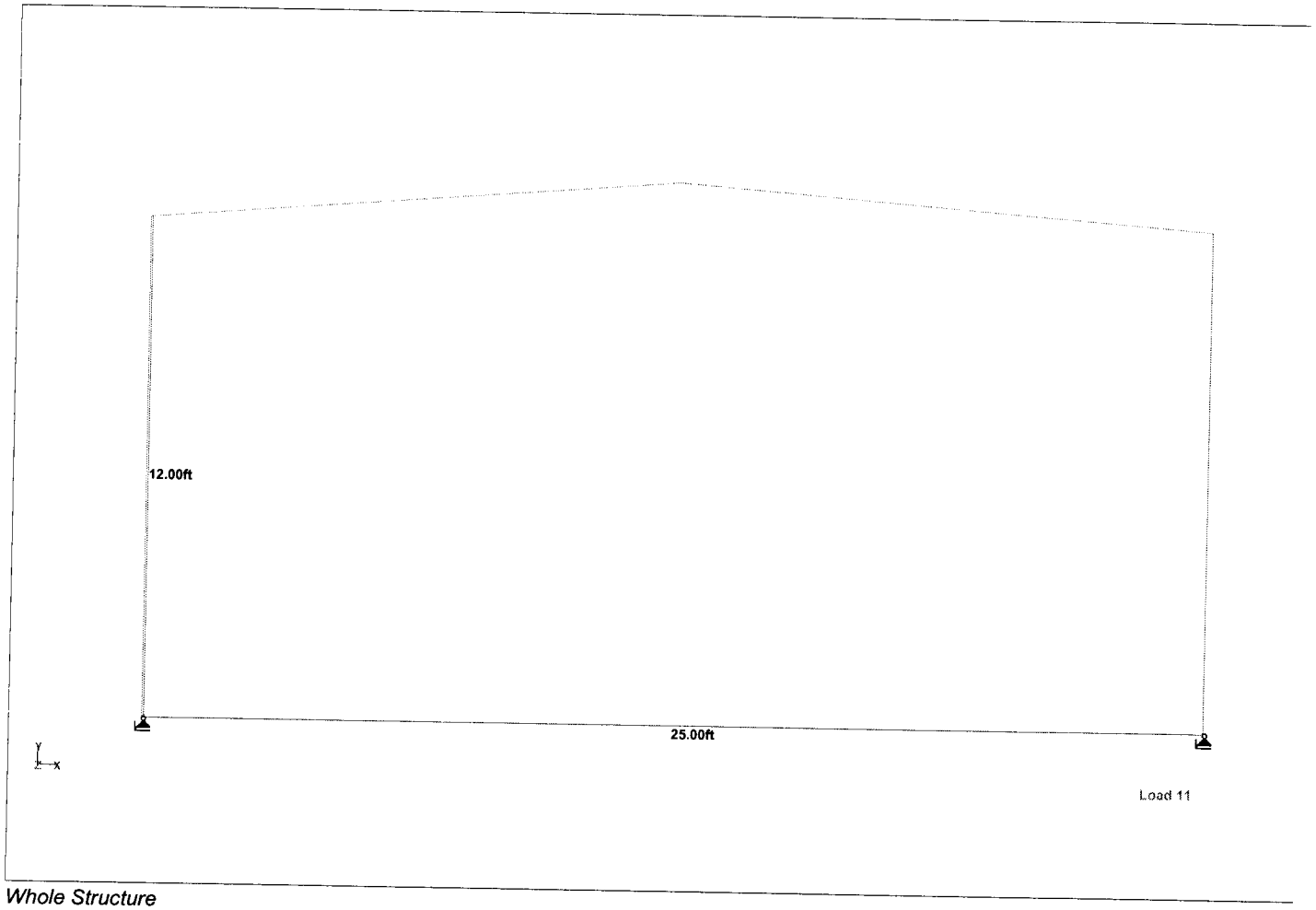
$W = 14.8$ k

$Q_k = 0.13(14.8)$

$Q_k = 2$ k



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Job Title Topock Groundwater Remediation Project	Part End Frame		
	Ref		
Client PG&E	By PJD	Date 14-Mar-13	Chd
	File END FRAME.std	Date/Time 15-Mar-201	



Whole Structure

Software licensed to ARCADIS	Job No RC000753.000	Sheet No 1	Re
Job Title Topock Groundwater Remediation Project	Part End Frame		
	Ref		
	By PJD	Date 14-Mar-13	Chd
Client PG&E	File END FRAME.std	Date/Time 15-Mar-201	

Basic Load Cases

Number	Name
1	DEAD
2	COLLATERAL
3	WIND1
4	WIND2
5	WIND3
6	WIND4
7	WIND5
8	LIVE1
9	LIVE2
10	Q1
11	Q2

Combination Load Cases

Comb.	Combination L/C Name	Primary	Primary L/C Name	Factor
13	1.2D + 1.6L1	1	DEAD	1.20
		2	COLLATERAL	1.20
		8	LIVE1	1.60
14	1.2D + 1.6L2	1	DEAD	1.20
		2	COLLATERAL	1.20
		9	LIVE2	1.60
15	1.2D + 1.6L1 + 0.8W2	1	DEAD	1.20
		2	COLLATERAL	1.20
		8	LIVE1	1.60
		4	WIND2	0.80
16	1.2D + 1.6L1 + 0.8(W4-W5)	1	DEAD	1.20
		2	COLLATERAL	1.20
		8	LIVE1	1.60
		6	WIND4	0.80
		7	WIND5	-0.80
17	1.2D + 1.6L2 + 0.8W2	1	DEAD	1.20
		2	COLLATERAL	1.20
		9	LIVE2	1.60
		4	WIND2	0.80
18	1.2D + 1.6L2 + 0.8(W4-W5)	1	DEAD	1.20
		2	COLLATERAL	1.20
		9	LIVE2	1.60
		6	WIND4	0.80
		7	WIND5	-0.80
19	1.2D + 0.5L1 + 1.6W2	1	DEAD	1.20
		2	COLLATERAL	1.20
		8	LIVE1	0.50
		4	WIND2	1.60
20	1.2D + 0.5L1 + 1.6(W4-W5)	1	DEAD	1.20
		2	COLLATERAL	1.20
		8	LIVE1	0.50
		6	WIND4	1.60
		7	WIND5	-1.60
21	1.2D + 0.5L2 + 1.6W2	1	DEAD	1.20
		2	COLLATERAL	1.20
		9	LIVE2	0.50
		4	WIND2	1.60
22	1.2D + 0.5L2 + 1.6(W4-W5)	1	DEAD	1.20
		2	COLLATERAL	1.20
		9	LIVE2	0.50
		6	WIND4	1.60
		7	WIND5	-1.60
23	0.9D + 1.6W1	1	DEAD	0.90
		3	WIND1	1.60
24	0.9D + 1.6(W3+W5)	1	DEAD	0.90
		5	WIND3	1.60

Combination Load Cases Cont...

Comb.	Combination L/C Name	Primary	Primary L/C Name	Factor
		7	WIND5	1.60
25	1.284D + 1.3Q1	1	DEAD	1.28
		2	COLLATERAL	1.28
		10	Q1	1.30
26	1.284D + 1.3Q2	1	DEAD	1.28
		2	COLLATERAL	1.28
		11	Q2	-1.30
27	0.816D + 1.3Q2	1	DEAD	0.82
		11	Q2	1.30
28	1.284D + 0.39Q1 + 1.3Q2	1	DEAD	1.28
		2	COLLATERAL	1.28
		10	Q1	0.39
		11	Q2	-1.30
29	0.816D + 0.39Q1 + 1.3Q2	1	DEAD	0.82
		10	Q1	0.39
		11	Q2	1.30
30	D + L1	1	DEAD	1.00
		2	COLLATERAL	1.00
		8	LIVE1	1.00
31	D + L2	1	DEAD	1.00
		2	COLLATERAL	1.00
		9	LIVE2	1.00
32	D + 0.75L1 + 0.75W2	1	DEAD	1.00
		2	COLLATERAL	1.00
		8	LIVE1	0.75
		4	WIND2	0.75
33	D + 0.75L1 + 0.75(W4-W5)	1	DEAD	1.00
		2	COLLATERAL	1.00
		8	LIVE1	0.75
		6	WIND4	0.75
		7	WIND5	-0.75
34	D + 0.75L2 + 0.75W2	1	DEAD	1.00
		2	COLLATERAL	1.00
		9	LIVE2	0.75
		4	WIND2	0.75
35	D + 0.75L2 + 0.75(W4-W5)	1	DEAD	1.00
		2	COLLATERAL	1.00
		9	LIVE2	0.75
		6	WIND4	0.75
		7	WIND5	-0.75
36	0.6D + 1.0W1	1	DEAD	0.60
		3	WIND1	1.00
37	0.6D + 1.0(W3+W5)	1	DEAD	0.60
		5	WIND3	1.00
		7	WIND5	1.00
38	1.06D + 0.91Q1	1	DEAD	1.06

Combination Load Cases Cont...

Comb.	Combination L/C Name	Primary	Primary L/C Name	Factor
		2	COLLATERAL	1.06
		10	Q1	0.91
39	1.06D + 0.91Q2	1	DEAD	1.06
		2	COLLATERAL	1.06
		11	Q2	0.91
40	0.54D + 0.91Q2	1	DEAD	0.54
		11	Q2	0.91
41	1.06D + 0.273Q1 + 0.91Q2	1	DEAD	1.06
		2	COLLATERAL	1.06
		10	Q1	0.27
		11	Q2	0.91
42	0.54D + 0.273Q1 + 0.91Q2	1	DEAD	0.54
		10	Q1	0.27
		11	Q2	0.91

```
STAAD PLANE
START JOB INFORMATION
ENGINEER DATE 14-Mar-13
JOB NAME Topock Groundwater Remediation Project
JOB CLIENT PG&E
JOB NO RC000753.0008
JOB PART End Frame
ENGINEER NAME PJD
END JOB INFORMATION
INPUT WIDTH 79
UNIT FEET KIP
JOINT COORDINATES
1 0 0 0; 2 25 0 0; 3 12.5 13 0; 4 0 12 0; 5 25 12 0;
MEMBER INCIDENCES
1 1 4; 2 2 5; 3 4 3; 4 3 5;
DEFINE MATERIAL START
ISOTROPIC STEEL
E 4.176e+006
POISSON 0.3
DENSITY 0.489024
ALPHA 6e-006
DAMP 0.03
TYPE STEEL
STRENGTH FY 5184 FU 8352 RY 1.5 RT 1.2
END DEFINE MATERIAL
MEMBER PROPERTY AMERICAN
1 TO 4 TABLE ST W24X55
CONSTANTS
MATERIAL STEEL ALL
SUPPORTS
1 2 PINNED
LOAD 1 LOADTYPE None  TITLE DEAD
MEMBER LOAD
3 4 UNI GY -0.1
JOINT LOAD
4 5 FY -1.1
LOAD 2 LOADTYPE None  TITLE COLLATERAL
MEMBER LOAD
3 4 UNI GY -0.04
LOAD 3 LOADTYPE None  TITLE WIND1
* TRANSVERSE WIND
MEMBER LOAD
1 UNI GX 0.018
3 UNI Y 0.235
2 UNI GX 0.138
4 UNI Y 0.162
LOAD 4 LOADTYPE None  TITLE WIND2
* TRANSVERSE WIND
MEMBER LOAD
1 UNI GX 0.175
2 UNI GX -0.018
3 UNI Y 0.078
4 UNI Y 0.007
LOAD 5 LOADTYPE None  TITLE WIND3
* LONGITUDINAL WIND SIDEWALL FRAME LOADS
MEMBER LOAD
3 4 UNI Y 0.235
1 UNI GX -0.162
2 UNI GX 0.162
LOAD 6 LOADTYPE None  TITLE WIND4
* LONGITUDINAL WIND SIDEWALL FRAME LOADS
MEMBER LOAD
3 4 UNI Y 0.078
1 UNI GX -0.007
2 UNI GX 0.007
LOAD 7 LOADTYPE None  TITLE WIND5
```

```
* LONGITUDINAL WIND X BRACE COLUMN LOADS
JOINT LOAD
1 2 FY 1.08
LOAD 8 LOADTYPE None  TITLE LIVE1
MEMBER LOAD
3 4 UNI GY -0.17
LOAD 9 LOADTYPE None  TITLE LIVE2
MEMBER LOAD
3 UNI GY -0.17
LOAD 10 LOADTYPE None  TITLE Q1
* E-W SEISMIC
JOINT LOAD
4 FX 0.8
LOAD 11 LOADTYPE None  TITLE Q2
* N-S SEISMIC
JOINT LOAD
1 2 FY 1.44
LOAD COMB 13 1.2D + 1.6L1
1 1.2 2 1.2 8 1.6
LOAD COMB 14 1.2D + 1.6L2
1 1.2 2 1.2 9 1.6
LOAD COMB 15 1.2D + 1.6L1 + 0.8W2
1 1.2 2 1.2 8 1.6 4 0.8
LOAD COMB 16 1.2D + 1.6L1 + 0.8(W4-W5)
1 1.2 2 1.2 8 1.6 6 0.8 7 -0.8
LOAD COMB 17 1.2D + 1.6L2 + 0.8W2
1 1.2 2 1.2 9 1.6 4 0.8
LOAD COMB 18 1.2D + 1.6L2 + 0.8(W4-W5)
1 1.2 2 1.2 9 1.6 6 0.8 7 -0.8
LOAD COMB 19 1.2D + 0.5L1 + 1.6W2
1 1.2 2 1.2 8 0.5 4 1.6
LOAD COMB 20 1.2D + 0.5L1 + 1.6(W4-W5)
1 1.2 2 1.2 8 0.5 6 1.6 7 -1.6
LOAD COMB 21 1.2D + 0.5L2 + 1.6W2
1 1.2 2 1.2 9 0.5 4 1.6
LOAD COMB 22 1.2D + 0.5L2 + 1.6(W4-W5)
1 1.2 2 1.2 9 0.5 6 1.6 7 -1.6
LOAD COMB 23 0.9D + 1.6W1
1 0.9 3 1.6
LOAD COMB 24 0.9D + 1.6(W3+W5)
1 0.9 5 1.6 7 1.6
LOAD COMB 25 1.284D + 1.3Q1
1 1.284 2 1.284 10 1.3
LOAD COMB 26 1.284D + 1.3Q2
1 1.284 2 1.284 11 -1.3
LOAD COMB 27 0.816D + 1.3Q2
1 0.816 11 1.3
* 30%Q1 + 100%Q2
LOAD COMB 28 1.284D + 0.39Q1 + 1.3Q2
1 1.284 2 1.284 10 0.39 11 -1.3
* 30%Q1 + 100%Q2
LOAD COMB 29 0.816D + 0.39Q1 + 1.3Q2
1 0.816 10 0.39 11 1.3
* SERVICE COMBINATIONS
LOAD COMB 30 D + L1
1 1.0 2 1.0 8 1.0
LOAD COMB 31 D + L2
1 1.0 2 1.0 9 1.0
LOAD COMB 32 D + 0.75L1 + 0.75W2
1 1.0 2 1.0 8 0.75 4 0.75
LOAD COMB 33 D + 0.75L1 + 0.75(W4-W5)
1 1.0 2 1.0 8 0.75 6 0.75 7 -0.75
LOAD COMB 34 D + 0.75L2 + 0.75W2
1 1.0 2 1.0 9 0.75 4 0.75
LOAD COMB 35 D + 0.75L2 + 0.75(W4-W5)
1 1.0 2 1.0 9 0.75 6 0.75 7 -0.75
```

```
LOAD COMB 36 0.6D + 1.0W1
1 0.6 3 1.0
LOAD COMB 37 0.6D + 1.0(W3+W5)
1 0.6 5 1.0 7 1.0
LOAD COMB 38 1.06D + 0.91Q1
1 1.06 2 1.06 10 0.91
LOAD COMB 39 1.06D + 0.91Q2
1 1.06 2 1.06 11 0.91
LOAD COMB 40 0.54D + 0.91Q2
1 0.54 11 0.91
* 30%Q1 + 100%Q2
LOAD COMB 41 1.06D + 0.273Q1 + 0.91Q2
1 1.06 2 1.06 10 0.273 11 0.91
* 30%Q1 + 100%Q2
LOAD COMB 42 0.54D + 0.273Q1 + 0.91Q2
1 0.54 10 0.273 11 0.91
PERFORM ANALYSIS
FINISH
```

Software licensed to ARCADIS		Job No RC000753.000	Sheet No 1
Job Title Topock Groundwater Remediation Project		Part End Frame	Ref
Client PG&E		By PJD	Date 14-Mar-13 Chd
		File END FRAME.std	Date/Time 21-Mar-201

Reactions

Node	L/C	Horizontal FX (kip)	Vertical FY (kip)	Horizontal FZ (kip)	Moment MX (kip-ft)	Moment MY (kip-ft)	Moment MZ (kip-ft)
1	1:DEAD	0.32	2.35	0.00	0.00	0.00	0.00
	2:COLLATERA	0.13	0.50	0.00	0.00	0.00	0.00
	3:WIND1	-1.18	-3.12	0.00	0.00	0.00	0.00
	4:WIND2	-1.61	-1.17	0.00	0.00	0.00	0.00
	5:WIND3	0.20	-2.94	0.00	0.00	0.00	0.00
	6:WIND4	-0.21	-0.98	0.00	0.00	0.00	0.00
	7:WIND5	0.00	-1.08	0.00	0.00	0.00	0.00
	8:LIVE1	0.55	2.13	0.00	0.00	0.00	0.00
	9:LIVE2	0.27	1.60	0.00	0.00	0.00	0.00
	10:Q1	-0.41	-0.38	0.00	0.00	0.00	0.00
	11:Q2	0.00	-1.44	0.00	0.00	0.00	0.00
2	1:DEAD	-0.32	2.35	0.00	0.00	0.00	0.00
	2:COLLATERA	-0.13	0.50	0.00	0.00	0.00	0.00
	3:WIND1	-0.62	-1.84	0.00	0.00	0.00	0.00
	4:WIND2	-0.20	0.11	0.00	0.00	0.00	0.00
	5:WIND3	-0.20	-2.94	0.00	0.00	0.00	0.00
	6:WIND4	0.21	-0.98	0.00	0.00	0.00	0.00
	7:WIND5	0.00	-1.08	0.00	0.00	0.00	0.00
	8:LIVE1	-0.55	2.13	0.00	0.00	0.00	0.00
	9:LIVE2	-0.27	0.53	0.00	0.00	0.00	0.00
	10:Q1	-0.39	0.38	0.00	0.00	0.00	0.00
	11:Q2	0.00	-1.44	0.00	0.00	0.00	0.00

Reactions

Node	L/C	Horizontal FX (kip)	Vertical FY (kip)	Horizontal FZ (kip)	Moment MX (kip-ft)	Moment MY (kip-ft)	Moment MZ (kip-ft)
1	13:1.2D + 1.6L	1.42	6.84	0.00	0.00	0.00	0.00
	14:1.2D + 1.6L	0.98	5.98	0.00	0.00	0.00	0.00
	15:1.2D + 1.6L	0.13	5.90	0.00	0.00	0.00	0.00
	16:1.2D + 1.6L	1.25	6.92	0.00	0.00	0.00	0.00
	17:1.2D + 1.6L	-0.31	5.05	0.00	0.00	0.00	0.00
	18:1.2D + 1.6L	0.81	6.07	0.00	0.00	0.00	0.00
	19:1.2D + 0.5L	-1.76	2.62	0.00	0.00	0.00	0.00
	20:1.2D + 0.5L	0.48	4.66	0.00	0.00	0.00	0.00
	21:1.2D + 0.5L	-1.90	2.35	0.00	0.00	0.00	0.00
	22:1.2D + 0.5L	0.34	4.39	0.00	0.00	0.00	0.00
	23:0.9D + 1.6W	-1.60	-2.88	0.00	0.00	0.00	0.00
	24:0.9D + 1.6(\	0.61	-4.31	0.00	0.00	0.00	0.00
	25:1.284D + 1.	0.04	3.17	0.00	0.00	0.00	0.00
	26:1.284D + 1.	0.58	5.54	0.00	0.00	0.00	0.00
	27:0.816D + 1.	0.26	0.05	0.00	0.00	0.00	0.00
	28:1.284D + 0.	0.42	5.39	0.00	0.00	0.00	0.00
	29:0.816D + 0.	0.10	-0.10	0.00	0.00	0.00	0.00
2	13:1.2D + 1.6L	-1.42	6.84	0.00	0.00	0.00	0.00
	14:1.2D + 1.6L	-0.98	4.28	0.00	0.00	0.00	0.00
	15:1.2D + 1.6L	-1.58	6.92	0.00	0.00	0.00	0.00
	16:1.2D + 1.6L	-1.25	6.92	0.00	0.00	0.00	0.00
	17:1.2D + 1.6L	-1.14	4.37	0.00	0.00	0.00	0.00
	18:1.2D + 1.6L	-0.81	4.36	0.00	0.00	0.00	0.00
	19:1.2D + 0.5L	-1.14	4.66	0.00	0.00	0.00	0.00
	20:1.2D + 0.5L	-0.48	4.66	0.00	0.00	0.00	0.00
	21:1.2D + 0.5L	-1.00	3.86	0.00	0.00	0.00	0.00
	22:1.2D + 0.5L	-0.34	3.86	0.00	0.00	0.00	0.00
	23:0.9D + 1.6W	-1.28	-0.83	0.00	0.00	0.00	0.00
	24:0.9D + 1.6(\	-0.61	-4.31	0.00	0.00	0.00	0.00
	25:1.284D + 1.	-1.08	4.17	0.00	0.00	0.00	0.00
	26:1.284D + 1.	-0.58	5.54	0.00	0.00	0.00	0.00
	27:0.816D + 1.	-0.26	0.05	0.00	0.00	0.00	0.00
	28:1.284D + 0.	-0.73	5.69	0.00	0.00	0.00	0.00
	29:0.816D + 0.	-0.41	0.20	0.00	0.00	0.00	0.00

Reactions

Node	L/C	Horizontal FX (kip)	Vertical FY (kip)	Horizontal FZ (kip)	Moment MX (kip-ft)	Moment MY (kip-ft)	Moment MZ (kip-ft)
1	30:D + L1	1.00	4.99	0.00	0.00	0.00	0.00
	31:D + L2	0.72	4.45	0.00	0.00	0.00	0.00
	32:D + 0.75L1	-0.35	3.58	0.00	0.00	0.00	0.00
	33:D + 0.75L1	0.70	4.53	0.00	0.00	0.00	0.00
	34:D + 0.75L2	-0.55	3.18	0.00	0.00	0.00	0.00
	35:D + 0.75L2	0.50	4.13	0.00	0.00	0.00	0.00
	36:0.6D + 1.0W	-0.99	-1.71	0.00	0.00	0.00	0.00
	37:0.6D + 1.0(\	0.39	-2.61	0.00	0.00	0.00	0.00
	38:1.06D + 0.9	0.10	2.68	0.00	0.00	0.00	0.00
	39:1.06D + 0.9	0.48	1.72	0.00	0.00	0.00	0.00
	40:0.54D + 0.9	0.17	-0.04	0.00	0.00	0.00	0.00
	41:1.06D + 0.2	0.36	1.61	0.00	0.00	0.00	0.00
	42:0.54D + 0.2	0.06	-0.14	0.00	0.00	0.00	0.00
2	30:D + L1	-1.00	4.99	0.00	0.00	0.00	0.00
	31:D + L2	-0.72	3.39	0.00	0.00	0.00	0.00
	32:D + 0.75L1	-1.01	4.53	0.00	0.00	0.00	0.00
	33:D + 0.75L1	-0.70	4.53	0.00	0.00	0.00	0.00
	34:D + 0.75L2	-0.81	3.34	0.00	0.00	0.00	0.00
	35:D + 0.75L2	-0.50	3.33	0.00	0.00	0.00	0.00
	36:0.6D + 1.0W	-0.81	-0.43	0.00	0.00	0.00	0.00
	37:0.6D + 1.0(\	-0.39	-2.61	0.00	0.00	0.00	0.00
	38:1.06D + 0.9	-0.83	3.38	0.00	0.00	0.00	0.00
	39:1.06D + 0.9	-0.48	1.72	0.00	0.00	0.00	0.00
	40:0.54D + 0.9	-0.17	-0.04	0.00	0.00	0.00	0.00
	41:1.06D + 0.2	-0.58	1.82	0.00	0.00	0.00	0.00
	42:0.54D + 0.2	-0.28	0.07	0.00	0.00	0.00	0.00

```
STAAD PLANE
START JOB INFORMATION
ENGINEER DATE 14-Mar-13
JOB NAME Topock Groundwater Remediation Project
JOB CLIENT PG&E
JOB NO RC000753.0008
JOB PART Interior Frame
ENGINEER NAME PJD
END JOB INFORMATION
INPUT WIDTH 79
UNIT FEET KIP
JOINT COORDINATES
1 0 0 0; 2 25 0 0; 3 12.5 13 0; 4 0 12 0; 5 25 12 0;
MEMBER INCIDENCES
1 1 4; 2 2 5; 3 4 3; 4 3 5;
DEFINE MATERIAL START
ISOTROPIC STEEL
E 4.176e+006
POISSON 0.3
DENSITY 0.489024
ALPHA 6e-006
DAMP 0.03
TYPE STEEL
STRENGTH FY 5184 FU 8352 RY 1.5 RT 1.2
END DEFINE MATERIAL
MEMBER PROPERTY AMERICAN
1 TO 4 TABLE ST W24X55
CONSTANTS
MATERIAL STEEL ALL
SUPPORTS
1 2 PINNED
LOAD 1 LOADTYPE None  TITLE DEAD
MEMBER LOAD
3 4 UNI GY -0.15
JOINT LOAD
4 5 FY -1.2
LOAD 2 LOADTYPE None  TITLE COLLATERAL
MEMBER LOAD
3 4 UNI GY -0.083
LOAD 3 LOADTYPE None  TITLE WIND1
* TRANSVERSE WIND
MEMBER LOAD
1 UNI GX 0.037
3 UNI Y 0.47
2 UNI GX 0.277
4 UNI Y 0.323
LOAD 4 LOADTYPE None  TITLE WIND2
* TRANSVERSE WIND
MEMBER LOAD
1 UNI GX 0.35
2 UNI GX -0.037
3 UNI Y 0.157
4 UNI Y 0.013
LOAD 5 LOADTYPE None  TITLE WIND3
* LONGITUDINAL WIND SIDEWALL FRAME LOADS
MEMBER LOAD
3 4 UNI Y 0.47
1 UNI GX -0.323
2 UNI GX 0.323
LOAD 6 LOADTYPE None  TITLE WIND4
* LONGITUDINAL WIND SIDEWALL FRAME LOADS
MEMBER LOAD
3 4 UNI Y 0.157
1 UNI GX -0.013
2 UNI GX 0.013
LOAD 7 LOADTYPE None  TITLE WIND5
```

```
* LONGITUDINAL WIND X BRACE COLUMN LOADS
JOINT LOAD
1 2 FY 1.08
LOAD 8 LOADTYPE None  TITLE LIVE1
MEMBER LOAD
3 4 UNI GY -0.33
LOAD 9 LOADTYPE None  TITLE LIVE2
MEMBER LOAD
3 UNI GY -0.33
LOAD 10 LOADTYPE None  TITLE Q1
* E-W SEISMIC
JOINT LOAD
4 FX 1
LOAD 11 LOADTYPE None  TITLE Q2
* N-S SEISMIC
JOINT LOAD
1 2 FY 1.44
LOAD COMB 13 1.2D + 1.6L1
1 1.2 2 1.2 8 1.6
LOAD COMB 14 1.2D + 1.6L2
1 1.2 2 1.2 9 1.6
LOAD COMB 15 1.2D + 1.6L1 + 0.8W2
1 1.2 2 1.2 8 1.6 4 0.8
LOAD COMB 16 1.2D + 1.6L1 + 0.8(W4-W5)
1 1.2 2 1.2 8 1.6 6 0.8 7 -0.8
LOAD COMB 17 1.2D + 1.6L2 + 0.8W2
1 1.2 2 1.2 9 1.6 4 0.8
LOAD COMB 18 1.2D + 1.6L2 + 0.8(W4-W5)
1 1.2 2 1.2 9 1.6 6 0.8 7 -0.8
LOAD COMB 19 1.2D + 0.5L1 + 1.6W2
1 1.2 2 1.2 8 0.5 4 1.6
LOAD COMB 20 1.2D + 0.5L1 + 1.6(W4-W5)
1 1.2 2 1.2 8 0.5 6 1.6 7 -1.6
LOAD COMB 21 1.2D + 0.5L2 + 1.6W2
1 1.2 2 1.2 9 0.5 4 1.6
LOAD COMB 22 1.2D + 0.5L2 + 1.6(W4-W5)
1 1.2 2 1.2 9 0.5 6 1.6 7 -1.6
LOAD COMB 23 0.9D + 1.6W1
1 0.9 3 1.6
LOAD COMB 24 0.9D + 1.6(W3+W5)
1 0.9 5 1.6 7 1.6
LOAD COMB 25 1.284D + 1.3Q1
1 1.284 2 1.284 10 1.3
LOAD COMB 26 1.284D + 1.3Q2
1 1.284 2 1.284 11 -1.3
LOAD COMB 27 0.816D + 1.3Q2
1 0.816 11 1.3
* 30%Q1 + 100%Q2
LOAD COMB 28 1.284D + 0.39Q1 + 1.3Q2
1 1.284 2 1.284 10 0.39 11 -1.3
* 30%Q1 + 100%Q2
LOAD COMB 29 0.816D + 0.39Q1 + 1.3Q2
1 0.816 10 0.39 11 1.3
* SERVICE COMBINATIONS
LOAD COMB 30 D + L1
1 1.0 2 1.0 8 1.0
LOAD COMB 31 D + L2
1 1.0 2 1.0 9 1.0
LOAD COMB 32 D + 0.75L1 + 0.75W2
1 1.0 2 1.0 8 0.75 4 0.75
LOAD COMB 33 D + 0.75L1 + 0.75(W4-W5)
1 1.0 2 1.0 8 0.75 6 0.75 7 -0.75
LOAD COMB 34 D + 0.75L2 + 0.75W2
1 1.0 2 1.0 9 0.75 4 0.75
LOAD COMB 35 D + 0.75L2 + 0.75(W4-W5)
1 1.0 2 1.0 9 0.75 6 0.75 7 -0.75
```

```
LOAD COMB 36 0.6D + 1.0W1
1 0.6 3 1.0
LOAD COMB 37 0.6D + 1.0(W3+W5)
1 0.6 5 1.0 7 1.0
LOAD COMB 38 1.06D + 0.91Q1
1 1.06 2 1.06 10 0.91
LOAD COMB 39 1.06D + 0.91Q2
1 1.06 2 1.06 11 0.91
LOAD COMB 40 0.54D + 0.91Q2
1 0.54 11 0.91
* 30%Q1 + 100%Q2
LOAD COMB 41 1.06D + 0.273Q1 + 0.91Q2
1 1.06 2 1.06 10 0.273 11 0.91
* 30%Q1 + 100%Q2
LOAD COMB 42 0.54D + 0.273Q1 + 0.91Q2
1 0.54 10 0.273 11 0.91
PERFORM ANALYSIS
FINISH
```

Reactions

Node	L/C	Horizontal FX (kip)	Vertical FY (kip)	Horizontal FZ (kip)	Moment MX (kip-ft)	Moment MY (kip-ft)	Moment MZ (kip-ft)
1	1:DEAD	0.48	3.08	0.00	0.00	0.00	0.00
	2:COLLATERA	0.27	1.04	0.00	0.00	0.00	0.00
	3:WIND1	-2.37	-6.25	0.00	0.00	0.00	0.00
	4:WIND2	-3.21	-2.34	0.00	0.00	0.00	0.00
	5:WIND3	0.39	-5.88	0.00	0.00	0.00	0.00
	6:WIND4	-0.43	-1.96	0.00	0.00	0.00	0.00
	7:WIND5	0.00	-1.08	0.00	0.00	0.00	0.00
	8:LIVE1	1.06	4.14	0.00	0.00	0.00	0.00
	9:LIVE2	0.53	3.10	0.00	0.00	0.00	0.00
	10:Q1	-0.52	-0.48	0.00	0.00	0.00	0.00
	11:Q2	0.00	-1.44	0.00	0.00	0.00	0.00
2	1:DEAD	-0.48	3.08	0.00	0.00	0.00	0.00
	2:COLLATERA	-0.27	1.04	0.00	0.00	0.00	0.00
	3:WIND1	-1.25	-3.67	0.00	0.00	0.00	0.00
	4:WIND2	-0.40	0.22	0.00	0.00	0.00	0.00
	5:WIND3	-0.39	-5.88	0.00	0.00	0.00	0.00
	6:WIND4	0.43	-1.96	0.00	0.00	0.00	0.00
	7:WIND5	0.00	-1.08	0.00	0.00	0.00	0.00
	8:LIVE1	-1.06	4.14	0.00	0.00	0.00	0.00
	9:LIVE2	-0.53	1.03	0.00	0.00	0.00	0.00
	10:Q1	-0.48	0.48	0.00	0.00	0.00	0.00
	11:Q2	0.00	-1.44	0.00	0.00	0.00	0.00

Reactions

Node	L/C	Horizontal FX (kip)	Vertical FY (kip)	Horizontal FZ (kip)	Moment MX (kip-ft)	Moment MY (kip-ft)	Moment MZ (kip-ft)
1	13:1.2D + 1.6L	2.60	11.57	0.00	0.00	0.00	0.00
	14:1.2D + 1.6L	1.75	9.91	0.00	0.00	0.00	0.00
	15:1.2D + 1.6L	0.03	9.69	0.00	0.00	0.00	0.00
	16:1.2D + 1.6L	2.26	10.86	0.00	0.00	0.00	0.00
	17:1.2D + 1.6L	-0.82	8.04	0.00	0.00	0.00	0.00
	18:1.2D + 1.6L	1.41	9.21	0.00	0.00	0.00	0.00
	19:1.2D + 0.5L	-3.71	3.27	0.00	0.00	0.00	0.00
	20:1.2D + 0.5L	0.75	5.60	0.00	0.00	0.00	0.00
	21:1.2D + 0.5L	-3.98	2.75	0.00	0.00	0.00	0.00
	22:1.2D + 0.5L	0.48	5.09	0.00	0.00	0.00	0.00
	23:0.9D + 1.6W	-3.36	-7.22	0.00	0.00	0.00	0.00
	24:0.9D + 1.6(\	1.06	-8.36	0.00	0.00	0.00	0.00
	25:1.284D + 1.	0.29	4.67	0.00	0.00	0.00	0.00
	26:1.284D + 1.	0.96	7.16	0.00	0.00	0.00	0.00
	27:0.816D + 1.	0.39	0.64	0.00	0.00	0.00	0.00
	28:1.284D + 0.	0.76	6.98	0.00	0.00	0.00	0.00
	29:0.816D + 0.	0.19	0.45	0.00	0.00	0.00	0.00
2	13:1.2D + 1.6L	-2.60	11.57	0.00	0.00	0.00	0.00
	14:1.2D + 1.6L	-1.75	6.60	0.00	0.00	0.00	0.00
	15:1.2D + 1.6L	-2.92	11.74	0.00	0.00	0.00	0.00
	16:1.2D + 1.6L	-2.26	10.86	0.00	0.00	0.00	0.00
	17:1.2D + 1.6L	-2.07	6.77	0.00	0.00	0.00	0.00
	18:1.2D + 1.6L	-1.41	5.90	0.00	0.00	0.00	0.00
	19:1.2D + 0.5L	-2.07	7.36	0.00	0.00	0.00	0.00
	20:1.2D + 0.5L	-0.75	5.60	0.00	0.00	0.00	0.00
	21:1.2D + 0.5L	-1.80	5.81	0.00	0.00	0.00	0.00
	22:1.2D + 0.5L	-0.48	4.05	0.00	0.00	0.00	0.00
	23:0.9D + 1.6W	-2.43	-3.09	0.00	0.00	0.00	0.00
	24:0.9D + 1.6(\	-1.06	-8.36	0.00	0.00	0.00	0.00
	25:1.284D + 1.	-1.59	5.92	0.00	0.00	0.00	0.00
	26:1.284D + 1.	-0.96	7.16	0.00	0.00	0.00	0.00
	27:0.816D + 1.	-0.39	0.64	0.00	0.00	0.00	0.00
	28:1.284D + 0.	-1.15	7.35	0.00	0.00	0.00	0.00
	29:0.816D + 0.	-0.58	0.83	0.00	0.00	0.00	0.00

Reactions

Node	L/C	Horizontal FX (kip)	Vertical FY (kip)	Horizontal FZ (kip)	Moment MX (kip-ft)	Moment MY (kip-ft)	Moment MZ (kip-ft)
1	30:D + L1	1.81	8.26	0.00	0.00	0.00	0.00
	31:D + L2	1.28	7.23	0.00	0.00	0.00	0.00
	32:D + 0.75L1	-0.86	5.47	0.00	0.00	0.00	0.00
	33:D + 0.75L1	1.23	6.56	0.00	0.00	0.00	0.00
	34:D + 0.75L2	-1.26	4.69	0.00	0.00	0.00	0.00
	35:D + 0.75L2	0.83	5.79	0.00	0.00	0.00	0.00
	36:0.6D + 1.0W	-2.08	-4.40	0.00	0.00	0.00	0.00
	37:0.6D + 1.0(\	0.68	-5.11	0.00	0.00	0.00	0.00
	38:1.06D + 0.9	0.32	3.93	0.00	0.00	0.00	0.00
	39:1.06D + 0.9	0.79	3.06	0.00	0.00	0.00	0.00
	40:0.54D + 0.9	0.26	0.35	0.00	0.00	0.00	0.00
	41:1.06D + 0.2	0.65	2.93	0.00	0.00	0.00	0.00
	42:0.54D + 0.2	0.12	0.22	0.00	0.00	0.00	0.00
2	30:D + L1	-1.81	8.26	0.00	0.00	0.00	0.00
	31:D + L2	-1.28	5.16	0.00	0.00	0.00	0.00
	32:D + 0.75L1	-1.85	7.39	0.00	0.00	0.00	0.00
	33:D + 0.75L1	-1.23	6.56	0.00	0.00	0.00	0.00
	34:D + 0.75L2	-1.45	5.06	0.00	0.00	0.00	0.00
	35:D + 0.75L2	-0.83	4.24	0.00	0.00	0.00	0.00
	36:0.6D + 1.0W	-1.54	-1.82	0.00	0.00	0.00	0.00
	37:0.6D + 1.0(\	-0.68	-5.11	0.00	0.00	0.00	0.00
	38:1.06D + 0.9	-1.23	4.81	0.00	0.00	0.00	0.00
	39:1.06D + 0.9	-0.79	3.06	0.00	0.00	0.00	0.00
	40:0.54D + 0.9	-0.26	0.35	0.00	0.00	0.00	0.00
	41:1.06D + 0.2	-0.93	3.19	0.00	0.00	0.00	0.00
	42:0.54D + 0.2	-0.39	0.48	0.00	0.00	0.00	0.00

ARCADIS

SUBJECT:

JOB NO:

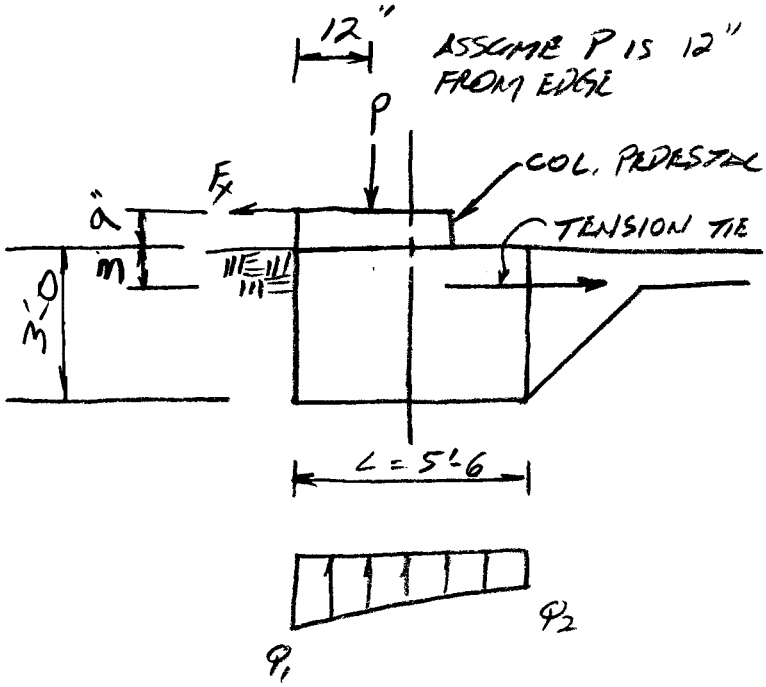
BY: [illegible] DATE: 3-21-13

CHKD: DATE:

PAGE

SHEET 1

SOIL BEARING



ARCADIS

By: PJD Date: 25-Mar-13 Page: _____ of _____
Checked by: _____ Date: _____ Job No. _____
Project: Topock Groundwater Remediation Projet MW 20 Bench Building
Subject: Column Foundations Interior Frame FACTORED LOADS
LC 30

CONC 0.15 KCF SOIL 0.125 KCF

LOAD COMBINATION 1.00 D + L

	FACTOR	L	B	H	A	WEIGHT (K)	X (FT)	WX (KFT)
DEAD LOADS								
FOOTING	1.00	5.50	5.50	3.00	16.50	13.61	2.75	-37.43
CONC PIER	1.00	2.50	1.50	0.50	1.25	0.28	1.25	-0.35
COLUMN LOAD	8.26 K					8.26	1.00	-8.26
HORIZ LOAD	-1.81 K						1.00	1.81
						22.15		-44.24

L/6 = 0.92 FT
Xc= 2.00
e= 0.75 FT < L/6

Q1= 1.33 KSF Q2= 0.13 KSF

ARCADIS

By: PJD Date: 25-Mar-13 Page: _____ of _____
Checked by: _____ Date: _____ Job No. _____
Project: Topock Groundwater Remediation Projet MW 20 Bench Building
Subject: Column Foundations Interior Frame FACTORED LOADS
LC 36

CONC 0.15 KCF SOIL 0.125 KCF

LOAD COMBINATION 0.60 D + W

	FACTOR	L	B	H	A	WEIGHT (K)	X (FT)	WX (KFT)
DEAD LOADS								
FOOTING	0.60	5.50	5.50	3.00	16.50	8.17	2.75	-22.46
CONC PIER	0.60	2.50	1.50	0.50	1.25	0.17	1.25	-0.21
COLUMN LOAD	-4.40 K					-4.40	1.00	4.40
HORIZ LOAD	2.08 K						1.00	-2.08
						3.94		-20.35

L/6 = 0.92 FT
Xc= 5.17
e= -2.42 FT > L/6
X= 0.99
Q1= 0.00 KSF Q2= 1.45 KSF

ARCADIS

By: PJD Date: 25-Mar-13 Page: _____ of _____
Checked by: _____ Date: _____ Job No. _____
Project: Topock Groundwater Remediation Projet MW 20 Bench Building
Subject: Column Foundations Interior Frame FACTORED LOADS
LC 37

CONC 0.15 KCF SOIL 0.125 KCF

LOAD COMBINATION 0.60 D + W

	FACTOR	L	B	H	A	WEIGHT (K)	X (FT)	WX (KFT)
DEAD LOADS								
FOOTING	0.60	5.50	5.50	3.00	16.50	8.17	2.75	-22.46
CONC PIER	0.60	2.50	1.50	0.50	1.25	0.17	1.25	-0.21
COLUMN LOAD	-5.11 K					-5.11	1.00	5.11
HORIZ LOAD	-0.68 K						1.00	0.68
						3.23		-16.88

L/6 = 0.92 FT
Xc= 5.23
e= -2.48 FT > L/6

X= 0.80

Q1= 0.00 KSF Q2= 1.46 KSF

ARCADIS

By: PJD Date: 25-Mar-13 Page: _____ of _____
Checked by: _____ Date: _____ Job No. _____
Project: Topock Groundwater Remediation Projet MW 20 Bench Building
Subject: Column Foundations Interior Frame FACTORED LOADS
LC 15

CONC 0.15 KCF SOIL 0.125 KCF

LOAD COMBINATION 1.20 D + 1.6L

	FACTOR	L	B	H	A	WEIGHT (K)	X (FT)	WX (KFT)
DEAD LOADS								
FOOTING	1.20	5.50	5.50	3.00	16.50	16.34	2.75	-44.92
CONC PIER	1.20	2.50	1.50	0.50	1.25	0.34	1.25	-0.42
COLUMN LOAD	11.74 K					11.74	1.00	-11.74
HORIZ LOAD	-2.92 K						1.00	2.92
						28.41		-54.16

L/6 = 0.92 FT
Xc= 1.91
e= 0.84 FT < L/6

Q1= 1.80 KSF Q2= 0.07 KSF

ARCADIS
Infrastructure · Water · Environment · Buildings

By: PJD Date: 25-Mar-13 Page: _____ of _____
Checked by: _____ Date: _____ Job No. _____
Project: Topock Groundwater Remediation Projet MW 20 Bench Building
Subject: Column Foundations
LC 30

L= 5.50 FT
B= 5.50 FT

T= 3.00 THICKNESS OF FOOTING

SY= 27.73 FT^3
SX= 27.73 FT^3

A= 30.25
Xc= 2.75 Yc= 2.75

GC= 0.15 KCF CONCRETE
GS= 0.12 KCF SOIL

DEAD LOADS

	P	X	X-Xc	P*(X-Xc)	Y	Yc-Y	P*(Y-Yc)
FOOTING	13.61	2.75	0.00	0.00	2.75	0.00	0.00
CONC PIER	0.94	1.25	-1.50	-1.41	1.25	1.50	1.41

14.55 K My= -1.41 KFT Mx= 1.41 KFT

Q1= 0.38 KSF Q2= 0.38 KSF Q3= 0.38 KSF Q4= 0.38 KSF

COLUMN LOAD

	P	X	X-Xc	P*(X-Xc)	Y	Yc-Y	P*(Y-Yc)
	4.99	1.00	-1.75	-8.73	1.00	1.75	8.73
-1						1.00	-1.00

4.99 K My= -8.73 KFT Mx= 7.73 KFT

Q1= -0.43 KSF Q2= -0.43 KSF Q3= -0.43 KSF Q4= -0.43 KSF

COMBINATIONS LC 30

1.00 D +L1
P= 19.54 K My= -10.14 KFT Mx= 10.14 KFT
ex= -0.52 ey= -0.52
Q1= -0.09 KSF Q2= -0.09 KSF Q3= -0.09 KSF Q4= -0.09 KSF Q<0
L'= 4.46 B'= 4.46 REDUCED AREA Q= 0.98 KSF

ARCADIS
Infrastructure · Water · Environment · Buildings

By: PJD Date: 25-Mar-13 Page: _____ of _____
Checked by: _____ Date: _____ Job No. _____
Project: Topock Groundwater Remediation Projet MW 20 Bench Building
Subject: Column Foundations
LC 37

L= 5.50 FT
B= 5.50 FT

T= 3.00 THICKNESS OF FOOTING

SY= 27.73 FT^3
SX= 27.73 FT^3

A= 30.25
Xc= 2.75 Yc= 2.75

GC= 0.15 KCF CONCRETE
GS= 0.12 KCF SOIL

DEAD LOADS

	P	X	X-Xc	P*(X-Xc)	Y	Yc-Y	P*(Y-Yc)
FOOTING	13.61	2.75	0.00	0.00	2.75	0.00	0.00
CONC PIER	0.94	1.25	-1.50	-1.41	1.25	1.50	1.41

14.55 K My= -1.41 KFT Mx= 1.41 KFT

Q1= 0.38 KSF Q2= 0.38 KSF Q3= 0.38 KSF Q4= 0.38 KSF

COLUMN LOAD

	P	X	X-Xc	P*(X-Xc)	Y	Yc-Y	P*(Y-Yc)
	-2.61	1.00	-1.75	4.57	1.00	1.75	-4.57
-0.39						1.00	-0.39

-2.61 K My= 4.57 KFT Mx= -4.96 KFT

Q1= 0.26 KSF Q2= 0.26 KSF Q3= 0.26 KSF Q4= 0.26 KSF

COMBINATIONS LC 37

1.00 D +L1
P= 11.94 K My= 3.16 KFT Mx= -3.16 KFT
ex= 0.26 ey= 0.26
Q1= 0.62 KSF Q2= 0.62 KSF Q3= 0.62 KSF Q4= 0.62 KSF

ARCADIS

SUBJECT: INTERIOR FOUNDATION

JOB NO:

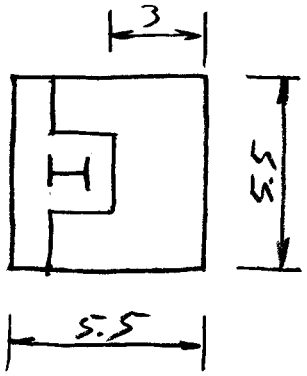
BY: [illegible] DATE: 3-25-13

CHKD: DATE:

PAGE

SHEET 1

CONCRETE STRENGTH UNDER FACTORED LOADS



$w_u = 1.75 \text{ ksf} (5.5 \text{ ft})$

$w_u = 9.63 \text{ k/ft}$



$L = 3$

$M_u = \frac{w L^2}{2}$

$M_u = \frac{9.63 (3)^2}{2}$

$M_u = 43.3 \text{ k ft}$

$V_u = wL$

$= 9.63 \text{ k/ft} (3 \text{ ft})$

$V_u = 29 \text{ k}$

FOR UPLIFT CASE, FOOTING UNDER ITS OWN WEIGHT

$w_u = 0.15 \text{ k/ft}^3 (3 \text{ ft}) (1.4)$

$w_u = 0.63 \text{ k/ft}^2$

$M_u = 0.63 (5.5)(3)^2/2$

$M_u = 16 \text{ k ft}$

ARCADIS
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By: PJD Date: 25-Mar-13 Page:
Checked by: Date: Job No.
Project: Topock MW 20 Bench Bldg
Subject: Interior Foundation

CONCRETE BEAM DESIGN BY ACI 318 OR 350

CODE = ACI 318

f'c = 4,000 PSI FY= 60,000 PSI ϕb= 0.90
Ec = 3605 KSI ϕv= 0.75

BEAM

Normal

B= 66.00 IN Tu < 109.39 KFT FOR TORSION TO BE NEGLECTED
H= 36.00 IN
BOTTOM COVER: 3.00 IN
SIDE COVER: 3.00 IN

FLEXURE
BOTTOM BARS Mu+ = 43.30 KFT
Sd Mu+ = 43.30 KFT

VERT CLR	QTY	BAR NO.	CLR SPA	As	
2.00				0	0
2.00				0	0
	6	5	11.2500	1.86	
					3.3125 Yc

d= 32.6875 IN

1.3258

As MAX = 0.75ρbal = 46.1249 IN^2 Sd = 1.0000
As MIN 7.1913 IN^2
REQ'D As= 0.2947 IN^2
As= 1.8600 IN^2 As < MIN ACI 12.11.3
ϕ Mn= 271.51 KFT Ld < = Mn/Vu + La
Mn > 4/3Mu OK Mn/Vu= 10.40 FT
4/3 Mu= 57.73 KFT

SERVICE LOAD Msl = 32.66057 KFT

Smax= 71.71 > 11.8750
OK

Cc = 3.0000 IN Clear Cover
n = 8.0 Es / Ec Mcr= 563.52 KFT
c = 3.6298 IN NA Ig= 256,608.00 IN^4
fs = 6.7 KSI Icr= 13,685.78 IN^4
Ie= 256,608.00 IN^4

ARCADIS
Infrastructure · Water · Environment · Buildings

By: PJD Date: 25-Mar-13 Page:
Checked by: Date: Job No. 0
Project: Topock MW 20 Bench Bldg
Subject: Interior Foundation

CONCRETE BEAM DESIGN BY ACI 318 OR 350

BEAM 0.00
TOP COVER 2.00 IN

TOP BARS Mu- = 16.00 KFT
Sd Mu- = 16.00 KFT

VERT CLR	QTY	BAR NO.	CLR SPA	As	
2.00				0	0
2.00				0	0
	6	5	11.2500	1.86	
					2.3125 Yc

d= 33.6875 IN

1.4000
As MAX = 0.75ρbal = 47.5360 IN^2 Sd = 1.0000
As MIN 7.4113 IN^2
REQ'D As= 0.1056 IN^2
As= 1.8600 IN^2 As < MIN
ϕ Mn= 279.88 KFT
Mn > 4/3Mu OK
4/3 Mu= 21.33 KFT

SERVICE LOAD Msl = 11.42857 KFT

Smax= 211.30 > 11.8750
OK

Cc = 2.0000 IN Clear Cover
n = 8.0 Es / Ec
c = 3.6881 IN NA
fs = 2.3 KSI

Mcr= 563.52 KFT
Ig= 256,608.00 IN^4
Icr= 14,569.42 IN^4
Ie= 256,608.00 IN^4

MAX AGG 2 in # 467

SHEAR Vu= 29 K
SERVICE SHEAR Vs= K
TENSION Tu= K
d= 32.6875 IN
STIRRUPS - BAR NO.
4SQRT(fc)bd= 545.78 K

SPACING MAX= 16.34375 IN
10 IN

ϕ Vc= 204.67 K
STIRRUPS NOT REQUIRED

#DIV/0!
Sd= 1.0000

Av= 0.00 IN^2
AvFyd/s= 0.00 K
Vs= 0.00 K

ϕ Vn= 204.67 K OK

ARCADIS

SUBJECT: ANCHOR BOLTS

JOB NO:

BY: RD DATE: 3-25-13

CHKD: DATE:

PAGE

SHEET 1

MAX ANCHOR BOLT FORCES

T_u = 8.4 k
LC 24

V_{u1} = 3.36 k
LC 23

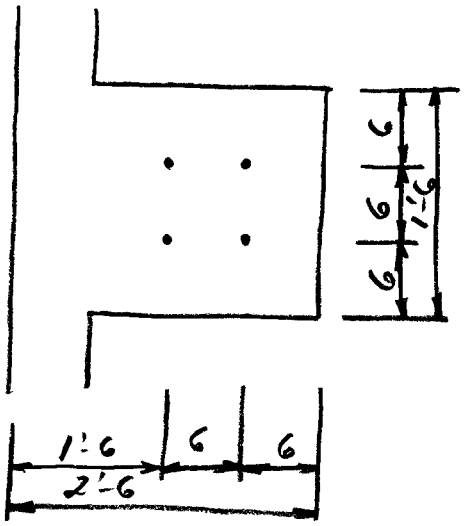
V_{u2} = 2.23 k
END WALL WIND

$$V_u = \sqrt{(3.36)^2 + (2.23)^2}$$

V_u = 4.1 k

USE (4) 3/4 Ø ASTM F1554 GR 36
THD RODS

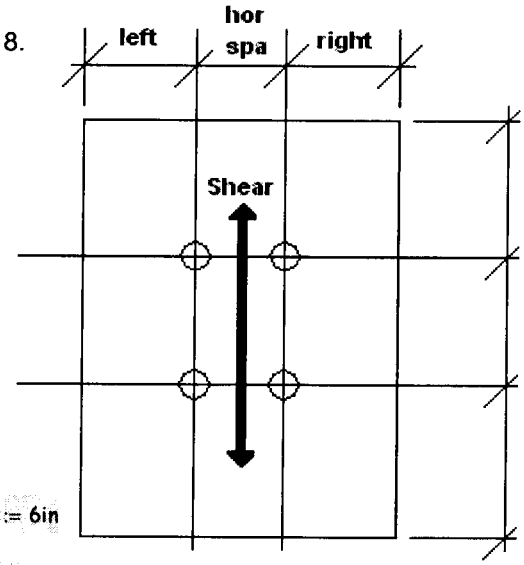
SPA = 6 IN EW
MIN EDGE = 9 IN
MIN EMBEDMENT = 9 IN



Group-Anchor Bolt Design

Reference:H:\MATHCAD WORKSHEETS\Units.xmcd

REFERENCE: Appendix D, ACI 318-05 & chapter 34 of PCA's Notes on ACI 318.



D.4 - GENERAL STRENGTH REQUIREMENTS FOR ANCHORS

$f'_c := 4000psi$

$n := 4$ - number of tensioned anchors in the group

$N_{ua} := 8.4kip$ - factored design load, Tension

$V_{ua} := 4.1kip$ - factored design load, Shear

$d_o := 0.75in$ - outside diameter of anchor or shaft diameter of headed stud, headed bolt ot hooked bolt.

Material := 1554 $f_y := 36ksi$ $f_{uta} := 58ksi$

typical_embedment = 9·in vert_anchor_spacing := 6in hor_anchor_spacing := 6in

top_edge := 6in bot_edge := 6in left_edge := 6in right_edge := 6in

$c_{amax} := \max(top\_edge, bot\_edge, right\_edge, left\_edge)$ $c_{amax} = 0.5\,ft$

$c_{amin} := \min(top\_edge, bot\_edge, right\_edge, left\_edge)$ $c_{amin} = 6\cdot in$

$h_{ef1} := typical\_embedment$ $h_{ef1} = 9\cdot in$ - effective embedment length

Is this an anchor group?

$answer_1 :=$ "Yes" if $\min(vert\_anchor\_spacing, hor\_anchor\_spacing) \le 3\cdot h_{ef1}$ $answer_1 = "Yes"$
"No, use single anchor factors." otherwise

a) Steel Strength of anchors in tension (D.5.1)

$\phi_{nsa} := 0.75$ - D.4.4, D.4.5 - Strength reduction factor based on anchor

$AB\_diam := d_o$ $n_t := 10$ - number of threads per inch of anchor - AISC 13th Ed.Manual pg 7-83 or AISC/ASD Manual pg 4-147. See table on the right.

$A_{se} := \frac{\pi}{4}\cdot\left(d_o - \frac{0.9743\cdot 1in}{n_t}\right)^2$ $A_{se} = 0.33\cdot in^2$ - effective cross sectional area of threaded anchor, ACI 318 pg. 399

$f_{ut} := \min(f_{uta}, 1.9f_y, 125ksi)$ $f_{uta} = 58\cdot ksi$ - specified tensile strength of anchor steel

$\phi N_{sa} := \phi_{nsa}\cdot n\cdot A_{se}\cdot f_{uta}$ $\phi N_{sa} = 58.2\cdot kips$ - Nsa, nominal strength of a single anchor or group of anchors in tension as governed by the steel strength

$A_{se\_required} := \frac{N_{ua}}{\phi_{nsa}\cdot n\cdot f_{uta}}$ $A_{se\_required} = 0.05\cdot in^2$

$check_1 :=$ "OK" if $A_{se} \ge A_{se\_required}$ $check_1 = "OK"$
"NG" otherwise

b) Concrete Breakout strength of Anchor in Tension (D.5.2)

$1.5h_{ef1} = 13.5\cdot in$ $vert\_anchor\_spacing = 6\cdot in$ $hor\_anchor\_spacing = 6\cdot in$

$top\_edge_1 := \min(top\_edge, 1.5h_{ef1})$ $right\_edge_1 := \min(right\_edge, 1.5h_{ef1})$ $bot\_edge_1 := \min(bot\_edge, 1.5h_{ef})$ $left\_edge_1 := \min(left\_edge,$

$A_{Nc} := (right\_edge_1 + hor\_anchor\_spacing + left\_edge_1)\cdot(top\_edge_1 + vert\_anchor\_spacing + bot\_edge_1)$ $A_{Nc} = 324\cdot in^2$

- A_{Nc} projected area of the failure surface approximated by a rectangle with edges bounded by 1.5hef and free edges of the concrete to the centerline of the anchors.

$\phi_{cbg} := 0.7$

- D.4.4 or D.4.5 - Strength reduction factor bas concrete breakout, Condition A or B.

$$h_{ef} := \begin{cases} \frac{c_{amax}}{1.5} & \text{if } c_{amax} \le 1.5h_{ef1} \\ h_{ef1} & \text{otherwise} \end{cases}$$ $h_{ef} = 4\cdot in$

- For the special case where there are 3 or 4 e with the largest edge distance ca max ≤1.5hef, embedment depth hef used in D-6 through D-11 limited to camax/1.5, D.5.2.3

$A_{Nco} := 9\cdot h_{ef}^2$ $A_{Nco} = 144\cdot in^2$

-Equation D-6, Ano, projected area of failure su of single anchor, away from the edges

$A_{Nc} := \min(A_{Nc}, n\cdot A_{Nco})$ $A_{Nc} = 324\cdot in^2$

-An, projected area of failure surface of anchor group of anchors, 1.5hef away from the edges

$k_c := 24$ $N_b := k_c\cdot\sqrt{f'_c\cdot\frac{1}{psi}}\cdot\left(h_{ef}\cdot\frac{1}{in}\right)^{1.5}\cdot lb$ $N_b = 12143.15lb$

- kc=24 Cast-In or kc=17 Post-Installed Anchors, D.5.2.2. See also RD.5.2.2. Equation D-7, Basic concrete breakout strength in tension of a sing anchor in cracked concrete

$e_{N'} := 0in$ $\psi_{ecN} := \begin{cases} \frac{1}{\left(1+\frac{2\cdot e_{N'}}{3\cdot h_{ef}}\right)} & \text{if } \frac{1}{\left(1+\frac{2\cdot e_{N'}}{3\cdot h_{ef}}\right)} \le 1 \\ 1.0 & \text{otherwise} \end{cases}$ $\psi_{ecN} = 1$

- Eccentricity in the connection, see D.5.2.4 for eccentricity requirements

$$\psi_{edN} := \begin{cases} 1.0 & \text{if } c_{amin} \ge 1.5\cdot h_{ef} \\ \left(0.7+\frac{0.3\cdot c_{amin}}{1.5h_{ef}}\right) & \text{otherwise} \end{cases}$$ $\psi_{edN} = 1$

-Equations D-10 & D-11, Modification Factor for e effects

$\psi_{cN} := 1.25$ $\psi_{cN} = 1.25$

- D.5.2.6 1.25 for Cast-in anchors, 1.4 for Post-Installed anchors with a value of kc = 17. Otherwise refer to ACI 355.2

$c_{ac} := 4.5in$ $c_{ac} = 4.5\cdot in$ $\psi_{cpN} := \begin{cases} 1.0 & \text{if } c_{amin} \ge c_{ac} \\ \frac{c_{amin}}{c_{ac}} & \text{if } \frac{c_{amin}}{c_{ac}} \ge \frac{1.5h_{ef}}{c_{ac}} \\ \frac{1.5h_{ef}}{c_{ac}} & \text{otherwise} \end{cases}$ $\psi_{cpN} = 1.33$

- D.8.6, critical edge distance as determined fr ACI 355.2. See D.8.6 for values of c_{ac}.

$\phi N_{cbg} := \phi_{cbg}\cdot\frac{A_{Nc}}{A_{Nco}}\cdot\psi_{ecN}\cdot\psi_{edN}\cdot\psi_{cN}\cdot\psi_{cpN}\cdot N_b$ $\phi N_{cbg} = 31.88\cdot kip$

- Equation D-6, Nominal concrete breakout str in tension of a group of anchors in tension

$$check_2 := \begin{cases} \text{"OK"} & \text{if } \phi N_{cbg} \ge N_{ua} \\ \text{"NG"} & \text{otherwise} \end{cases}$$ $check_2 = \text{"OK"}$

c) Pullout Strength of anchors in tension (D.5.3)

$\phi_{pn} := 0.7$ - D.4.4 or D.4.5 - Strength reduction factor based on concrete breakout, Condition A or B.

$AB\_diam = \frac{3}{4}\cdot in$ - Anchor diameter, see table 34-2 in Notes on ACI 318-05 for Bearing area or washers & nuts.

$\psi_{cP} := 1.0$ - D.5.3.6 For an anchor located in a region where analysis indicates no cracking at service load level. Where cracking will occur ψ_{cP} shall be taken as 1.0.

$$A_{brg\_reqd} := \frac{\frac{N_{ua}}{n}}{\phi_{pn}\cdot\psi_{cP}\cdot 8\cdot f'_c}$$

$A_{brg\_reqd} = 0.09\cdot in^2$ - Bearing area from equation D-15, in ACI 318-05

$A_{brg} := 0.911 in^2$ - Bearing area of a heavy hex nut per table 34-2 of the Notes on ACI 318-05 or of a flat round washer. See table on adjacent page

$$check3 := \begin{cases} \text{"OK"} & \text{if } A_{brg} \geq A_{brg\_reqd} \\ \text{"NG"} & \text{otherwise} \end{cases}$$

$check3 = \text{"OK"}$

$N_p := 8\cdot A_{brg}\cdot f'_c$

$\phi N_{pn} := \phi_{pn}\cdot\psi_{cP}\cdot N_p$ $\phi N_{pn} = 20.41\cdot kip$

d) Concrete side face blowout strength of a headed anchor in tension (D.5.4)

$\phi_{nsb} := 0.7$ $c_{a1} := \min(c_{amin}, c_{amax})$ $c_{a2} := \max(c_{amin}, c_{amax})$

$$N_{sb} := \begin{cases} 160\cdot c_{a1}\cdot\sqrt{A_{brg}}\cdot\sqrt{\frac{f'_c}{psi}}\cdot psi & \text{if } c_{a1} \leq 0.4 h_{ef} \\ \left(160\cdot c_{a1}\cdot\sqrt{A_{brg}}\cdot\sqrt{\frac{f'_c}{psi}}\cdot psi\right)\cdot\frac{\left(1+\frac{c_{a2}}{c_{a1}}\right)}{4} & \text{if } c_{a1} \leq 0.4 h_{ef} \wedge c_{a2} \leq 3\cdot c_{a1} \\ \text{"Not Applicable"} & \text{otherwise} \end{cases}$$

- Equation D-17, nominal side-face blowout strength of a anchor (usually applies to cast anchors), without modifica a perpendicular edge distance. Use for anchor groups. Th requirements are applicable to Cast-in anchors.

$N_{sb} = \text{"Not Applicable"}$

$s := \min(vert\_anchor\_spacing, hor\_anchor\_spacing, 6c_{a1})$

$\phi N_{sbg} := \phi_{nsb}\cdot\left(1+\frac{s}{6\cdot c_{a1}}\right)\cdot N_{sb}$ $\phi N_{sbg} = 816.67\cdot kip$

- Equation D-18, nominal strength of the group of anchors side-face blowout (usually applies to cast anchors), withc modification for a perpendicular edge distance. Use for groups.

$$check2 := \begin{cases} \text{"OK"} & \text{if } \phi N_{sbg} \geq N_{ua} \\ \text{"NG"} & \text{otherwise} \end{cases}$$

$check2 = \text{"OK"}$

Summary of design requirements for tensile loading:

Steel strength of anchor in tension D.5.1 : $\phi N_{sa} = 58.2\cdot kip$

Concrete breakout strength of anchor in tension D.5.2 : $\phi N_{cbg} = 31.88\cdot kip$

Pullout strength of anchor in tension D.5.3 : $\phi N_{pn} = 20.41\cdot kip$

Concrete side-face blowout strength of a headed anchor in tension : $\phi N_{sbg} = 816.67\cdot kip$

e) Steel strength of anchor in shear (D.6.1)

$\phi_s := 0.7$ grout_pad := 0.8

$V_{sa} := n \cdot 0.6 \cdot A_{se} \cdot f_{uta} \cdot grout\_pad$ $V_{sa} = 37.25 \cdot kip$ $\phi V_s := \phi_s \cdot V_{sa}$ $\phi V_s = 26.07 \cdot kip$

$check4 := \begin{cases} \text{"OK"} & \text{if } \phi V_s \geq V_{ua} \\ \text{"NG"} & \text{otherwise} \end{cases}$ $check4 = \text{"OK"}$

- Equation D-20, D.6.1.2 b for cast-in headed bolts and for post-instc anchors where sleeves do not extend through shear plane. Also see D.6.1.3 for anchors used with built up grout pads.

f) Concrete Breakout Strength of anchor in shear (D.6.2)

$\phi_{vcbg} := 0.7$

The two anchors located closest to the edge toward which the shear is directed will control the concrete bre strength. These anchors are assumed to carry one half of the shear. The total breakout strength will be twi value calculated for these two anchors (the anchors away from the edge are assumed to develop the same valu

$ca1 := \min(top\_edge, bot\_edge)$ $c_{a1} = 6 \cdot in$ $1.5 \cdot c_{a1} = 9 \cdot in$

- Applicable only to shear as shown on the diagram at the beginning of this worksheet. If shear is applied in the other direction, change the input parameters of cc to right_edge & left_edge. Similar for right & left edges.

$right\_edge_1 := \min(right\_edge, 1.5c_{a1})$ $right\_edge_1 = 6 \cdot in$

$left\_edge_1 := \min(left\_edge, 1.5c_{a1})$ $left\_edge_1 = 6 \cdot in$

$Avc := (right\_edge_1 + hor\_anchor\_spacing + left\_edge_1) \cdot (1.5 \cdot c_{a1})$ $A_{vc} = 162 \cdot in^2$

- Avc, projected concrete failure area of an anchor or anchors

$A_{vco} := 4.5 \cdot c_{a1}^2$ $A_{vco} = 162 \cdot in^2$

- Avco, pojected concrete failure area of one anchor, u limited by corner influences, spacing or member thickn

$A_{vc} := \min(Avc, n \cdot A_{vco})$ $A_{vc} = 162 \cdot in^2$

$eV' := 0in$ $\psi_{ecV} := \begin{cases} \dfrac{1}{\left(1 + \dfrac{2 \cdot eV'}{3 \cdot c_{a1}}\right)} & \text{if } \dfrac{1}{\left(1 + \dfrac{2 \cdot eV'}{3 \cdot c_{a1}}\right)} \leq 1 \\ 1.0 & \text{otherwise} \end{cases}$ $\psi_{ecV} = 1$

- NO eccentricity in the connection, see D.6.2.5 for eccentricity requirements

$ca2 := \min(right\_edge, left\_edge)$ $c_{a2} = 6 \cdot in$

- Applicable only to shear as shown on the diagram at the beginning of this worksheet. If shear is applied in the other direction, change the input parameters to top_edge & bot_edge in the calculation of ca1 above and right & left edge also above.

$\psi_{edV} := \begin{cases} 1.0 & \text{if } c_{a2} \geq 1.5 \cdot c_{a1} \\ \left(0.7 + 0.3 \cdot \dfrac{c_{a2}}{1.5 \cdot c_{a1}}\right) & \text{otherwise} \end{cases}$ $\psi_{edV} = 0.9$ - D.6.2.6

$\psi_{cV} := 1$ $\psi_{cV} = 1$

- D.6.2.7, For anchors located in a region of the membe where analysis indicates no cracking at service loads. Conservative, for locations where cracking is likely to occur.

$l_e := \min(typical\_embedment, 8 \cdot d_o)$ $l_e = 6 \cdot in$

$V_b := 7 \cdot \left(\dfrac{l_e}{d_o}\right)^{0.2} \cdot \sqrt{d_o \cdot \dfrac{1}{in}} \cdot \sqrt{f'_c \cdot \dfrac{1}{psi}} \cdot \left(c_{a1} \cdot \dfrac{1}{in}\right)^{1.5} \cdot lb$ $V_b = 8.54 \cdot kip$

- D.6.2.2 load bearing length of the anchor for shear. A basic breakout strength in shear of a single anchor in c concrete Vb.

Total breakout strength of the four anchor group (2 anchors) :

$\phi V_{cbg} := 2 \cdot \phi_{cbg} \cdot \dfrac{A_{vc}}{A_{vco}} \cdot \psi_{ecV} \cdot \psi_{edV} \cdot \psi_{cV} \cdot V_b$ $\phi V_{cbg} = 10.76 \cdot kip$ $check5 := \begin{cases} \text{"OK"} & \text{if } \phi V_{cbg} \geq V_{ua} \end{cases}$ $check5 = \text{"OK"}$

g) Concrete Pryout Strength of anchor in shear (D.6.3)

$\phi_{cpg} := 0.7$

$$k_{cp} := \begin{cases} 1.0 & \text{if } h_{ef} < 2.5in \\ 2.0 & \text{if } h_{ef} \geq 2.5in \end{cases}$$

$k_{cp} = 2$ - D.6.3.1, kcp coefficient for pryout strength

$$\phi V_{cpg} := \phi_{cpg} \cdot k_{cp} \cdot \frac{\phi N_{cbg}}{\phi_{cbg}}$$

$\phi V_{cpg} = 63.75 \cdot kip$ - Equation D-30, D.6.3.1 Nominal pryout strength

$$check_6 := \begin{cases} \text{"OK"} & \text{if } \phi V_{cpg} \geq V_{ua} \\ \text{"NG"} & \text{otherwise} \end{cases}$$

$check_6 = \text{"OK"}$

Summary of design requirements for SHEAR:

SSteel strength of anchor in shear D.6.1 : $\phi V_s = 26.07 \cdot kip$

Concrete breakout strength of anchor in tension D.6.2 : $\phi V_{cbg} = 10.76 \cdot kip$

Concrete pryout strength of anchor in shear D.6.3 : $\phi V_{cpg} = 63.75 \cdot kip$

Therefore, $\phi V_n := \min(\phi V_s, \phi V_{cbg}, \phi V_{cpg})$ $\phi V_n = 10.76 \cdot kip$

h) Interaction of tensile and shear forces (D.7)

Is the full TENSION strength permitted?

$$answer3 := \begin{cases} \text{"yes"} & \text{if } V_{ua} \le 0.2 \cdot \phi V_n \\ \text{"no"} & \text{otherwise} \end{cases}$$

answer3 = "no"

Is the full SHEAR strength permitted?

$$answer4 := \begin{cases} \text{"yes"} & \text{if } N_{ua} \le 0.2 \cdot \phi N_n \\ \text{"no"} & \text{otherwise} \end{cases}$$

answer4 = "no"

If both answers above are "NO", the interaction equation must be used.

$$interaction\_equation := \frac{N_{ua}}{\phi N_n} + \frac{V_{ua}}{\phi V_n}$$

interaction_equation = 0.79

$$check7 := \begin{cases} \text{"OK"} & \text{if } interaction\_equation \le 1.2 \\ \text{"NG"} & \text{otherwise} \end{cases}$$

check7 = "OK"

i) Required edge distances, spacings, and center to center spacing (D.8)

Minimum center to center spacing of the anchors:

$min\_spacing := 4 \cdot d_o$

min_spacing = 3 in

- Section D.8.1 & D.8.4, minimum spacing of ancho shall be 4 do for untorqued cast-in anchors, 6 do f torqued cast-in anchors and post installed anchors Otherwise refer to ACI 355.2 for product-specif tests.

Minimum edge distance for the anchors:

min_edge_distance_ACI := 3in

(per ACI 318, 7.7)

min_edge_distance_ACI = 3 in

- Section D.8.2 ~ D.8.4,

DOWELS TO TIE THE PEDESTAL TO FOOTING

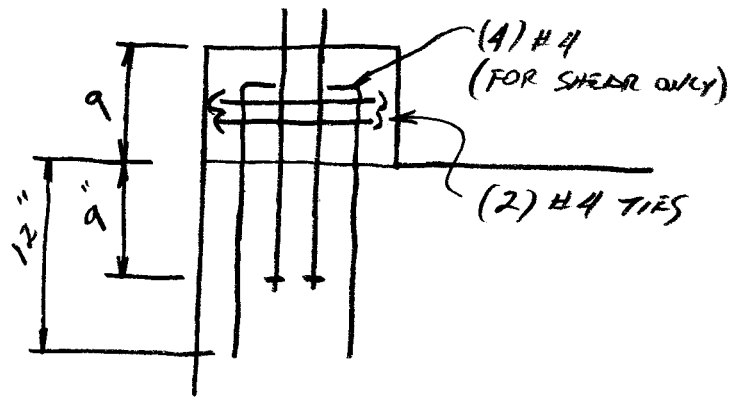
#4 BAR HOOK L_{DH} = 7 in H_{min} = 9 in PEDESTAL HEIGHT

FOR TENSION $A_{s\ req'd} = \frac{8.4^k}{0.9(60^k/in^2)} = 0.156\ in^2$

FOR SHEAR $A_{s\ req'd} = \frac{4.1^k}{0.75(60)\,0.6} = 0.152$

A_s = 0.31 in²

USE (4) #4 A_s = 0.4 in²



ARCADIS

SUBJECT:

JOB NO:

BY: [illegible] DATE: 3-25-13

CHKD: DATE:

PAGE

SHEET 1

TENSION TIE BETWEEN OPPOSITE COLUMNS

$T_u = 2.08_K$

$A_s = \frac{2.08}{\phi 9(60)} = 0.04\ in^2$

USE (2) #4's HOOKED A36MD ANCHOR BOLTS

ARCADIS

SUBJECT: LATERAL SOIL RESISTANCE

JOB NO:

BY: DATE: 3-25-13

CHKD: DATE:

PAGE

SHEET 1

INTERIOR FRAME

TRANSVERSE DIRECTION

LC			
32	−0.86	−1.85	= 2.71
34	−1.26	−1.45	= 2.71
36	−2.08	−1.54	= 3.62

LC 36 $V = 2.08$ UPLIFT = 4.4k 0.6D + W

WT OF FOOTING

$W = 0.15(5.5)(5.5)3$

$W = 13.6k$

NET DL = $0.6(13.6) - 4.4$

$= 3.76k$

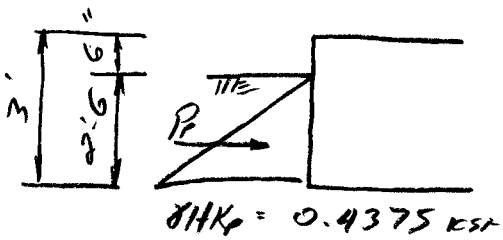
$\mu = 0.45$

FRICTIONAL RESISTANCE $F_F = 3.76(0.45) = 1.7k$

PASSIVE PRESSURE RESISTANCE $\gamma K_p = 175 k/ft^2$

$P_P = 0.4375 \frac{k}{ft^2} \left(\frac{2.5ft}{2}\right) 5.5ft$

$P_P = 3k$



B = 5.5 ft

$P_P + F_F = 3k + 1.7k = 4.7k$

$\frac{4.7}{2.08} = 2.26$

ARCADIS

SUBJECT: MASONRY WALL

JOB NO:

BY: [illegible] DATE: 3-25-13

CHKD: DATE:

PAGE

SHEET 1

CONNECTION TO FLEXIBLE DIAPHRAGM

12.11.2.1 $F_p = 0.8\, S_{DS}\, I\, W_p$

$= 0.8(0.42)\,1/(61\text{ plf})$

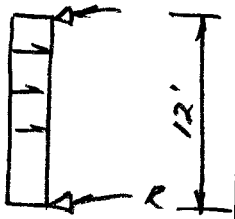
$F_p = 20.5$ PSF

$0.7\rho Q_E = 0.7(1.3)(20.5) = 18.7$ psf

ΔT TOP & BOTTOM $R = 18.7\ \frac{\text{ft}}{2}\ (12\text{ ft})$

$R = 112$ PLF

MIN FORCE = 280 PLF (12.11.2 c)



ARCADIS

SUBJECT:

JOB NO:

BY: DATE:

CHKD: DATE:

PAGE

SHEET 1

WIND PRESSURE ON INTERNAL WALL

$P = q_H GC_{pi}$ (6-22) $GC_{pi} = 0.55$ PART. ENCLOSED

$q_H = 0.00256 K_z K_{zt} K_D V^2 I$

$K_z = 0.85$
$K_{zt} = 1$
$K_D = 0.85$
$V = 90$
$I = 1$

$q_H = 15 PSF$

$P = 15 PSF (0.55)$
$P = 8.24 PSF$

0.7E CONTROLS ALLOWABLE STRESS

ARCADIS

SUBJECT: MASONRY PARTITION WALL

JOB NO:

BY: DATE: 3-25-13

CHKD: DATE:

PAGE

SHEET 1

ASCE 7 13.3 NON STRUCTURAL COMPONENTS

$$F_p = \frac{0.4 a_p S_{DS} W_p}{R_p/I_p}\left(1+2\frac{z}{h}\right) \qquad S_{DS} = 0.42$$

$I_p = 1$ (13.1.3)

8" REINFORCED CMU $W_p = 61 psf$ $h = 15m$ $z = 15$

TBC 13.5-1 $a_p = 1$ $R_p = 2.5$ REINFORCED MASONRY

$$F_p = \frac{0.4(1)(0.42)}{2.5/1}(1+2(1))W_p$$

$F_p = 0.202 W_p$

$F_p \leq 1.6 S_{DS} I_p W_p$

$F_p \leq 1.6(0.42) W_p$

$F_p \leq 0.672 W_p$

$F_p \geq 0.3 S_{DS} I_p W_p$

$F_p \geq 0.3(0.42)1 W_p$

$F_p \geq 0.126 W_p$

USE $F_p = 0.202 W_p$

$F_p = 0.202(61 psf)$

$F_p = 12.3 \#/ft^2$

$0.7 \rho Q_E = 0.7(1.3)12.3 = 11.2 psf$ ALLOWABLE STRESS

VERTICAL LOAD 1.06D

$(1.0 + 0.14 S_{DS})D + 0.7\rho Q_E$

REINFORCING - 8" CMU #4@48

Reference:H:\MATHCAD WORKSHEETS\Units.xmcd
Reference:H:\MATHCAD WORKSHEETS\Masonry weights.xmcd(R)

$b := 48in$ Vertical Bar Spacing

$t := 7.625in$ Block SIze

$q_d := q_{w848}$ Weight of Masonry Wall

$q_d = 61 \cdot psf$

$H := 12ft$ Wall Height

WALL SEISMIC LOAD

$q_w := 0.91 \cdot 12.3psf$ 0.91Qe

LOAD CASE 1.06D+0.91Qe

$w := q_w \cdot b$ $w = 44.772 \cdot \frac{lb}{ft}$

$e_1 := 0$ Actual eccentricity of axial load only

$M_w := \frac{w \cdot H^2}{8}$ $M_w = 805.896 \cdot lb \cdot ft$

$P := 1.06\left(q_d \cdot \frac{H}{2} \cdot b\right)$ 1.06D Axial @ H/2

$P = 1.552 \times 10^3 lb$

WALL MOMENT

$M_1 := 1.0M_w$ $M_1 = 805.896 \cdot lb \cdot ft$

$f_m := 1500\frac{lb}{in^2}$ $E_m := 900 \cdot f_m$ $E_m = 1.35 \times 10^3 \cdot ksi$

$n := \frac{29000000\frac{lb}{in^2}}{E_m}$ $n = 21.48$

$d := \frac{t}{2}$ $d = 3.8125 \cdot in$

$As := 0.44in^2$ 1 # 4

$\rho := \frac{As}{b \cdot d}$ $\rho = 0.0024$

$k_1 := \sqrt{(n \cdot \rho)^2 + 2 \cdot n \cdot \rho} - n \cdot \rho$ $k_1 = 0.2739$ $k_1 \cdot d = 1.0442 \cdot in$ $t_f = 1.25 \cdot in$

$$k := \begin{cases} k_1 & \text{if } k_1 \cdot d \le t_f \\ \dfrac{n \cdot \rho + \dfrac{t_f^2}{2 \cdot d^2}}{n \cdot \rho + \dfrac{t_f}{d}} & \text{otherwise} \end{cases}$$

Neutral Axis Location:

NA = "Flange"

$k = 0.2739$

$k \cdot d = 1.0442 \cdot in$

$j := 1 - \frac{k}{3}$ $j = 0.9087$

STRESS IN MASONRY

$$f_b := \begin{cases} 2 \cdot \dfrac{M_1}{j \cdot k \cdot b \cdot d^2} & \text{if } k \cdot d \le t_f \\ \dfrac{2 \cdot M_1 \cdot k \cdot d}{\left(2 \cdot k \cdot d - t_f\right) \cdot b \cdot t_f \cdot \left(d - \dfrac{t_f}{2}\right)} & \text{otherwise} \end{cases}$$

$f_b = 111.391 \cdot psi$

STRESS IN STEEL

$f_s := \frac{M_1}{As \cdot j \cdot d}$ $f_s = 6344.1 \cdot psi$

ALLOWABLE STRESSES

$F_b := 0.33 \cdot f_m$ $F_b = 495 \cdot psi$

$F_s := 24000psi$

AXIAL

Properties For 8 in CMU Grouted at 48 in O.C.

$A_1 := A_{848}$ $I_1 := I_{848}$

$A_1 = 57 \cdot \frac{in^2}{ft}$ $I_1 = 377.08 \cdot \frac{in^4}{ft}$

$A := A_1 \cdot b$ $A = 228 \cdot in^2$ $I := I_1 b$ $I = 1508.3 \cdot in^4$

$r := \sqrt{\frac{I}{A}}$ $r = 2.572 \cdot in$ $\frac{H}{r} = 55.986$

$e_1 = 0 \cdot in$ Actual eccentricity of axial load only

$$F_a := \begin{cases} 0.25 \cdot f_m \cdot \left[1 - \left(\frac{H}{140 \cdot r}\right)^2\right] & \text{if } \frac{H}{r} \le 99 \\ 0.25 \cdot f_m \cdot \left(70 \cdot \frac{r}{H}\right)^2 & \text{if } \frac{H}{r} > 99 \end{cases}$$

$f_a := \frac{P}{A}$ $f_a = 6.8 \cdot psi$

$F_a = 315 \cdot psi$

$P_e := \pi^2 \cdot E_m \cdot \frac{I}{H^2} \cdot \left(1 - 0.577 \frac{e_1}{r}\right)^3$

$P_e = 9.692 \times 10^5 \cdot lb$

$\frac{f_a}{F_a} + \frac{f_b}{F_b} \le 1$ $\frac{P}{P_e} \le 0.25$

$\frac{f_a}{F_a} + \frac{f_b}{F_b} = 0.2466$ $\frac{P}{P_e} = 0.0016$

IN PLANE FORCES $(1.0+0.14S_{DS})D + 0.7\rho Q_E$

$F_p = 11.2\ \#/ft^2\ (12ft)(25ft)$ $0.7\rho Q_E$

$F_p = 3.4k$

$W = 61\ psf\ (12ft)$

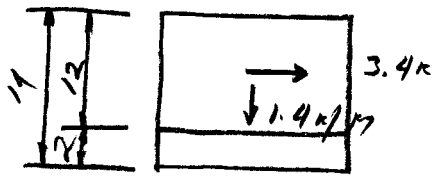
$W = 0.73\ k/ft$ CMU WALL

WEIGHT OF FOOTING

$0.15\ (2ft)\ 2ft = 0.6\ k/ft$

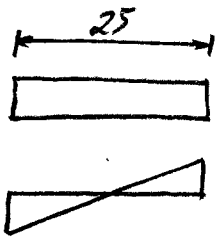
$W = 1.06\ (0.73 + 0.6)\ k/ft$ $1.06D$

$W = 1.4\ k/ft$



$M = 3.4k\ (8ft)$

$M = 27.2\ k\text{-}ft$



$S = \frac{(25)^2 2}{6}$

$S = 208.3\ ft^3$

SOIL BEARING

$f_p = \frac{1.4\ k/ft}{2ft} \pm \frac{27.2\ k\text{-}ft}{208.3\ ft^3}$

$f_p = 0.7\ ksf + 0.131\ ksf = 0.83\ ksf$

$f_p = 0.7 - 0.131 = 0.57\ ksf$

Attachment C
Geotechnical Summary (*on CD-ROM only*)

- Geotechnical Data Summary and Proposed Supplemental Geotechnical Investigation
- Selected Boring Logs from RFI/RI Report Volume 2 (CH2M HILL 2009)
- *Geotechnical Investigation Report, Topock Compressor Station, Water Treatment Plant* (CH2M HILL 2004)
- *Geotechnical Investigation, Topock AOC 4 Remediation – Pre-Work Plan Data Collection Activities, PG&E Compressor Station, Needles, California* (CH2M HILL 2009)

Geotechnical Data Summary and Proposed Supplemental Geotechnical Investigation

ATTACHMENT C: GEOTECHNICAL ANALYSIS

Geotechnical Data Summary and Proposed Supplemental Geotechnical Investigation

The purpose of this geotechnical summary is to provide information on existing site geology and geotechnical data in support of the groundwater remedy design and to propose areas where supplemental geotechnical investigation is needed to verify design parameters. Coordination with the Soil RCRA Facility Investigation/Remedial Investigation (RFI/RI) investigation program was conducted in planning the supplemental geotechnical investigation to minimize the number of required boreholes, thereby minimizing ground disturbance.

C.1 Summary of Existing Site Geologic and Geotechnical Data

In 2004 and 2009, CH2M HILL conducted geotechnical investigations in and around the compressor station and Area of Concern (AOC) 4, respectively. Results were presented in the following reports and are summarized below:

- *Geotechnical Investigation Report, Topock Compressor Station, Water Treatment Plant*. Prepared by CH2M HILL in September 2004. (Full report presented in PDF format as part of this Attachment to Appendix C of the 60% Basis of Design Report on the Appendix C CD-ROM).
- *Geotechnical Investigation, Topock AOC 4 Remediation – Pre-Work Plan Data Collection Activities, PG&E Compressor Station, Needles, California*. Prepared by CH2M HILL in October 2009. (Full report presented in PDF format as part of this Attachment to Appendix C on the Appendix C CD-ROM).

In addition, geologic information for the MW-20 Bench and hydrogeologic cross sections throughout the site are also summarized in the sections below. Original results were reported in the following reports:

- *Work Plan for Installation of Extraction Well TW-3D, Interim Measure No. 3 Groundwater Extraction System, PG&E Topock Compressor Station, Needles, California.* Prepared by CH2M HILL in October 2005.
- *RCRA Facility Investigation/Remedial Investigation Report, PG&E Topock Compressor Station, Needles, California, Volume 2 – Hydrogeologic Characterization and Results of Groundwater and Surface Water Investigation.* Prepared by CH2M HILL in February 2009. A selection of relevant borings logs from this report is included following this geotechnical data summary on the Appendix C CD-ROM.

C.1.1 Compressor Station

The 2004 geotechnical investigation found that in the vicinity of monitoring wells MW-13 and MW-14 the area consists of alternating layers of gravelly sand and sandy gravel down to an approximate elevation of 435 feet above mean sea level (msl). In the vicinity of MW-37D gravelly sand with clay and sandy clay layers starts at an elevation of approximately 465 feet msl underlying the sandy gravel. The difference in material in this boring can be attributed to the fact that it was located in a wash that transports the finer material from higher elevations.

Soil borings B-01, B02, B-02A, and B-03 were also advanced during this investigation. Exhibit C.1-1 presents a summary of the generalized subsurface profile and design strength parameters. Complete details of the soil borings can be found in the 2004 *Geotechnical Investigation Report*, which is included in PDF format as part of this Attachment to Appendix C on the Appendix C CD-ROM. Generally, medium dense to very dense, silty sands and poorly graded silty sands underlie the proposed treatment plant site. Blow counts in the dry, silty sands were generally in the range of 20 to greater than 50. Therefore, liquefaction potential of the site soils is estimated to be low, especially where the groundwater is greater than 50 feet below ground surface (bgs).

In addition, the following conclusions were made as a result of the 2004 geotechnical investigation:

- Expansion/Collapse – Based on the medium dense to very dense granular material encountered at the project site, expansion and collapse potential is regarded as low.

- Settlement – Based on the medium dense to very dense granular material encountered at the project site (above and below the proposed/ existing footing elevation), and the relatively deep groundwater table (>45 feet), consolidation settlement is not considered an issue. Secondary compression settlement has been determined to be negligible.

EXHIBIT C.1-1
Generalized Subsurface Soil Profile and Design Strength Parameters
Groundwater Remedy Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Geologic Unit	Approximate Elevation of Layer (± feet)	Soil Type [1]	Average Corrected SPT N-Values [2] (blows per foot)	Total Unit Weight (lbs/ft^3)	Friction Angle (degree)
Boring B-01					
Alluvium	508-498	SMg	20	120	32
Alluvium	498-493	SMg	>50	120	35
Alluvium	493-474	SW-SM	>50	120	35
Alluvium	<474	SMg	>50	120	35
Boring B-02					
Alluvium	505-495	SMg	46	120	32
Alluvium	<495	SMg	>50	120	35
Boring B-02A					
Alluvium	505-495	SMg	63	120	32
Alluvium	<495	SMg	>50	120	35
Boring B-03					
Alluvium	508-498	SMg	44	120	32
Alluvium	498-488	SMg	>50	120	35
Alluvium	<488	SP-SM	>50	120	35

Notes:
[1] Unified Soil Classification System per ASTM standard D2487 and D2488.
[2] SPT = standard penetration test described in ASTM Standard D1586.
Source: *Geotechnical Investigation Report, Topock Compressor Station, Water Treatment Plant* (CH2M HILL 2004)

- Corrosion Conditions – Comparison between the laboratory test results and the Caltrans corrosion criteria indicates that the onsite soils are considered to be corrosive to concrete structures. The Caltrans corrosion criteria should not be applied to piping and other metal structures. Concrete in contact with onsite soil shall be batched using Type V cement in accordance with the 2001 California Building Code (CBC). Adequate concrete cover over reinforcing steel should be provided in accordance with good construction practices and design standards. Exhibit C.1-2 summarizes the results of the laboratory corrosion tests.
- Solubility – The solubility results are low at this site, so it is not expected to be an issue. Exhibit C.1-3 summarizes the results of the solubility tests.
- Seismicity – The Chemehuevi Graben Fault, approximately 18.8 kilometers from the project site, is the controlling fault at the project site. The Chemehuevi Graben Fault is a normal style fault with a maximum credible earthquake (MCE) moment magnitude (Mw) of 6.0. The fault is classified as Seismic Source Type C, the project site lies in Seismic Zone 3, and the soil profile is classified as type SD as defined in the 2001 CBC.

EXHIBIT C.1-2
Summary of Laboratory Corrosion Test
Groundwater Remedy Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Boring	Sample Depth (feet)	Soil Type[1]	Minimum Resistivity (ohm-cm)	pH	Sulfate Content (ppm)	Chloride Content (ppm)
B-01	6.5-8.0	SM	370	8.63	2,888	1,025
B-02	6.5-8.0	SM	725	8.67	3,988	350

Notes:
[1] Unified Soil Classification System per ASTM standard D2487 and D2488.
Source: *Geotechnical Investigation Report, Topock Compressor Station, Water Treatment Plant* (CH2M HILL 2004)

EXHIBIT C.1-3
Summary of Solubility Tests
Groundwater Remedy Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Boring	Sample Depth (feet)	Soil Type	Solubility (%)
B-01	6.5-8.0	SM	0.79
B-03	5.0-6.5	SM	0.33

Note:
[1] Unified Soil Classification System per ASTM standard D2487 and D2488.
Source: *Geotechnical Investigation Report, Topock Compressor Station, Water Treatment Plant* (CH2M HILL 2004)

Using the attenuation curves of Sadigh et al. (see Blake 1998), probabilistic analyses indicate that a horizontal peak ground acceleration (HPGA) of 0.07g may be used for a 10 percent probability of exceedance in 50 years. Deterministic analyses indicate a peak ground acceleration (PGA) of 0.20g at the project site.

Recommendations that were discussed in 2004 geotechnical investigation include:

- Shallow foundations are recommended for support of the water treatment plant. The depth of foundation support should be down to a minimum of 2 feet bgs.
- The slab and footings should be set on a minimum 6-inch-thick layer of granular base leveling course. The granular material should consist of well-graded sand and gravel with a maximum particle size of 3 inches and no more than 6 percent passing the No. 200 sieve. The granular material should be placed in 6-inch lifts and compacted to 95 percent of maximum dry density per American Society for Testing and Materials (ASTM) D1557.
- The native soil under the granular base course should be well compacted down to a depth of 12 inches to a minimum of 95 percent of maximum dry density per ASTM D1557 to provide a firm, unyielding surface. If the native soil under the granular course cannot be compacted to a minimum of 95 percent of maximum dry density per ASTM D1557, it should be removed to a maximum depth of 1 foot and replaced with competent granular backfill compacted in 6-inch lifts.
- The foundation design should be based on an evaluation of the allowable bearing capacity, settlement, and sliding coefficient of friction.
- Bearing capacity – Based on the calculations, it was determined that the subgrade at or near the bottom of the proposed footings will have an allowable bearing capacity of 2,000 pounds per square foot.

- Siding coefficient of friction – An ultimate sliding coefficient of friction equal to 0.45 may be used for foundation design.
- Cut and fill slopes – Cut slopes in the native soil are recommended to be 2H:1V or flatter. In fill areas, the native soil should be placed in 6-inch lifts and compacted to 95 percent of maximum dry density per ASTM D1557.

C.1.2 AOC 4

During the 2009 geotechnical investigation, four geotechnical borings were drilled in the areas on top of the ravine slopes in the AOC 4 area. The scope of the geotechnical investigation did not include evaluation of fill along the slope face and at the bottom of the slope. The four borings were drilled until the augers refused on possible rock or other obstructions. Exhibit C.1-4 presents a summary of field exploration details. Complete results of the 2009 investigation can be found in the 2009 *Geotechnical Investigation, Topock AOC 4 Remediation – Pre-Work Plan Data Collection Activities* report, which is included as part of this Attachment to Appendix C on the Appendix C CD-ROM.

EXHIBIT C.1-4
Summary of Field Exploration Details
Groundwater Remedy Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Exploration Number	Approximate Location (NAD 83 Lat./Long,)	Approximate Ground Surface Elevation (feet)	Type of Boring	Depth to Auger Refusal (feet)	Groundwater Depth (feet)
AOC4-GEO1	34°42’47” N; 114° 29’37” W	611.0	Hollow-stem auger	38.5	NE
AOC4-GEO2	34°42’47” N; 114°29’38” W	611.0	Hollow-stem auger	56	NE
AOC4-GEO3	34°42’46” N; 114°29’37” W	612.0	Hollow-stem auger	26	NE
AOC4-GEO4	34°42’46” N; 114°29’36” W	612.0	Hollow-stem auger	8.5	NE

Notes:
NE = Not Encountered
Source: *Geotechnical Investigation, Topock AOC 4 Remediation – Pre-Work Plan Data Collection Activities, PG&E Compressor Station, Needles, California* (CH2M HILL 2009)

Based on the soil borings, the subsurface materials in the vicinity of AOC 4 generally consist of gray to grayish brown, dry, medium dense to very dense, silty sand and silty gravel. The gravel sizes ranged from 0.5 to 3 inches. The uncorrected standard penetration test (SPT) N-value in this zone ranges from 17 for 12 inches of penetration to 50 for 6 inches of penetration.

Below the fill layer and alluvial sediments, weathered rock materials were encountered in some of the borings to the explored maximum depths overlying relatively unweathered metadiorite bedrock. The weathered rock generally consists of dense to very dense gravel and sand with silt. Gravel sizes varied from less than an inch up to 5 inches. In some areas broken cobbles or fragments of bedrock were present in the recovered samples. The uncorrected SPT N-values within the native soil zone were above 50. Detailed boring logs are presented in the 2009 *Geotechnical Investigation, Topock AOC 4 Remediation – Pre-Work Plan Data Collection Activities* report that is included as part of this Attachment.

Results and conclusions of the 2009 geotechnical investigation include:

- The depth of debris fill materials encountered in the borings extends approximately 5 feet bgs on the nearly level area of AOC 4 and contains silty sand and gravel mixed with debris including some trash, roots and peaty materials. This depth corresponds to elevations of 606 feet and 607 feet above mean sea level on the west and east sides of the AOC 4 area, respectively, above the ravines.
- The debris fill is underlain by possible weakly cemented alluvium and weathered metadiorite bedrock. These materials consist of dense to very dense silty sand (SM) to silty gravels (GM). The gravel sizes ranges from 0.5 to 3 inches.
- Boring refusal, indicating bedrock or obstructions, was encountered at depths varying from 56 to 5 feet bgs. Boring AOC4-GEO2, located on the west edge of the existing slope, encountered refusal at EL 556 feet or about 56 feet bgs. Boring AOC4-GEO4, located on the east side of the existing slope, encountered refusal at EL 607 feet or at about 5 feet bgs. With respect to the exposed bedrock observed near the investigation site, boring refusal is interpreted as the surface of relatively unweathered bedrock.
- Based on the results of the slope stability analyses, a 35-foot-tall slope with a 1H: 1V slope ratio is expected to be globally stable during construction and remediation activities. A factor of safety (FOS) for slope failure of 1.2 was computed for this condition. An FOS of 1.1 or greater is normally considered adequate for temporary slopes during construction activities.
- It is recommended that temporary slopes be maintained no steeper than 1H: 1V and not higher than 35 feet. Shorter, steeper slopes may be achievable and should be evaluated if proposed.
- The surficial stability of a localized side slope should be considered during the grading and other construction activities. Localized instabilities, if left unchecked, could lead to larger stability issues.

C.1.3 MW-20 Bench Geology

In the vicinity of the MW-20 Bench, the current active interim measure (IM) extraction well TW-2D is screened from 115 feet to 150 feet bgs, in the lower portion of the Alluvial Aquifer above Miocene conglomerate bedrock. During initial pumping tests, TW-2D was pumped at sustained rates of 90 to 100 gallons per minute (gpm). The specific capacity of TW-2D has increased by a factor of two since installation and is currently 8 gpm per foot of drawdown.

Well TW-2D is screened in sandy gravel alluvial deposits that appear to be more conductive than the formations encountered at similar elevations in monitoring wells MW-20 to the south or MW-31 to the north. Although the saturated alluvium above bedrock is thicker to the north of TW-2D, the alluvial deposits at the two monitoring well locations generally had higher clay content and may be less productive than the formation at the TW-2D/TW-2S well pair.

Well TW-2S is screened as a water table extraction well, with the bottom of the screen at 95 feet bgs and the top of the screen at 45 feet bgs. The static water level in both TW-2S and TW-2D is roughly 45 feet bgs under non-pumping conditions. The screened intervals of TW-2S and TW-2D are separated, with TW-2S screened above 95 feet and TW-2D screened below 115 feet. The reason for drilling separate shallow TW-2S and deep TW-2D wells was that an aquitard appeared to be present at the intervening depth in the MW-20 wells, and Consultative Technical Workgroup members expressed concern that a single extraction well should not be screened across the aquitard. However, this aquitard does not appear to be present in the northern portion of the MW-20 bench at the MW-31 location.

A fine-grained unit that forms a local aquitard was encountered at a depth between 100 and 110 feet bgs in TW-2D. Flowing sands were encountered within the fine-grained horizon during drilling at well MW-20. The TW-2 wells were drilled using mud rotary methods, which did not allow for identification of flowing sands.

C.1.4 Hydrogeologic Cross Sections

In the 2009 RFI/RI hydrogeologic characterization report a series of cross sections were prepared to illustrate the site hydrogeology, hydrostratigraphy, bedrock structure, and aquifer distribution and geometry. The hydrogeologic features shown on several of the cross sections which are pertinent to the 60% design are summarized below. A complete discussion of the cross section and site hydrogeology can be found in Volume 2 of the 2009 RFI/RI report.

Hydrogeologic Cross Section A-A' (Figure 5-2 of the 2009 RFI/RI) extends northward from the bedrock outcrop of the Chemehuevi Mountains, along the upper part of Bat Cave Wash, and farther north to the Colorado River floodplain. Wells shown include the former injection well PGE-8 (SWMU 2) as well as the well clusters in the upland area (MW-24), IM extraction area (TW-2, TW-3, MW-20), and the floodplain (MW-34, MW-36, MW-39). Also shown on this cross section are the southward pinch-out of the saturated Alluvial Aquifer, the Alluvial Aquifer hydrostratigraphic units, and the inferred depiction of bedrock contacts and the projected trace of the regional Chemehuevi detachment fault.

Hydrogeologic Cross Section B-B' (Figure 5-3 of the 2009 RFI/RI) extends along the axis of Bat Cave Wash and illustrates the progressive south-to-north thickening of the saturated Alluvial Aquifer. The Alluvial Aquifer consists of the older alluvial fan deposits of the Tertiary Alluvium and Basal Alluvium.

Hydrogeologic Cross Section E-E' (Figure 5-6 of the 2009 RFI/RI) extends from the IM-3 injection area eastward to the Colorado River. Key features shown include the generalized Miocene bedrock structure and the inferred distribution and depositional contacts of the alluvial fan deposits (Toa0, Toa) and the younger fluvial sediments of the Colorado River (Qr1, Qr2, Qr3). As shown on this cross section, the injection interval at the injection well field (wells IW-2 and IW-3) span the mid-depth and deep portions of the Alluvial Aquifer.

Hydrogeologic Cross Section F-F' (Figure 5-7 of the 2009 RFI/RI) extends eastward from the MW-20 bench across the floodplain to the MW-34 monitoring well cluster adjacent to the Colorado River. Features shown include the screen depths of the two active IM extraction wells (TW-3D and PE-1) and the distribution and depositional contacts of the alluvial fan deposits (Toa0, Toa) and the younger fluvial sediments of the Colorado River (Qr1, Qr2, Qr3).

C.2 Proposed Areas for Supplemental Geotechnical Investigation to support Remedy Design

Collection of additional geotechnical samples to support remedy design was coordinated with the Soil RFI/RI investigation program; as a result, no new boreholes will be required just for geotechnical data collection, thereby minimizing disturbance. Geotechnical samples will be collected from proposed soil sample locations SD-19 and SD-20 near the Compressor Station and Bat Cave Wash; and AOC11-3 on the Transwestern Bench (see Exhibit C.2-1). The supplemental geotechnical data will be evaluated to verify design assumptions associated with the new pipe bridge that crosses Bat Cave Wash and the new Central Maintenance Facility at the Transwestern Bench.

As PG&E continues to engage in discussions with transportation agencies, counties, and other property owners/land managers to obtain institutional controls, access agreements, and permits, additional geotechnical data may be required to meet specific requirements of agencies and/or property owners/land managers. This attachment will be updated as needed to reflect changes in requirements.

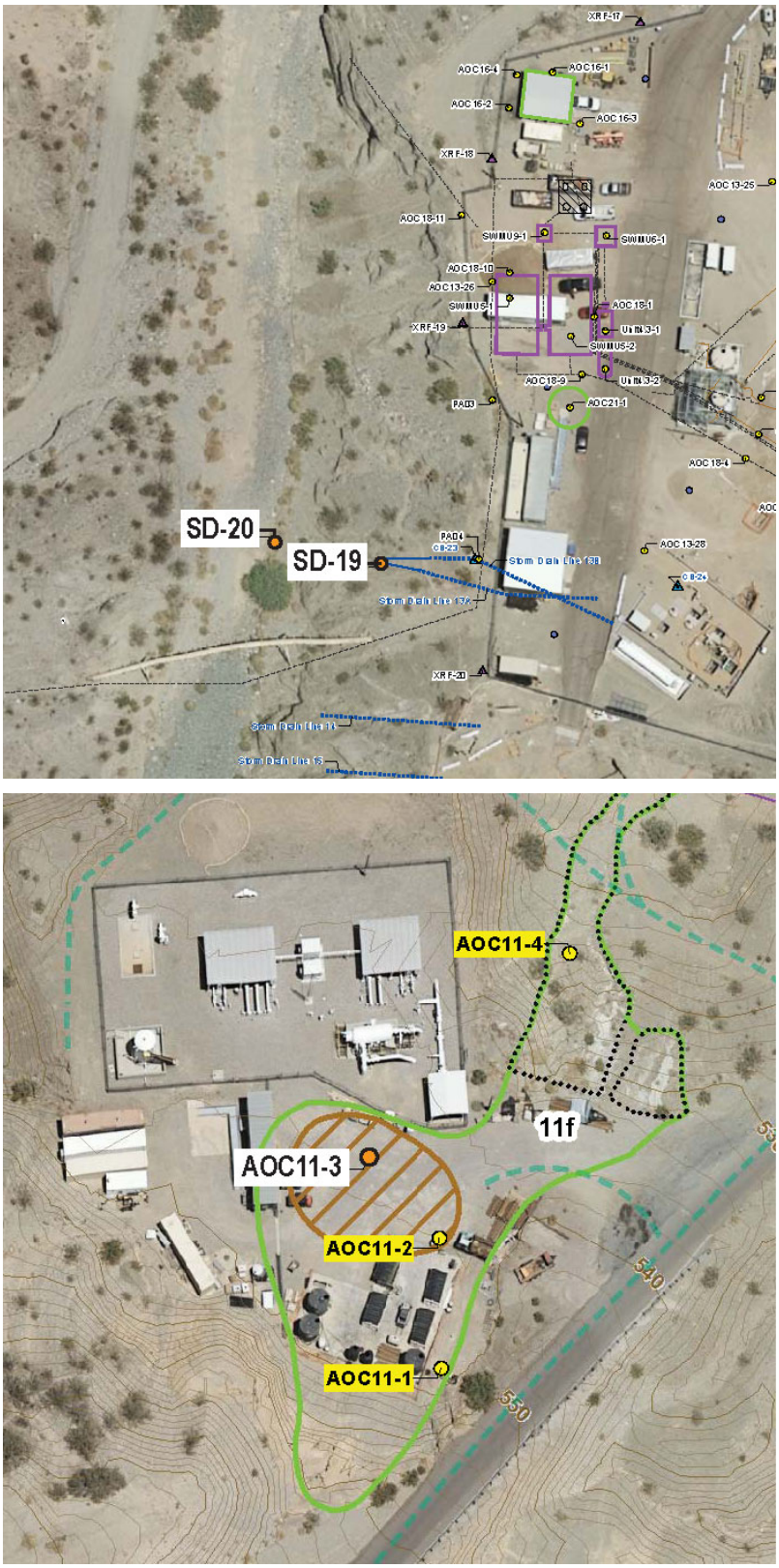


EXHIBIT C.2-1
Geotechnical Sampling Locations in Bat Wash Cave and the Transwestern Bench
Groundwater Remedy Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Source: Soil RFI/RI Work Plan (CH2M HILL 2012)

C.3 References

Blake, T.F. 1998. *FRISKSP, A Computer Program for the Probabilistic Estimation of Seismic Hazard Using Faults as Earthquake Sources*. User's Manual.

CH2M HILL. 2004. *Geotechnical Investigation Report, Topock Compressor Station, Water Treatment Plant.* September.

_____. 2005. *Work Plan for Installation of Extraction Well TW-3D, Interim Measures No. 3 Groundwater Extraction System, PG&E Topock Compressor Station, Needles, California.* October.

_____.2009a. *RCRA Facility Investigation/Remedial Investigation Report, PG&E Topock Compressor Station, Needles, California, Volume 2 – Hydrogeologic Characterization and Results of Groundwater and Surface Water Investigation.* February.

_____. 2009b. *Geotechnical Investigation, Topock AOC 4 Remediation – Pre-Work Plan Data Collection Activities, PG&E Compressor Station, Needles, California.* October.

_____.2012. *Soil RCRA Facility Investigation/RemediaI Investigation Work Plan, PG&E Compressor Station, Needles, California.* September 5.

International Code Council and the California Building Standards Commission. 2001. *2001 California Building Code*. California Code of Regulations Title 24, Part 2.

Selected Boring Logs

ALISTO ENGINEERING GROUP
WALNUT CREEK, CALIFORNIA

LOG OF WELL MW-9

SEE SITE PLAN

ALISTO PROJECT NO: *10-320-06* DATE DRILLED: *07/01/97*

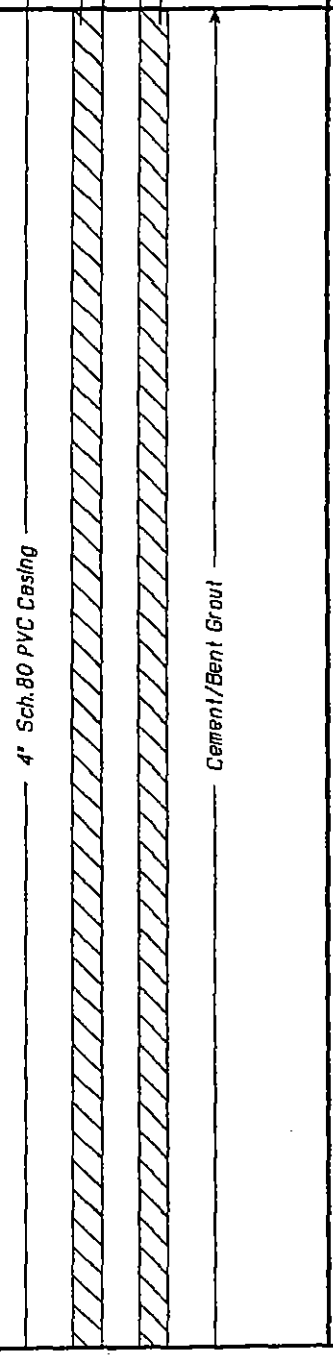
CLIENT: *Pacific Gas and Electric Co.*

LOCATION: *Topock Compressor Station*

DRILLING METHOD: *Resonant Sonic, Continuous Coring*

DRILLING COMPANY: *Boart Longyear* CASING ELEVATION: *536.18*

LOGGED BY: *Dan Salaices* APPROVED BY: *Dan Salaices*



DEPTH feet	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
		GP	sandy GRAVEL: Pale yellowish brown, to light gray; 85% gravel, 4–40 mm, subangular; 15% sand, mostly fine; dry.
		SP	SAND: Moderate yellowish brown; fine grained, dry, fill ?
5		GM	silty GRAVEL: moderate brown to dark yellowish brown; 70% gravel, 4–30 mm, subangular.
		GP	sandy GRAVEL: Pale yellowish brown, to light gray; 85% gravel, 4–40 mm, subangular; 15% sand, mostly fine; dry.
			8.5' sandy GRAVEL: Light olive gray; 80% gravel, 4–30 mm, subangular; 40% sand, fine to coarse.
10			7.5' color change to yellowish gray; 80% gravel, 4–40 mm, subangular; 20% sand, mostly fine and coarse, dry.
		GM	sandy silty GRAVEL: Pale yellowish brown; 70% gravel, 4–30 mm, subangular, occasional cobble fragment; 15% sand, fine and coarse grained; 15% fines; dry.
15			
20			
			Same: color change to moderate brown, moist.
25			
30			

ALISTO ENGINEERING GROUP
WALNUT CREEK, CALIFORNIA

LOG OF WELL MW-9

SEE SITE PLAN

ALISTO PROJECT NO: *10-320-08* DATE DRILLED: *07/01/97*

CLIENT: *Pacific Gas and Electric Co.*

LOCATION: *Topock Compressor Station*

DRILLING METHOD: *Resonant Sonic, Continuous Coring*

DRILLING COMPANY: *Boart Longyear* CASING ELEVATION: *536.18*

LOGGED BY: *Dan Salaices* APPROVED BY: *Dan Salaices*

WELL DIAGRAM	DEPTH feet	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
4" Sch.80 PVC Casing; Cement/Bent Grout; Bentonite	40		GM	Same: 80% gravel; 20% sand, fine to coarse grained; 20% fines; dry.
	45			
	50			
	55		GP SP	gravelly SAND/sandy GRAVEL: moderate yellowish brown; appears to be 50% gravel, 4-30mm; 50% sand, fine to coarse grained; moist.
	60		GP GC	sandy clayey GRAVEL: moderate yellowish brown; 70% gravel, 4-30 mm, subangular; 20% sand, fine to coarse grained; 10% fines; damp.
	65		GP	sandy GRAVEL: moderate yellowish brown; 70 % gravel, 4-30 mm, subangular and somewhat fractured; 30% sand, fine to coarse grained; damp.
			GM	sandy silty GRAVEL: Moderate yellowish brown; 70% gravel, 4-50 mm, subangular and somewhat fractured; 15% sand, fine to coarse; 15% fines; moist.

ALISTO ENGINEERING GROUP
WALNUT CREEK, CALIFORNIA

LOG OF WELL MW-9

SEE SITE PLAN

ALISTO PROJECT NO: *10-320-06* DATE DRILLED: *07/01/97*

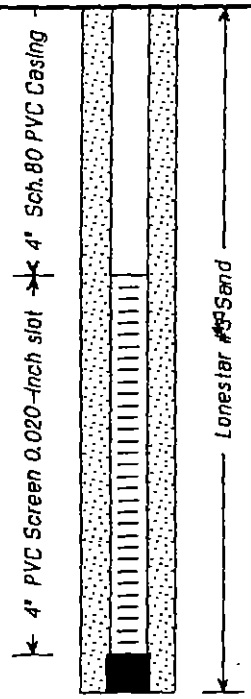
CLIENT: *Pacific Gas and Electric Co.*

LOCATION: *Topock Compressor Station*

DRILLING METHOD: *Resonant Sonic, Continuous Coring*

DRILLING COMPANY: *Boart Longyear* CASING ELEVATION: *536.18*

LOGGED BY: *Dan Salaices* APPROVED BY: *Dan Salaices*



DEPTH feet	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
75		GM	
		GP GM	sandy silty GRAVEL: moderate brown; 70% gravel, 4-30 mm, subangular; 20% sand, fine to coarse grained; 10% fines; very moist.
80		GC	clayey GRAVEL: dark yellowish brown; 80% gravel, 4-30 mm, occasional cobble fragments; 20% sand, fine grained; 20% fines; wet.
85		GM	RED FANGLOMERATE sandy silty GRAVEL: (GM although rock at 88.5) moderate reddish brown, wet to 88.5, dry at 88.5.
90			refusal at 89 feet. Total depth of borehole is 89 feet.
95			
00			

ALISTO ENGINEERING GROUP
WALNUT CREEK, CALIFORNIA

LOG OF WELL MW-13

SEE SITE PLAN

ALISTO PROJECT NO: *10-320-06* DATE DRILLED: *07/09/97*

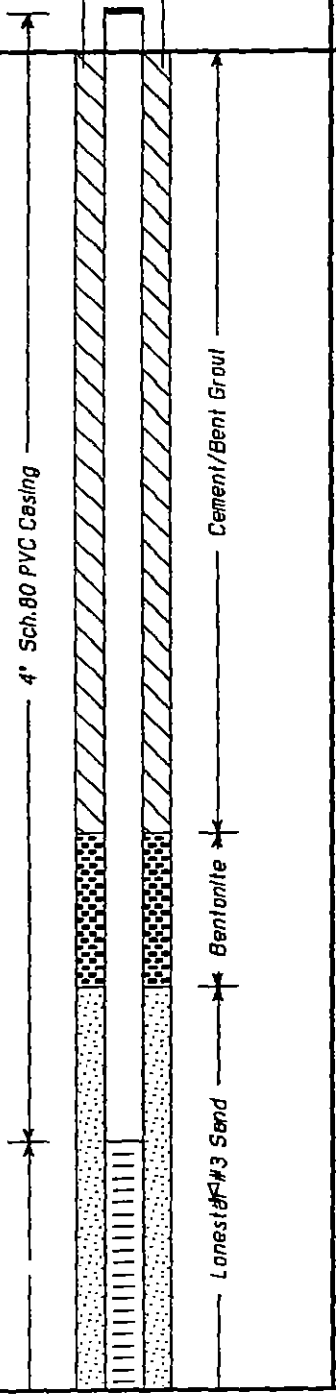
CLIENT: *Pacific Gas and Electric Co.*

LOCATION: *Topock Compressor Station*

DRILLING METHOD: *Resonant Sonic, Continuous Coring*

DRILLING COMPANY: *Boart Longyear* CASING ELEVATION: *488.19*

LOGGED BY: *Ted Moise/Dan Birch* *APPROVED BY: Dan Salaices*



DEPTH feet	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
		SP	gravelly SAND: yellowish gray; 50% sand, fine to coarse grained; 45% gravel, 4-50 mm, subangular, occasional cobbles; minor fines; dry.
5			color change to light olive gray
10			
		GP	sandy GRAVEL: light gray; 60% gravel, 4-75 mm, subangular; 40% sand, fine to medium grained; dry.
15			
			at 18 feet, 150 mm cobble.
20			at 19.5 feet, color change to pale yellowish brown; 70% gravel; 30% sand, fine to medium grained. Possibly older alluvium.
25			at 28.5 feet, 60% gravel, 40% sand.
30			Wet at 30 feet.
		SP	gravelly SAND: pale brown; 60% sand, fine to coarse grained;

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WALNUT CREEK, CALIFORNIA

LOG OF WELL MW-13

SEE SITE PLAN

ALISTO PROJECT NO: *10-320-06* DATE DRILLED: *07/09/97*

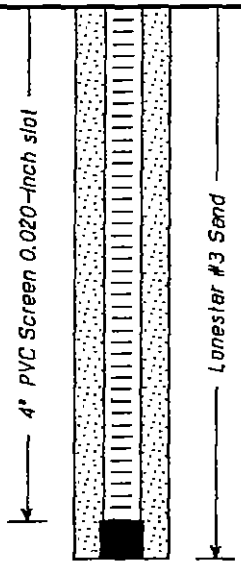
CLIENT: *Pacific Gas and Electric Co.*

LOCATION: *Topock Compressor Station*

DRILLING METHOD: *Resonant Sonic, Continuous Coring*

DRILLING COMPANY: *Boart Longyear* CASING ELEVATION: *488.19*

LOGGED BY: *Ted Moise/Dan Birch* APPROVED BY: *Dan Salaices*

WELL DIAGRAM	DEPTH feet	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
	40		SP	35% gravel, 4–40 mm, subangular; wet.
				At 40 feet, color change to pale red; 70% sand, fine to coarse grained; 30% gravel, 4–25 mm, subangular.
	45			At 43 feet, color change to light brownish gray, cobble to 100 mm.
	50			Total depth of borehole is 48.5 feet.
	55			
	60			
	65			

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WALNUT CREEK, CALIFORNIA

LOG OF WELL MW-14

SEE SITE PLAN

ALISTO PROJECT NO: *10-320-06* DATE DRILLED: *07/14-15/97*

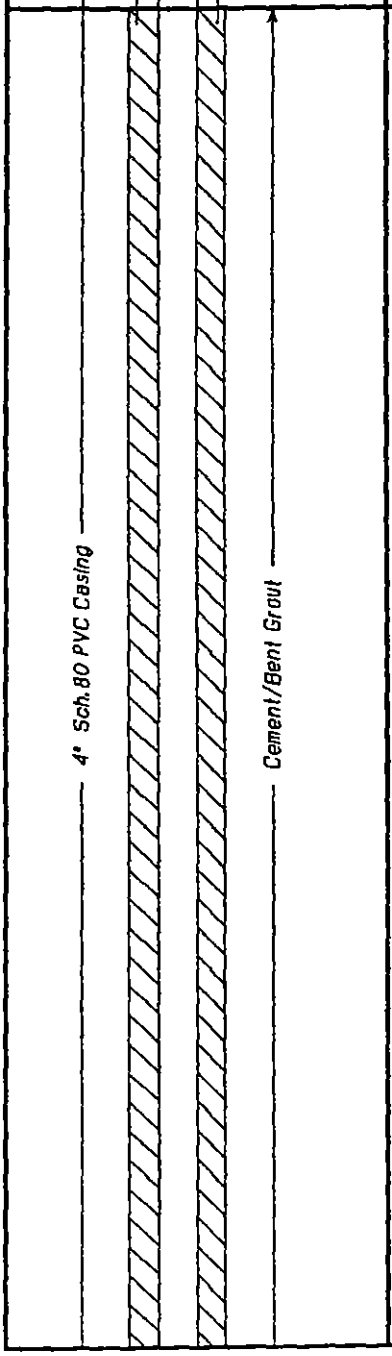
CLIENT: *Pacific Gas and Electric Co.*

LOCATION: *Topock Compressor Station*

DRILLING METHOD: *Resonant Sonic, Continuous Coring*

DRILLING COMPANY: *Boart Longyear* CASING ELEVATION: *570.54*

LOGGED BY: *Ted Moise/Ken Simas* APPROVED BY: *Dan Salaices*



DEPTH feet	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
		GP	sandy GRAVEL: grayish orange pink; 70% gravel, 4-75 mm, rounded to subangular; 30% sand, fine to coarse grained; dry.
		SP	gravelly SAND: pale yellowish brown; 80% sand, fine to coarse grained; 20% gravel, 4-50 mm, subangular; dry.
5			
			At 8 feet, 60% sand, fine to coarse grained; 40% gravel, 4-70 mm, subangular.
10			
		GP	sandy GRAVEL: pale yellowish brown; 60% gravel, 4-35 mm; subangular; 40% sand, fine to coarse grained, dry.
15			
		SP	gravelly SAND: pale yellowish brown; 80% sand, fine to coarse grained; 10% gravel, 4-20 mm, subangular, dry.
20			At 20 feet, 55% sand, fine to coarse grained; 45% gravel, 4-50 mm.
			At 22 feet, color change to light gray; 60% sand, fine to coarse grained; 40% gravel, 4-50 mm, angular to subrounded.
25			At 25 feet, color change to light olive gray; 40% gravel, 4-25 mm, subangular.
30			At 30 feet, color change to pale yellowish brown; 75% sand, fine to coarse grained; 25% gravel, 4-80 mm, subangular; dry.

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WALNUT CREEK, CALIFORNIA

LOG OF WELL MW-14

SEE SITE PLAN

ALISTO PROJECT NO: *10-320-06* DATE DRILLED: *07/14-15/97*

CLIENT: *Pacific Gas and Electric Co.*

LOCATION: *Topock Compressor Station*

DRILLING METHOD: *Resonant Sonic, Continuous Coring*

DRILLING COMPANY: *Boart Longyear* CASING ELEVATION: *570.54*

LOGGED BY: *Ted Moise/Ken Simas* APPROVED BY: *Dan Salaices*

WELL DIAGRAM	DEPTH feet	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
4" Sch.80 PVC Casing; Cement/Bent Grout	40		SP	At 38 feet, gravel, 4-40 mm, subangular. At 38 feet, color change to light olive gray; 60% sand, fine to coarse grained; 40% gravel, 4-75 mm, subrounded to subangular; dry.
	45		GP SP	sandy GRAVEL/gravelly SAND: Pale yellowish brown; 50% sand, fine to coarse grained; 50% gravel, 4-75 mm, subangular to subrounded; dry.
	50		SP	gravelly SAND: Pale yellowish brown; 70% sand, fine to coarse grained; 30% gravel, 4-75 mm, subangular. At 50 feet, 60% sand, fine to coarse grained; 40% gravel, 4-65 mm, subrounded to subangular; dry.
	55			At 54 feet; color change to light gray, 55% sand, fine to coarse grained; 40% gravel, 4-35 mm, subangular to subrounded; 5% fines; dry.
	60			At 57 feet, 65% sand, fine to coarse grained; 30% gravel, subangular to subrounded, 4-75 mm; 5% fines.
	65		GP	sandy GRAVEL: light gray; 60% gravel, subangular to subrounded, 4-75 mm; 40% sand, fine to coarse grained.

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WALNUT CREEK, CALIFORNIA

LOG OF WELL MW-14

SEE SITE PLAN

ALISTO PROJECT NO: *10-320-06* DATE DRILLED: *07/14-15/97*

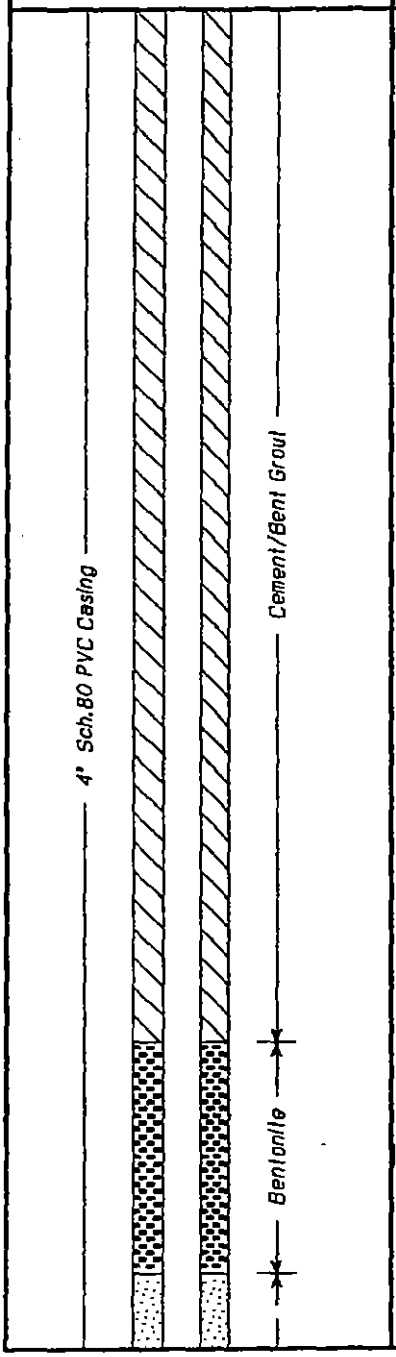
CLIENT: *Pacific Gas and Electric Co.*

LOCATION: *Topock Compressor Station*

DRILLING METHOD: *Resonant Sonic, Continuous Coring*

DRILLING COMPANY: *Boart Longyear* CASING ELEVATION: *570.54*

LOGGED BY: *Ted Moise/Ken Simas* APPROVED BY: *Dan Salaices*



DEPTH feet	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
		GP	Same
75		SP	gravelly SAND: pale yellowish brown; 80% sand, fine to coarse grained; 40% gravel, 4–50 mm, subangular.
80		GP SP	sandy GRAVEL/gravelly SAND: light olive brown; 50% sand, fine to coarse grained; 50% gravel, 4–50 mm, subangular. At 78.5 feet, 1.5 foot long boulder core, 8-inches wide. Rock flour is light gray.
85		SP	gravelly SAND: light olive gray; 80% sand, fine to coarse grained; 40% gravel, 4–50 mm, subangular.
90		GP SP	sandy GRAVEL/gravelly SAND: light olive gray, 50% sand, fine to coarse grained; 50% gravel, 4–50 mm, subangular.
95		SP	gravelly SAND: light gray; 80% sand, fine to coarse grained; 20% gravel, 4–50 mm, subangular.
100		GP	sandy GRAVEL: light gray; 75% gravel, 4–50 mm, subangular to subrounded; 25% sand, fine to coarse grained, dry.
		GP SP	

ALISTO ENGINEERING GROUP
WALNUT CREEK, CALIFORNIA

LOG OF WELL MW-14

SEE SITE PLAN

ALISTO PROJECT NO: *10-320-08* DATE DRILLED: *07/14-15/97*

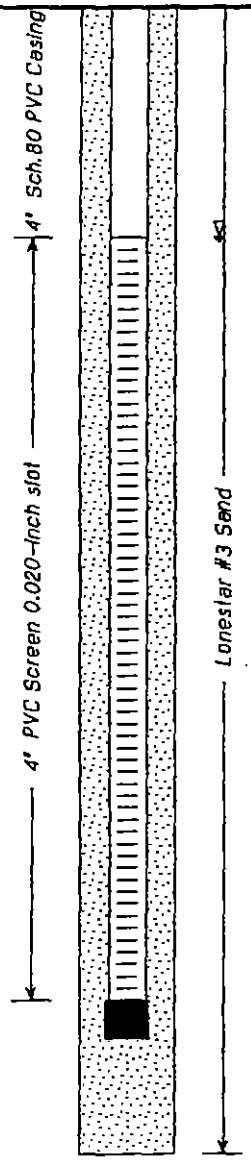
CLIENT: *Pacific Gas and Electric Co.*

LOCATION: *Topock Compressor Station*

DRILLING METHOD: *Resonant Sonic, Continuous Coring*

DRILLING COMPANY: *Boart Longyear* CASING ELEVATION: *570.54*

LOGGED BY: *Ted Moise/Ken Simas* APPROVED BY: *Dan Salaices*



DEPTH feet	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
		GP SP	sandy GRAVEL/gravelly SAND: moderate brown; 50% gravel, 4-75 mm, subrounded to subangular; 50% sand, fine to coarse grained; damp.
		SP	gravelly SAND: light olive brown; 60% sand, fine to coarse grained; 40% gravel, subangular, 4-40 mm; moist to wet.
110		GP	sandy GRAVEL: light olive gray; 60% gravel, subangular to subrounded, 4-75 mm; 40% sand, fine to coarse grained; wet at 111 feet.
115			At 116 feet, color change to light brown; gravel 4-75 mm.
			At 117.5 feet, 140 mm cobble, light gray rock flour.
		SP	gravelly SAND: pale yellowish brown; 65% sand, fine to coarse grained, 30% gravel, subangular, 4-75 mm; 5% fines; wet.
120			
125		GP GM	sandy silty GRAVEL: pale yellowish brown; 55% gravel, subangular, 4-50 mm, occasional cobble to 80 mm; 35% sand, fine to coarse grained; 10% fines; wet.
		SP	gravelly SAND: pale yellowish brown; 60% sand, fine to coarse grained; 35% gravel, subangular, 4-20 mm; 5% fines; wet.
130		SM	gravelly silty SAND: pale yellowish brown; 60% sand, fine to coarse grained; 20% gravel, subangular, 4-30 mm; 20% fines; wet.
		SP	gravelly SAND: light olive gray; 65% sand, fine to coarse grained; 30% gravel, subangular, 4-25 mm; 5% fines; wet.
135			Total depth of the boring is 135 feet.

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WALNUT CREEK, CALIFORNIA

LOG OF BORING MW-20/70

SEE SITE PLAN

ALISTO PROJECT NO: *10-320-08* DATE DRILLED: *03/24-25/98*

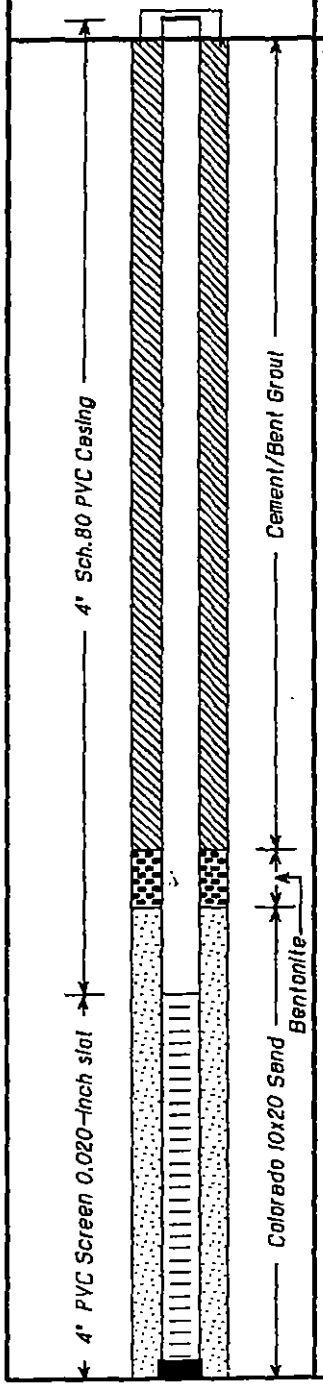
CLIENT: *Pacific Gas and Electric Co.*

LOCATION: *Topock Compressor Station*

DRILLING METHOD: *AP-1000 Dual Tube Percussion*

DRILLING COMPANY: *THF Drilling* CASING ELEVATION:

LOGGED BY: *Dan Salaices* *APPROVED BY: Dan Salaices*



DEPTH feet	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
		GP	sandy GRAVEL: moderate yellowish-brown; ~60-70% gravel, subrounded, to 80 mm; ~30-40% sand.
10		SP	SAND: pale yellowish-brown; very fine- to fine-grained; ~5% gravel.
20		GP	sandy GRAVEL: light brownish-gray; cobble at 21-24 feet. Changes at 24 feet of color to moderate yellowish-brown; ~60-70% gravel, subrounded, to 80 mm.
30		SP	gravelly SAND: light gray; ~80% sand, very fine- to fine-grained; ~10% gravel, subrounded, to 50 mm. gravelly SAND continued.
40			SAND: reddish brown; fine- to very fine-grained; ~5% fines; damp.
50		GP	sandy GRAVEL: reddish-brown; ~55% gravel, subrounded, to 80 mm; ~45% sand.
60			Appears wet at 60 feet.

ALISTO ENGINEERING GROUP
WALNUT CREEK, CALIFORNIA

LOG OF BORING MW-20/100

SEE SITE PLAN

ALISTO PROJECT NO: *10-320-09* DATE DRILLED: *04/28-29/99*

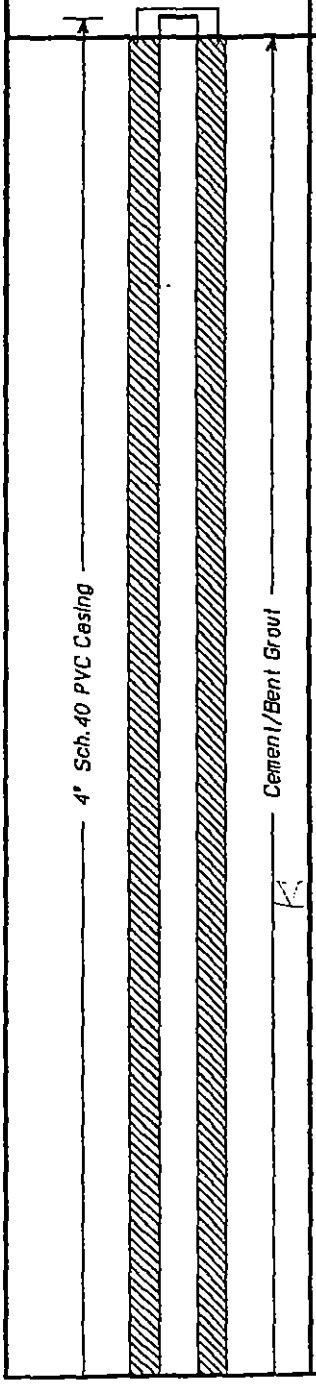
CLIENT: *Pacific Gas and Electric Co.*

LOCATION: *Topock Compressor Station*

DRILLING METHOD: *Roto Sonic, Continuous Coring*

DRILLING COMPANY: *Boart Longyear* CASING ELEVATION:

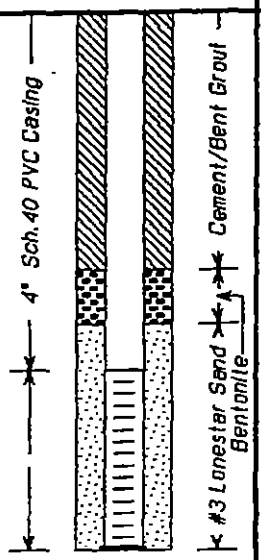
LOGGED BY: *Chris Reinheimer* APPROVED BY: *Dan Hidalgo*



DEPTH feet	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
10		GP	sandy GRAVEL: moderate yellowish-brown; ~60-70% gravel, subrounded, ~80 mm; ~30-40% sand.
20		SP	SAND: pale yellowish-brown; very fine- to fine-grained; ~5% gravel.
30		GP	sandy GRAVEL: light brownish-gray; cobble at 21 to 24 feet. At 24 feet color change to moderate yellowish-brown; ~60-70% gravel, subrounded, ~80 mm.
40		SP	gravelly SAND: light gray; ~80% sand, very fine- to fine-grained; ~10% gravel, subrounded, ~50 mm. gravelly SAND continued.
			SAND: reddish-brown; very fine- to fine-grained; ~5% fines; damp.
50		GP	sandy GRAVEL: reddish-brown; ~55% gravel, subrounded, ~80 mm; ~45% sand.
60		SP	gravelly SAND: brown to reddish-brown; 70% sand, fine- to coarse-grained; gravel, subrounded to subangular, 4 to 10 mm; wet.
		SC	gravelly clayey SAND: reddish-brown; 70% sand, fine- to coarse-grained; gravel, 4 to 8 mm; ~15% fines, plastic; wet.

ALISTO ENGINEERING GROUP
WALNUT CREEK, CALIFORNIA

LOG OF BORING MW-20/100



DEPTH feet	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
		SC	gravelly clayey SAND continued.
		SP	SAND: reddish-brown; fine- to coarse-grained; minor gravel, fine-grained; wet.
		SC	gravelly clayey SAND: reddish-brown; 70% sand, fine- to coarse-grained; gravel, 4 to 8 mm; ~15% fines, plastic; wet.
80		SP	SAND: reddish-brown; fine- to coarse-grained; minor gravel, fine-grained; wet.
		SC	gravelly clayey SAND: reddish-brown; 70% sand, fine- to coarse-grained; gravel, 4 to 8 mm; ~15% fines, plastic; wet.
		SP	gravelly SAND: reddish-brown; 85% sand, very fine- to coarse-grained; gravel; wet.
90		SC	gravelly clayey SAND: reddish-brown; 70% sand, fine- to coarse-grained; gravel, 4 to 8 mm; ~15% fines, plastic; wet.
		SP	gravelly SAND: reddish-brown; ~85% sand, very fine- to coarse-grained; gravel, ~4 to 20 mm; wet.
			At 98 feet color change to moderate yellowish-brown; 80% sand, medium- to coarse-grained.
100			At 98 feet color change to brown; 85% sand, very fine- to coarse-grained.
			Total depth of borehole at 98.5 feet.
110			
120			
130			
140			
150			

ALISTO ENGINEERING GROUP
WALNUT CREEK, CALIFORNIA

LOG OF BORING MW-20/130

SEE SITE PLAN

ALISTO PROJECT NO: *10-320-09* DATE DRILLED: *04/25-27/99*

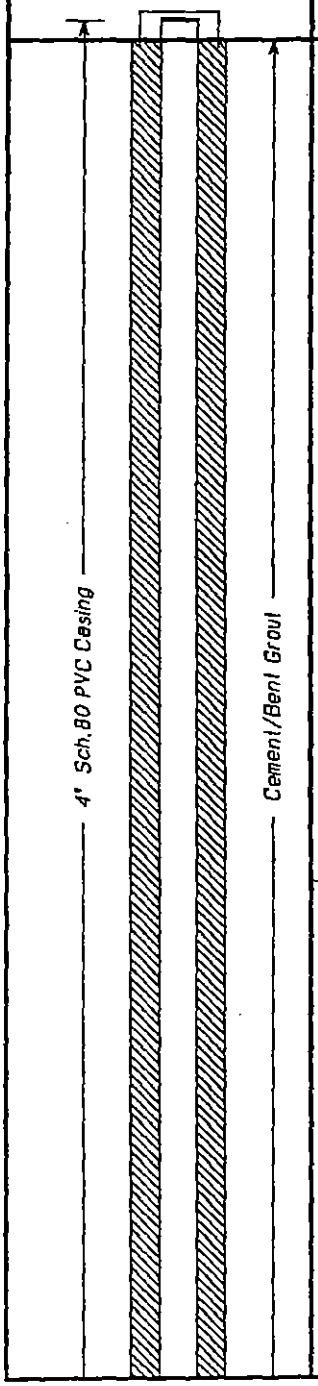
CLIENT: *Pacific Gas and Electric Co.*

LOCATION: *Topock Compressor Station*

DRILLING METHOD: *Roto Sonic, Continuous Coring*

DRILLING COMPANY: *Boart Longyear* CASING ELEVATION:

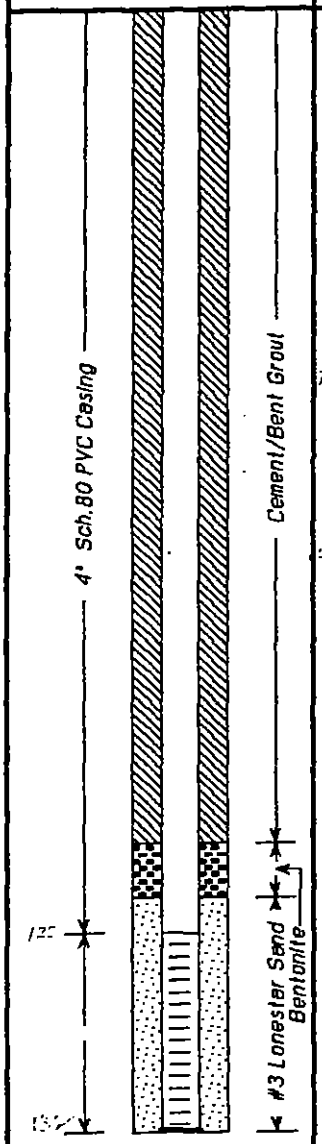
LOGGED BY: *Dan Hidalgo & Chris Reinhelmer* APPROVED BY: *Dan Hidalgo*



DEPTH feet	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
		GP	sandy GRAVEL: moderate yellowish-brown; ~60-70% gravel, subrounded, ~90 mm; ~30-40% sand.
10		SP	SAND: pale yellowish-brown; very fine- to fine-grained; ~5% gravel.
20		GP	sandy GRAVEL: light brownish-gray; cobbles at 21 to 24 feet. At 24 feet color change to moderate yellowish-brown; ~60-70% gravel, subrounded, ~90 mm.
30		SP	gravelly SAND: light gray; ~90% sand, very fine- to fine-grained; ~10% gravel, subrounded, ~50 mm. gravelly SAND continued.
40			SAND: reddish-brown; very fine- to fine-grained; ~5% fines; damp.
50		GP	sandy GRAVEL: reddish-brown; ~55% gravel, subrounded, ~90 mm; ~45% sand.
60		SP	gravelly SAND: brown to reddish-brown; 70% sand, fine- to coarse-grained; gravel, subrounded to subangular, 4 to 10 mm; wet.
		SC	gravelly clayey SAND: reddish-brown; 70% sand, fine- to coarse-grained; gravel, 4 to 8 mm; ~15% fines, plastic; wet.

ALISTO ENGINEERING GROUP
WALNUT CREEK, CALIFORNIA

LOG OF BORING MW-20/130



DEPTH feet	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
		SC	gravelly clayey SAND continued.
		SP	SAND: reddish-brown; fine- to coarse-grained; minor gravel, fine-grained; wet.
		SC	gravelly clayey SAND: reddish-brown; 70% sand, fine- to coarse-grained; gravel, 4 to 8 mm; ~15% fines, plastic; wet.
80		SP	SAND: reddish-brown; fine- to coarse-grained; minor gravel, fine-grained; wet.
		SC	No recovery.
		SP	gravelly clayey SAND: reddish-brown; 70% sand, fine- to coarse-grained; gravel, 4 to 8 mm; ~15% fines, plastic; wet.
90			gravelly SAND: reddish-brown; 85% sand, very fine- to coarse-grained; gravel, ~4 to 20 mm; wet.
		SC	gravelly clayey SAND: reddish-brown; 70% sand, fine- to coarse-grained; gravel, 4 to 8 mm; ~15% fines, plastic; wet.
		SP	gravelly SAND: reddish-brown; ~85% sand, very fine- to coarse-grained; gravel, ~4 to 20 mm; wet.
			At 98 feet color change to moderate yellowish-brown; 80% sand, medium- to coarse-grained.
100		ML	At 98 feet color change to brown; 85% sand, very fine- to coarse-grained.
			gravelly sandy SILT: medium reddish-brown with less than 2% greenish-gray stain; ~80% fines, non-plastic; ~20% gravel to 2", coarse-grained; moist to wet.
			gravelly sandy SILT continued.
110		SP	silty SAND: medium reddish-brown; ~80% sand, medium- to coarse-grained; ~10% gravel; ~10% fines, non-plastic; wet.
			At 114 feet change to ~30% gravel.
		ML	gravelly sandy SILT: medium reddish-brown with less than 2% greenish-gray stain; ~80% fines, non-plastic; ~20% gravel to 2", coarse-grained; moist to wet.
120		SC	clayey SAND: medium-orange; 80% sand, medium- to coarse-grained; ~30% fines, medium plasticity; ~10% gravel to 2"; wet to saturated.
		GM	silty GRAVEL: medium reddish-brown; ~70% gravel to 3"; ~30% fines, non-slight plasticity; moist.
130			At 129.5 feet changes to ~80% gravel to 3"; ~15% fines, non plastic; angular clast to 2"; damp.
			RED FANGLOMERATE cemented dry, drill refusal at 132 feet.
			Total depth of borehole at 132 feet.
140			
150			

SHEET 1 of 10	**PROJECT NUMBER:** 326128.01.07.AR	**BORING NUMBER:** MW-41

SOIL BORING LOG

PROJECT NAME: IM-3 Hydrogeologic Investigation, PG&E Topock		**HOLE DEPTH (ft):** 320.0	**DRILLING CONTRACTOR:** WDC Exploration & Wells, Montclair, CA	
SURFACE ELEVATION: 476.9 ft. MSL	**NORTHING (CCS NAD 27 Z 5):** 2,103,536.66	**EASTING (CCS NAD 27 Z 5):** 7,614,578.85	**DATE STARTED:** 10/22/2004	**DATE COMPLETED:** 11/05/2004
DRILLING METHOD: Rotosonic		**WATER LEVEL (ft):** ---	**DRILLING EQUIPMENT:** Gefco SS-15K-HL	
LOCATION: Bat Cave Wash, Parcel No. 650-151-06			**LOGGED BY:** T. McDonald	

DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/ NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.	COMMENTS DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.
5				SW	**WELL GRADED SAND WITH GRAVEL (SW)** - 45% rnd to ang gravel/cobbles up to 0.75", 40% f-m sand, 10% coarse sand, 5% silty clay.	0 to 20 ft not collected in core barrel during conductor casing set. Description is from homogenized cuttings
10						
15						
20						
25		CC1	11			Box 1 - 20 to 23 ft Box 2: 23 to 27 ft
30				GW-GM	**WELL GRADED GRAVEL WITH SILT AND SAND (GW-GM)** - 65% f-c gravel avg 2.5" up to 3", 20% c sand, 10% silt/clay, 5% f-m sand, sand and gravel ang to subang, metamorphic, 50% of gravels are highly weathered, moist, abrupt lower boundary.	Box 3: 27 to 31 ft
35				SC	**SILTY SAND WITH GRAVEL (SC)** - olive brn (2.5Y 4/3), 30% c sand, 25-30% silt, 20% m sand, 10% f gravel (0.2" to 0.75"), 10% f sand, sand and gravel ang to subang, metamorphic, moist.	Box 4: 31 to 34 ft Appears to be fining upward from to 31 to __ ft bgs Box 5: 34 to 38 ft

CH2MHILL

PROJECT NUMBER: 326128.01.07.AR

BORING NUMBER: MW-41

SOIL BORING LOG

PROJECT NAME: IM-3 Hydrogeologic Investigation, PG&E Topock		**HOLE DEPTH (ft):** 320.0	**DRILLING CONTRACTOR:** WDC Exploration & Wells, Montclair, CA
SURFACE ELEVATION: 476.9 ft. MSL	**NORTHING (CCS NAD 27 Z 5):** 2,103,536.66	**EASTING (CCS NAD 27 Z 5):** 7,614,578.85	**DATE STARTED:** 10/22/2004 / **DATE COMPLETED:** 11/05/2004
DRILLING METHOD: Rotosonic		**WATER LEVEL (ft):** ---	**DRILLING EQUIPMENT:** Gefco SS-15K-HL
LOCATION: Bat Cave Wash, Parcel No. 650-151-06			**LOGGED BY:** T. McDonald

DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/ NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.	COMMENTS DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.
		CC2	8.5	SW-SC	**WELL GRADED SAND WITH SILT AND GRAVEL (SW-SC)** - olive brn (2.5Y 4/3), 40% f sand, 30% m sand, 10-15% silt, 10% c sand, 5-10% f gravel, sand and gravel ang to subang, metamorphic, moist, abrupt lower boundary.	
40				SW	**WELL GRADED SAND WITH GRAVEL (SW)** - brn (7.5YR 4/4), 50% m sand, 20% f sand, 15% c sand, 10% f gravel coarsening with depth, 5% silt, moderate caliche development, sand and gravel ang to subang, metamorphic, moist.	Box 6: 38 to 42 ft
				SW-SM	**SAND WITH SILT AND GRAVEL (SW-SM)** - brn (10YR 4/4), 40% m sand, 25% c sand, 10-15% f gravel, 10-15% silt, 10% f sand well graded, sand and gravel ang to subang, metamorphic. - lt to moderate caliche	Box 7: 42 to 46 ft Appears to encounter water table at 45 to 46 ft bgs
45		CC3	9.5			
50				SW	**WELL GRADED SAND WITH GRAVEL (SW)** - dark grayish brn to brn (10YR 4/2-4/3), 60% m sand, 15% f sand, 15% f-m gravel, 10% f sand, ang to subang, metamorphic, wet. - 20% f gravel	Box 8: 46 to 50 ft
					- 5% gravel, 15% silt	Box 9: 50 to 54 ft
55		CC4	10		- 30% f gravel, 25% vf sand, 15% silt, 15% f sand, 5% m sand, 10% c sand	Box 10: 54 to 58 ft
60					- brn (10YR 4/3), 40% c sand , 15% f sand, 15% m sand, 15% f gravel, 10% c gravel, 5% silt, ang to subang, metamorphic, wet	Box 11: 58 to 62 ft
						Box 12: 62 to 66 ft Collect grain size sample at 62 to 64 ft, ID: MW-41D-63
65		CC5	10		- 5% silt, 10% f sand, 10% m sand, 60% c sand, 5-10% f gravel	Collect grain size sample at 65 to 66 ft, ID: MW-41D-66
						Box 13: 66 to 70 ft
70					- increasing silt content, 10% silt at 70 ft bgs, 15% silt at 71 ft bgs	Collect groundwater grab sample, ID: MW-41D-70

CH2MHILL

PROJECT NUMBER:	BORING NUMBER:
326128.01.07.AR	MW-41

SOIL BORING LOG

PROJECT NAME: IM-3 Hydrogeologic Investigation, PG&E Topock		**HOLE DEPTH (ft):** 320.0	**DRILLING CONTRACTOR:** WDC Exploration & Wells, Montclair, CA	
SURFACE ELEVATION: 476.9 ft. MSL	**NORTHING (CCS NAD 27 Z 5):** 2,103,536.66	**EASTING (CCS NAD 27 Z 5):** 7,614,578.85	**DATE STARTED:** 10/22/2004	**DATE COMPLETED:** 11/05/2004
DRILLING METHOD: Rotosonic		**WATER LEVEL (ft):** ---	**DRILLING EQUIPMENT:** Gefco SS-15K-HL	
LOCATION: Bat Cave Wash, Parcel No. 650-151-06			**LOGGED BY:** T. McDonald	

DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/ NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.	COMMENTS DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.
75		CC6	9.5		**WELL GRADED SAND WITH GRAVEL (SW)** - dark grayish brn to brn (10YR 4/2-4/3), 60% m sand, 15% f sand, 15% f-m gravel, 10% f sand, ang to subang, metamorphic, wet.	Box 14: 70 to 74 ft Box 15: 74 to 78 ft Box 16: 78 to 82 ft
80					- 10-15% silt - 5-10% silt	Stop drilling at 80 ft bgs on 10/22/04, continue drilling on 10/23/04
85		CC7	10			Box 17: 82 to 86 ft
				ML	**SANDY SILT WITH GRAVEL (ML)** - greenish gray (GLEY1 5/5GY), 50% silt, 20% vf sand, 10% f sand, 10% m sand, 10% f gravel, sand and gravel ang to subang, metamorphic, silty plastic, silty sticky to not sticky, moist to wet. Abrupt lower boundary (< 2 cm).	Box 18: 86 to 90 ft
90				SW	**WELL GRADED SAND WITH GRAVEL (SW)** - brn (7.5YR 4/4), 40% f sand, 20% m sand, 20% c sand, 10% silt, 10% f gravel, sand and gravel ang to subang, metamorphic, moist, distinct layers of 15-20% silt < 2 cm thick.	
95		CC8	10	SM	**SILTY SAND WITH GRAVEL (SM)** - brn (10YR 5/3-4/3), 35% f sand, 20% silt, 15% f gravel 0.2" to 1", 10% vf sand, 10% m sand, 10% c sand, sand and gravel dominantly ang to subang, v few subrnd, metamorphic and v few conglomerate, moist.	Box 19: 90 to 94 ft Collect grain size sample at 93 ft, ID: MW-41D-93
100					- silt caliche	Box 20: 94 to 98 ft
				SW-SM	**SAND WITH SILT AND GRAVEL (SW-SM)** - brn (7.5YR 4/3), 30% m sand, 20% f sand, 20% c sand, 20% f-m gravel, 10% silt, sand and gravel ang to subang, metamorphic, moist to wet, silt caliche.	Box 21: 98 to 102 ft Drilled 100 to 110 ft but dropped core during retrieval and recovered on next run
105		CC9	5		- 15% silt, 5% f-m gravel	Box 22: 102 to 106 ft

CH2MHILL

PROJECT NUMBER:	BORING NUMBER:
326128.01.07.AR	MW-41

SOIL BORING LOG

PROJECT NAME: IM-3 Hydrogeologic Investigation, PG&E Topock		**HOLE DEPTH (ft):** 320.0	**DRILLING CONTRACTOR:** WDC Exploration & Wells, Montclair, CA	
SURFACE ELEVATION: 476.9 ft. MSL	**NORTHING (CCS NAD 27 Z 5):** 2,103,536.66	**EASTING (CCS NAD 27 Z 5):** 7,614,578.85	**DATE STARTED:** 10/22/2004	**DATE COMPLETED:** 11/05/2004
DRILLING METHOD: Rotosonic		**WATER LEVEL (ft):** ---	**DRILLING EQUIPMENT:** Gefco SS-15K-HL	
LOCATION: Bat Cave Wash, Parcel No. 650-151-06			**LOGGED BY:** T. McDonald	

DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/ NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.	COMMENTS DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.
				SW	**WELL GRADED SAND WITH GRAVEL (SW)** - brn (7.5YR 4/4), 30% m sand, 30% c sand, 20% f sand, 15% f-m gravel, 5% silt, sand and gravel ang to subang, metamorphic, moist. Moderate caliche development, silty cemented throughout. Distinct 1/8" silt layers are dark gray (5Y4/1), 90% silt, 10% vf sand.	Box 23: 106 to 110 ft
				SW	**WELL GRADED SAND (SW)** - brn (10YR 4/3), 30% f sand, 30% m sand, 15% silt, 15% c sand, 10% f gravel, ang to subang, metamorphic, wet.	
110						
					WELL GRADED SAND WITH GRAVEL (SW) - brn (10YR 4/3 at top, 7.5YR 4/3 at bottom), 30% m sand, 30% c sand, 25% f-c gravel, 10% f sand, 5% silt, sand ang to subang and fining downwards, gravel ang to subrnd, metamorphic, wet.	Box 24: 110 to 114 ft
		CC10	14			
115						Box 25: 114 to 118 ft
				SW	- 20% silt	Box 26: 118 to 122 ft
120						
					SILT WITH GRAVEL (MH) - dark brn (2.5Y 4/3 or 4/4), 65% silt, 30% f-m ang to subang gravel up to 2.75", 5% clay, 5% c sand, metamorphic, med-high elasticity, sticky, plastic, dry, caliche on gravels, abrupt lower boundary.	Box 27: 122 to 126 ft
						Collect grain size sample at 122 to 124 ft, ID: MW-14D-123
125		CC11	10	MH	- interbedded sand with gravels, brn (7.5YR 4/3), 30% c sand, 20% f gravel, 20% m sand, 20% f gravel, 10% silt, well graded	Box 28: 126 to 130 ft
130						
					SILTY SAND (SW) - dark greenish gray (Y2 4/10G), 30% vf sand, 30% f sand, 20% silt, 10% m-c sand, 10% ang to subang gravel, metamorphic, moist. Moderate caliche development. Mottled brn (7.5YR 4/4) over 10% of surface, mottling increases to 50% of surface at bottom 3".	Box 29: 130 to 134 ft
				SW	- 80% silt, 10% f sand, 10% c sand	Box 30: 134 to 138 ft
135		CC12	10			
					WELL GRADED SAND WITH GRAVEL (SW) - 40% m sand, 25% f-c gravel (1/5" to 1"), 20% c sand, 10% f sand, 5% silt, ang to subang, metamorphic, wet.	Collect grain size sample at 136.5 to 137.5 ft, ID: MW-14D-137
						Box 31: 138 to 142 ft
140					- 10% silt, slit horizontal fabric in gravels	Collect groundwater sample at 139 ft

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326128.01.07.AR	MW-41

SOIL BORING LOG

PROJECT NAME: IM-3 Hydrogeologic Investigation, PG&E Topock		**HOLE DEPTH (ft):** 320.0	**DRILLING CONTRACTOR:** WDC Exploration & Wells, Montclair, CA	
SURFACE ELEVATION: 476.9 ft. MSL	**NORTHING (CCS NAD 27 Z 5):** 2,103,536.66	**EASTING (CCS NAD 27 Z 5):** 7,614,578.85	**DATE STARTED:** 10/22/2004	**DATE COMPLETED:** 11/05/2004
DRILLING METHOD: Rotosonic		**WATER LEVEL (ft):** ---	**DRILLING EQUIPMENT:** Gefco SS-15K-HL	
LOCATION: Bat Cave Wash, Parcel No. 650-151-06			**LOGGED BY:** T. McDonald	

DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/ NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION	COMMENTS
					SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.	DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.
					WELL GRADED SAND WITH GRAVEL (SW) - 40% m sand, 25% f-c gravel (1/5" to 1"), 20% c sand, 10% f sand, 5% silt, ang to subang, metamorphic, wet.	bgs, ID: MW-41D-139 Appears to be reworked due to drilling
					- dark grayish brn (10YR 4/2), 40% f sand, 20% f-c gravel 1/5" up to 3", 10% m sand, 5-10% silt, moist. Mottling in blocks of brn (7.5YR 4/3)	Box 32: 142 to 146 ft
145						
					- 35% m sand, 25% c sand, 25% f sand, 15% gravel, 5-10% silt, well graded, caliche development throughout and increased cementation with depth	Box 33: 146 to 150 ft
150		CC13	15	SW		Box 34: 150 to 154 ft
155						Box 35: 154 to 158 ft
						Reworking at 140 to 176 indicated by lack of fabric, no silt layers around gravels, color, and blocks of mottled brown
160						
					- brn (10YR 4/3 to 7.5YR 4/3), 5% silt, 10% f sand, 40% m sand, 35% c sand, 10% f gravel, well graded, sand and gravel ang to subang - metamorphic. Gravels less than 2 cm	
165		CC14	10			
					WELL GRADED SAND WITH SILT (SW-SM) - brn (7.5YR 4/2 to 4/3), 35% m sand, 30% f sand, 15% c sand, 10-15% silt, 5-10% f-c gravel (0.2" avg, up to 2"), ang to subang with v few subang gravel, moist to wet.	
170						
				SW-SM		Collect grain size sample at 172.5 to 173.5 ft, ID: MW-41D-173
175						

CH2MHILL

PROJECT NUMBER: 326128.01.07.AR

BORING NUMBER: MW-41

SOIL BORING LOG

PROJECT NAME: IM-3 Hydrogeologic Investigation, PG&E Topock		**HOLE DEPTH (ft):** 320.0	**DRILLING CONTRACTOR:** WDC Exploration & Wells, Montclair, CA
SURFACE ELEVATION: 476.9 ft. MSL	**NORTHING (CCS NAD 27 Z 5):** 2,103,536.66	**EASTING (CCS NAD 27 Z 5):** 7,614,578.85	**DATE STARTED:** 10/22/2004 / **DATE COMPLETED:** 11/05/2004
DRILLING METHOD: Rotosonic		**WATER LEVEL (ft):** ---	**DRILLING EQUIPMENT:** Gefco SS-15K-HL
LOCATION: Bat Cave Wash, Parcel No. 650-151-06			**LOGGED BY:** T. McDonald

DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/ NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.	COMMENTS DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.
180		CC15	10		**WELL GRADED SAND WITH SILT (SW-SM)** - brn (7.5YR 4/2 to 4/3), 35% m sand, 30% f sand, 15% c sand, 10-15% silt, 5-10% f-c gravel (0.2" avg, up to 2"), ang to subang with v few subang gravel, moist to wet. - < 5% red mottling (2.5YR 4/6), < 5% silt, 20% f sand, 50% m sand, 20% c sand, 5% gravel	
185				SW	**WELL GRADED SAND WITH GRAVEL (SW)** - brn (10YR 5/3), 50% m sand, 20% c sand, 20% f sand, 5% silt, 5% gravel avg 0.5", ang to subang, metamorphic, wet.	
				SP	**POORLY GRADED SAND (SP)** - grayish brn (10YR 5/2), 85% m sand, 10% f sand, < 5% silt, ang to subang, metamorphic, wet.	
190		CC16	18	SW	**WELL GRADED SAND WITH GRAVEL (SW)** - brn (10YR 5/3), 50% m sand, 20% f sand, 20% c sand, 5% silt, 5% gravel avg 0.5", ang to subang, metamorphic, wet.	
195				SM	**SILTY SAND WITH GRAVEL (SM)** - brn (7.5YR 4/3) with 15% dark greenish gray (GLEY1 4/10Y) and 10% red (10R 4/6) mottling, 25% m sand, 25% c sand, 20% silt, 15% f sand, 15% gravel 0.5" - 2.5", ang to subang with v few subrnd, metamorphic. Silty caliche development, faint fabric with aligned gravels.	
200						
205				SW-SM	**WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)** - brn (7.5YR 4/3) with 10% dark greenish gray (GLEY1 4/10Y) mottling, 30% m sand, 25% c sand, 20% f sand, 15% gravel from 0.5" - 2.5", 10% silt, sand and gravel ang to subang, metamorphic, silt caliche development, abrupt lower boundary.	
210						

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326128.01.07.AR	MW-41

SOIL BORING LOG

PROJECT NAME: IM-3 Hydrogeologic Investigation, PG&E Topock		**HOLE DEPTH (ft):** 320.0	**DRILLING CONTRACTOR:** WDC Exploration & Wells, Montclair, CA	
SURFACE ELEVATION: 476.9 ft. MSL	**NORTHING (CCS NAD 27 Z 5):** 2,103,536.66	**EASTING (CCS NAD 27 Z 5):** 7,614,578.85	**DATE STARTED:** 10/22/2004	**DATE COMPLETED:** 11/05/2004
DRILLING METHOD: Rotosonic		**WATER LEVEL (ft):** ---	**DRILLING EQUIPMENT:** Gefco SS-15K-HL	
LOCATION: Bat Cave Wash, Parcel No. 650-151-06			**LOGGED BY:** T. McDonald	

DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/ NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.	COMMENTS DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.
		CC17	18	GW-GM	**WELL GRADED GRAVEL WITH SILT AND SAND (GW-GM)** - brn (7.5YR 4/2), 50% gravel up to 2" , 20% m sand, 20% c sand, 5% silt, 5% f sand, sand and gravel ang to subang, metamorphic.	Appears to be coarsening upward sequence 210 to 213 ft bgs
215				SW-SM	**WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)** - brn (7.5YR 4/3) with 10% dark greenish gray (GLEY1 4/10Y) mottling, 30% m sand, 25% c sand, 20% f sand, 15% gravel from 0.5" to 2", 10% silt, ang to subang, metamorphic with lt caliche development.	
220				SW	**WELL GRADED SAND WITH SILT AND GRAVEL (SW)** - brn (7.5YR 4/3), 40% m sand, 30% f sand, 20% c sand, 5% silt, 5% gravel, sand and gravel ang to subang, metamorphic, wet, moderate to strong caliche development, silt fabric with horizontally aligned gravels and c sand.	Core from 220 to 233 appears to be washed out from drilling process
				SP	**POORLY GRADED SAND (SP)** - dark grayish brn (2.5Y 4/2), 50% m sand, 50% c sand, subang, metamorphic, wet.	
225					**WELL GRADED SAND (SW)** - brn (7.5YR 5/3), 40% m sand, 30% c sand, 15% f sand, 10% gravel, 5% silt, sand and gravel ang to subang, metamorphic, wet, silt cementation. - 10% silt - reddish brn (5YR 4/3), 45% m sand, 5-10% silt, 10% f sand, 5-10% gravel .5 to 8 cm, moderate caliche development	
230		CC18	17			
235					- 60-70% m sand, 20% c sand, 5% silt, 5% gravel 0.5 - 2 cm - 45% m sand, 30% c sand, 5-10% silt, 10% f sand, 5-10% gravel 0.5 to 8 cm	
240					- 30% m sand, 30% c sand, 10-15% silt, 15% f sand, 10-15% gravel, some caliche, wet	
245						

CH2MHILL

PROJECT NUMBER:	BORING NUMBER:
326128.01.07.AR	MW-41

SOIL BORING LOG

PROJECT NAME: IM-3 Hydrogeologic Investigation, PG&E Topock		**HOLE DEPTH (ft):** 320.0	**DRILLING CONTRACTOR:** WDC Exploration & Wells, Montclair, CA	
SURFACE ELEVATION: 476.9 ft. MSL	**NORTHING (CCS NAD 27 Z 5):** 2,103,536.66	**EASTING (CCS NAD 27 Z 5):** 7,614,578.85	**DATE STARTED:** 10/22/2004	**DATE COMPLETED:** 11/05/2004
DRILLING METHOD: Rotosonic		**WATER LEVEL (ft):** ---	**DRILLING EQUIPMENT:** Gefco SS-15K-HL	
LOCATION: Bat Cave Wash, Parcel No. 650-151-06			**LOGGED BY:** T. McDonald	

DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/ NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.	COMMENTS DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.
250		CC19	10	SW	**WELL GRADED SAND (SW)** - brn (7.5YR 5/3), 40% m sand, 30% c sand, 15% f sand, 10% gravel, 5% silt, sand and gravel ang to subang, metamorphic, wet, silt cementation. - reddish brn (5YR 4/4), 5% red (10R 4/8), 5% grayish green (GLEY1 4/5G) mottled, 60-70% m sand, 10-15% silt, 15% f sand, 5% gravel, some caliche, silty consolidated - 40% f sand, 40% m sand, 10% c sand, 5% silt, 5% f gravel, very few c gravel of 4 to 5 cm, silty indurated, slit fabric with horizontal gravel, strongest at base	
255		CC20	9		- brn (10YR 5/3) matrix, 60% yellowish red (5YR 4/6), 20% v dark greenish gray GLEY2 3/5BG mottling, 30% f sand, 20% vf sand, 20% m sand, 15-20% silt, 5% c sand, 5% c gravel, few thin layers of 25-30% silt, abrupt lower boundary - reddish brn (5YR 4/4), 40% f sand, 35% c sand, 10% m sand, 10% f gravel up to 2 cm, 5% silt, gravel ang to subang, c sand ang to subround, metamorphic, wet, slit clay films on gravels	
260						
265		CC21	9		- red (2.5YR 4/4 to 4/6), 5-10% silt/clay, 30% f sand, 30% c sand, 20% m sand, 15% gravel, increased induration, v few weak clay films around gravels - strong caliche - 2 to 6 cm gravels from 267 to 268 ft bgs	
270						
275		CC22	5		- brn (5YR 4/4), 50% c sand, 25% f gravel up to 0.5", 10% f sand, 10% m sand, 5% clay/silt - v few spots of dk greenish gray (GLEY2 4/5BG) mottling, 40% f sand, 20% m sand, 20% c sand, 10% silt, 10% f gravel, well graded, silty indurated, moderate caliche, strongest in top 6 inches	
280					**SILTY SAND WITH GRAVEL (SM)** - dark reddish brn (2.5YR 3/3), 30% f sand, 25% silt, 20% c sand, 15% gravel, 10% m sand, subang, little metamorphic, wet, silty indurated, weathered.	

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326128.01.07.AR	MW-41

SOIL BORING LOG

PROJECT NAME: IM-3 Hydrogeologic Investigation, PG&E Topock		**HOLE DEPTH (ft):** 320.0	**DRILLING CONTRACTOR:** WDC Exploration & Wells, Montclair, CA	
SURFACE ELEVATION: 476.9 ft. MSL	**NORTHING (CCS NAD 27 Z 5):** 2,103,536.66	**EASTING (CCS NAD 27 Z 5):** 7,614,578.85	**DATE STARTED:** 10/22/2004	**DATE COMPLETED:** 11/05/2004
DRILLING METHOD: Rotosonic		**WATER LEVEL (ft):** ---	**DRILLING EQUIPMENT:** Gefco SS-15K-HL	
LOCATION: Bat Cave Wash, Parcel No. 650-151-06			**LOGGED BY:** T. McDonald	

DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/ NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.	COMMENTS DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.
285		CC23	5	SM	**SILTY SAND WITH GRAVEL (SM)** - dark reddish brn (2.5YR 3/3), 30% f sand, 25% silt, 20% c sand, 15% gravel, 10% m sand, subang, little metamorphic, wet, silty indurated, weathered.	
290		CC24	15	SW	**WELL GRADED SAND (SW)** - grayish brn (10YR 5/2), 40% m sand, 25% c sand, 15% f sand, 10% fines, 10% gravel to 0.5", sand and gravel ang to subang, some metamorphic, wet, silty indurated, trace caliche.	
295				SM	**SILTY SAND (SM)** - grayish brn (10YR 5/2), 30% m sand, 25% fines, 25% gravel, 20% c sand, 10% f sand, ang to subang, some metamorphic, wet, moderately indurated.	Angled bedding plane seen at 301' (photo)
300				SW	**SAND (SW)** - dark red (2.5YR 3/6) with brn (7.5YR4/3 clay layer, 30% m sand, 25% gravel up to 1.5", 20% c sand, 15% fines, 10% f sand, weathered bedrock, moderately indurated, wet.	
305		CC25	15	BR	**CONGLOMERATE (BR)** - dark reddish brn (2.5YR 3/3), 30% m sand, 30% c sand, 20% f sand, 10% fines, 10% gravel up to 1.5", ang to subang, dry, strongly indurated.	
				BR	**CONGLOMERATE (BR)** - reddish brn (2.5YR 4/4), 30% m sand, 30% c sand, 20% f sand, 10% fines, 10% gravel, gravel subrnd, dry.	
310				BR	**CONGLOMERATE (BR)** - reddish brn (2.5YR 4/3), 30% f sand, 20% fines, 20% c sand, 20% subang gravel up to 1", 10% m sand, wet.	
315					**CONGLOMERATE (BR)** - dark reddish brn (2.5YR 3/3), 30% m sand, 30% subang gravel to 1.5", 20% f sand, 10% fines, 10% c sand, dry, silty indurated, weathered.	

PROJECT NUMBER:	BORING NUMBER:
326128.01.07.AR	MW-41

SOIL BORING LOG

PROJECT NAME: IM-3 Hydrogeologic Investigation, PG&E Topock		**HOLE DEPTH (ft):** 320.0	**DRILLING CONTRACTOR:** WDC Exploration & Wells, Montclair, CA	
SURFACE ELEVATION: 476.9 ft. MSL	**NORTHING (CCS NAD 27 Z 5):** 2,103,536.66	**EASTING (CCS NAD 27 Z 5):** 7,614,578.85	**DATE STARTED:** 10/22/2004	**DATE COMPLETED:** 11/05/2004
DRILLING METHOD: Rotosonic		**WATER LEVEL (ft):** ---	**DRILLING EQUIPMENT:** Gefco SS-15K-HL	
LOCATION: Bat Cave Wash, Parcel No. 650-151-06			**LOGGED BY:** T. McDonald	

DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/ NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.	COMMENTS DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.
320		CC26	5	BR	**CONGLOMERATE (BR)** - dark reddish brn (2.5YR 3/3), 30% m sand, 30% subang gravel to 1.5", 20% f sand, 10% fines, 10% c sand, dry, silty indurated, weathered. - silty more indurated, moist	Well Completion: TD = 311.5' bgs; Screen Interval = 271 to 291 ft bgs; Filter Pack = 299 - 261 ft bgs; Stick-up Approx = 2.6 ft; Sump = 291 to 311 bgs
					Boring Terminated at 320 ft	

ABBREVIATIONS

cc = continuous core run
brn = brown
lt = light
dk = dark
vf = very fine-grained
f = fine-grained
m = medium-grained
c = coarse-grained
vc = very coarse-grained
ang = angular
subang = subangular
subrnd = subrounded
rnd = rounded
br = bedrock formation
ss = sandstone
conglom = conglomerate
comptd = compacted
qtz = quartz

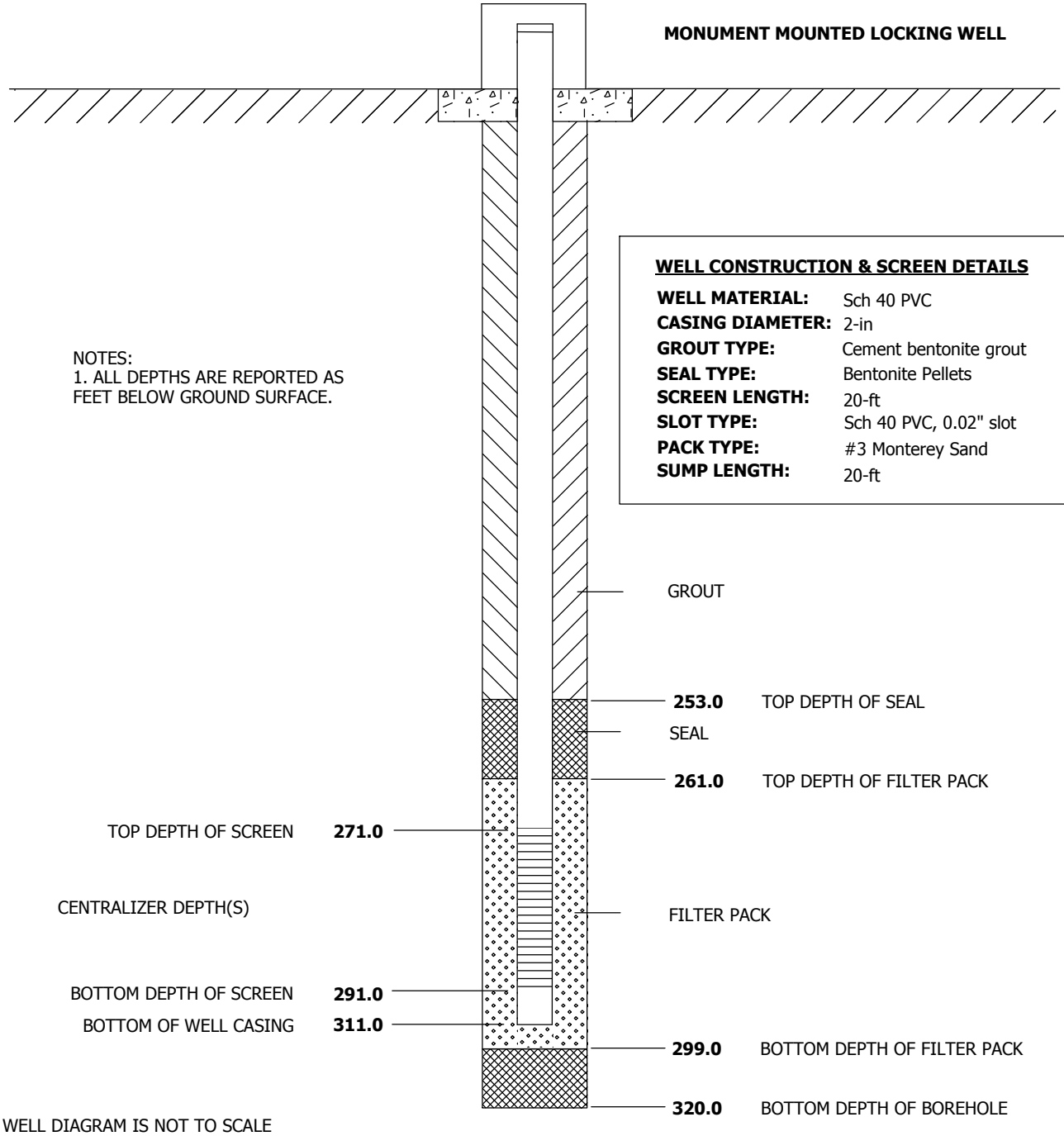
CH2MHILL

WELL COMPLETION DIAGRAM

PROJECT NO: 326128.01.07.AR	**PROJECT:** IM-3 Hydrogeologic Investigation, PG&E Topock	**WELL NO:** **MW-41D**

LOCATION: Bat Cave Wash, Parcel No. 650-151-06

DRILLING CONTRACTOR: WDC Exploration & Wells, Montclair, CA	**DRILLING START DATE:** 10/22/2004
DRILLING METHOD: Rotosonic	**DRILLING END DATE:** 11/05/2004
LOGGER: T. McDonald	**WELL COMPLETION DATE:** 11/05/2004
TOP OF WELL CASING (NGVD 29): 479.42	**NORTHING COORDINATE (CCS DAND 27, ZONE 5):** 2103536.66
GROUND SURFACE ELEVATION (NGVD 29): 476.88	**EASTING COORDINATE (CCS NAD 27 ZONE 5):** 7614578.85



WELL DIAGRAM IS NOT TO SCALE

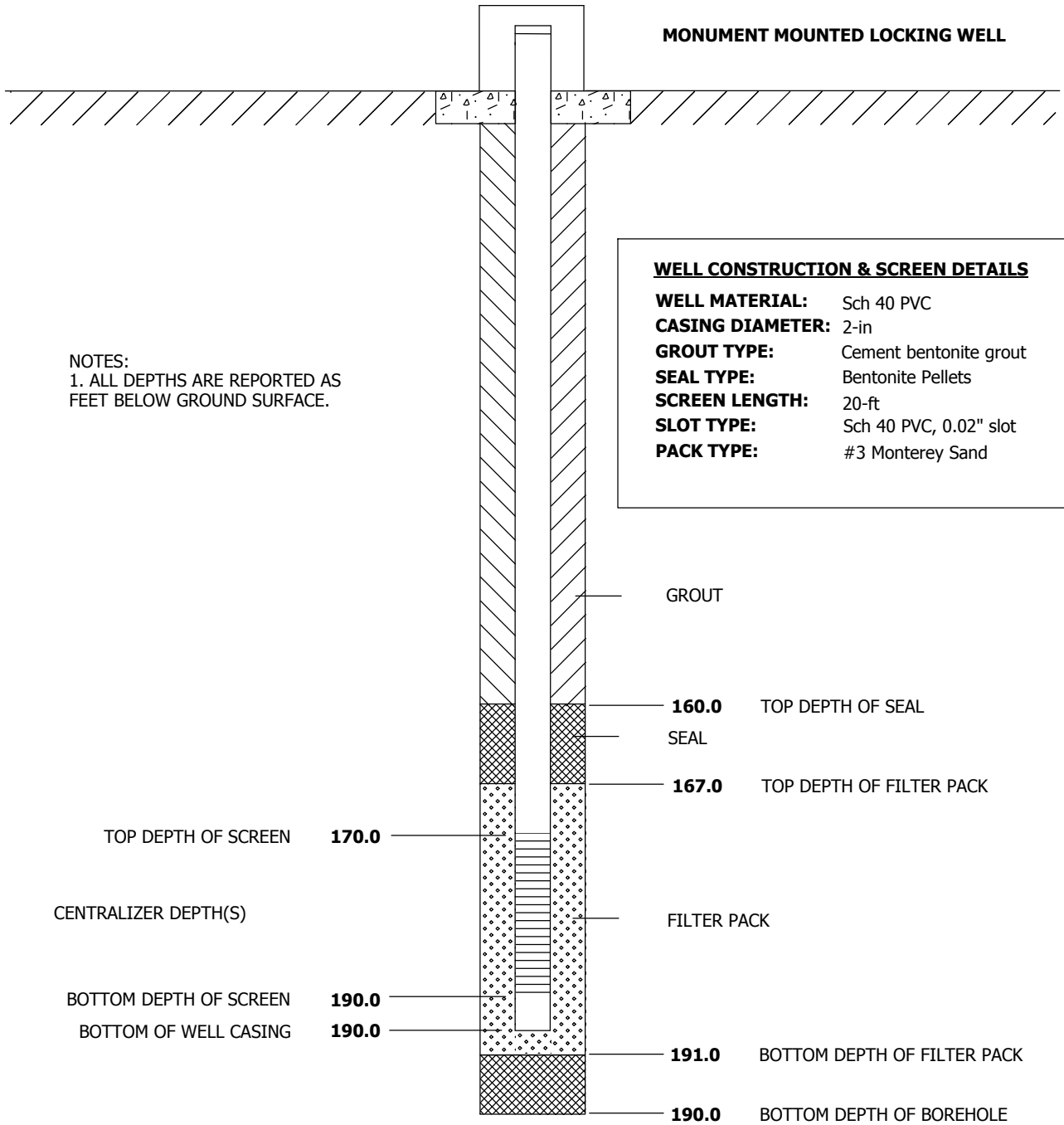
CH2MHILL

WELL COMPLETION DIAGRAM

PROJECT NO: 326128.01.07.AR	**PROJECT:** IM-3 Hydrogeologic Investigation, PG&E Topock	**WELL NO:** **MW-41M**

LOCATION: Bat Cave Wash, Parcel No. 650-151-06

DRILLING CONTRACTOR: WDC Exploration & Wells, Montclair, CA	**DRILLING START DATE:** 11/01/2004
DRILLING METHOD: Rotosonic	**DRILLING END DATE:** 11/01/2004
LOGGER: T. McDonald	**WELL COMPLETION DATE:** 11/07/2004
TOP OF WELL CASING (NGVD 29): 479.84	**NORTHING COORDINATE (CCS DAND 27, ZONE 5):** 2103527.41
GROUND SURFACE ELEVATION (NGVD 29): 477.06	**EASTING COORDINATE (CCS NAD 27 ZONE 5):** 7614583.19



WELL DIAGRAM IS NOT TO SCALE

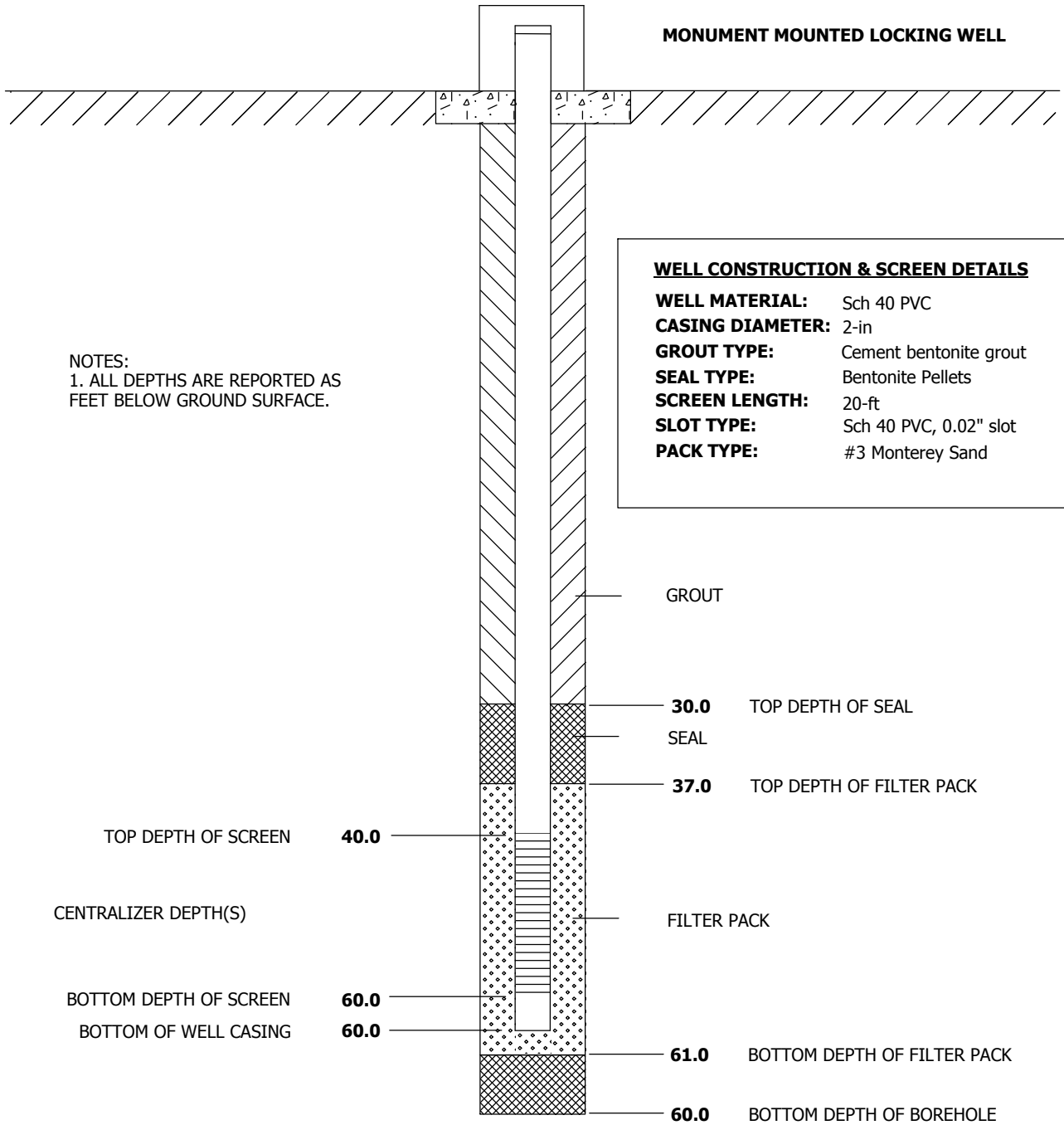
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WELL COMPLETION DIAGRAM

PROJECT NO: 326128.01.07.AR	**PROJECT:** IM-3 Hydrogeologic Investigation, PG&E Topock	**WELL NO:** **MW-41S**

LOCATION: Bat Cave Wash, Parcel No. 650-151-06

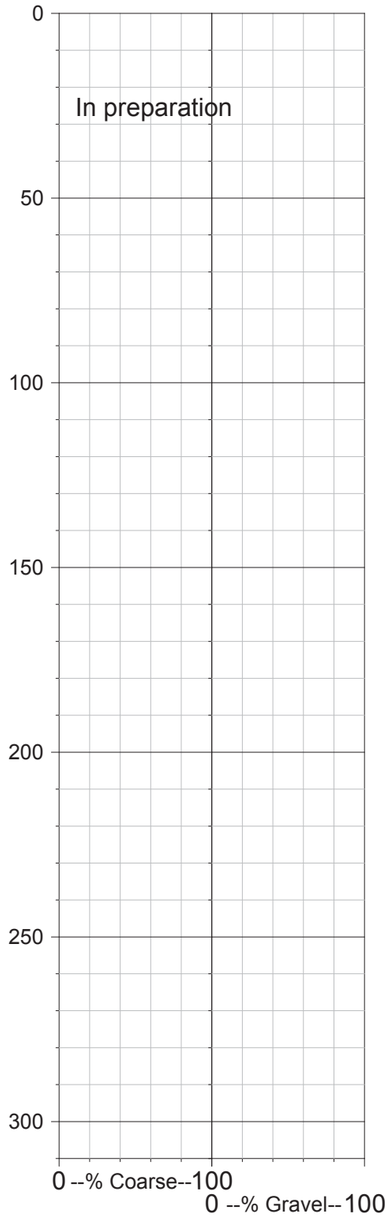
DRILLING CONTRACTOR: WDC Exploration & Wells, Montclair, CA	**DRILLING START DATE:** 11/01/2004
DRILLING METHOD: Rotosonic	**DRILLING END DATE:** 11/01/2004
LOGGER: T. McDonald	**WELL COMPLETION DATE:** 11/08/2004
TOP OF WELL CASING (NGVD 29): 480.07	**NORTHING COORDINATE (CCS DAND 27, ZONE 5):** 2103518.07
GROUND SURFACE ELEVATION (NGVD 29): 477.41	**EASTING COORDINATE (CCS NAD 27 ZONE 5):** 7614588.78



WELL DIAGRAM IS NOT TO SCALE

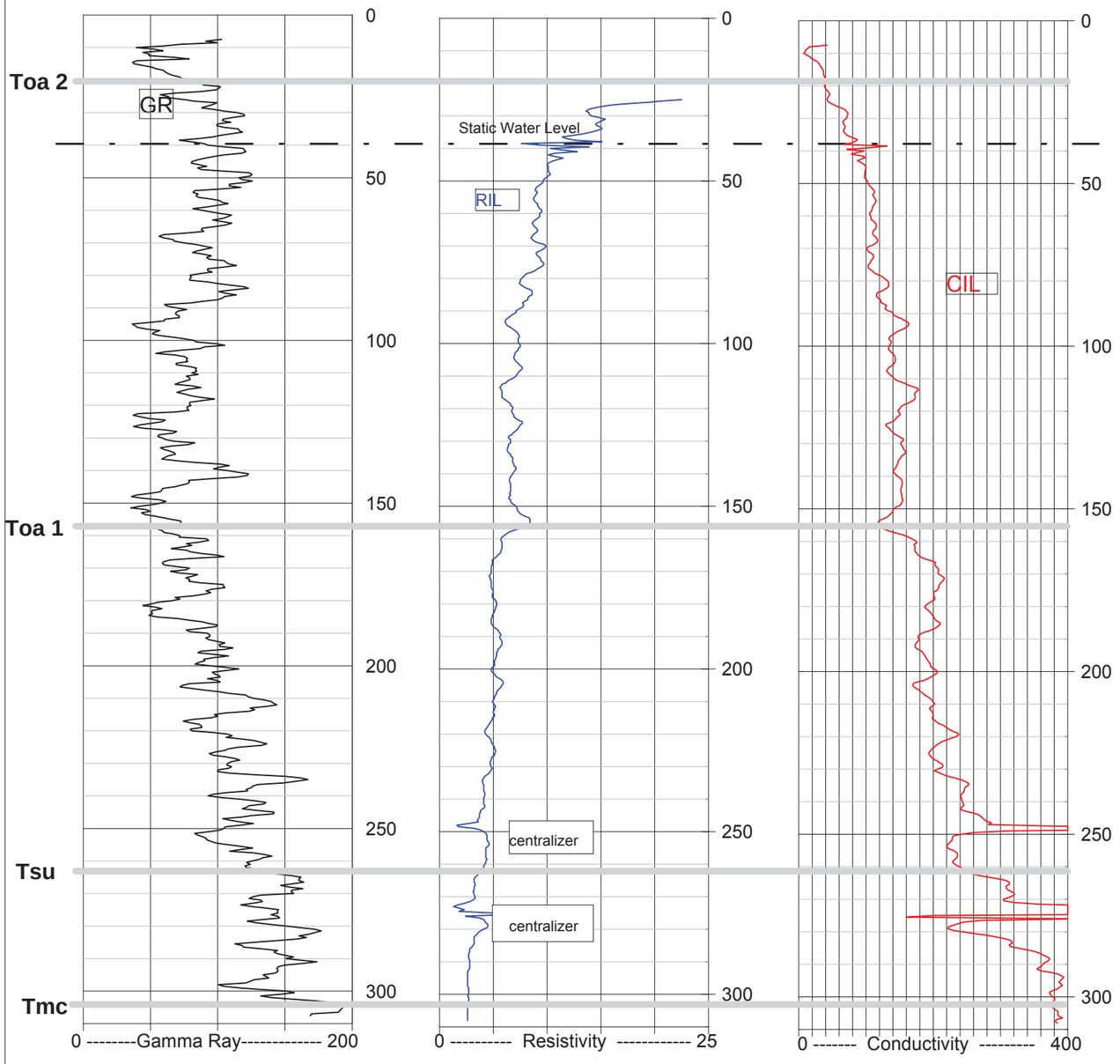
CH2MHILL

MW-41D Core Log



Plots show percentages of coarse sediment (> No. 200 sieve) and gravel-size fragments logged in MW-41D core.

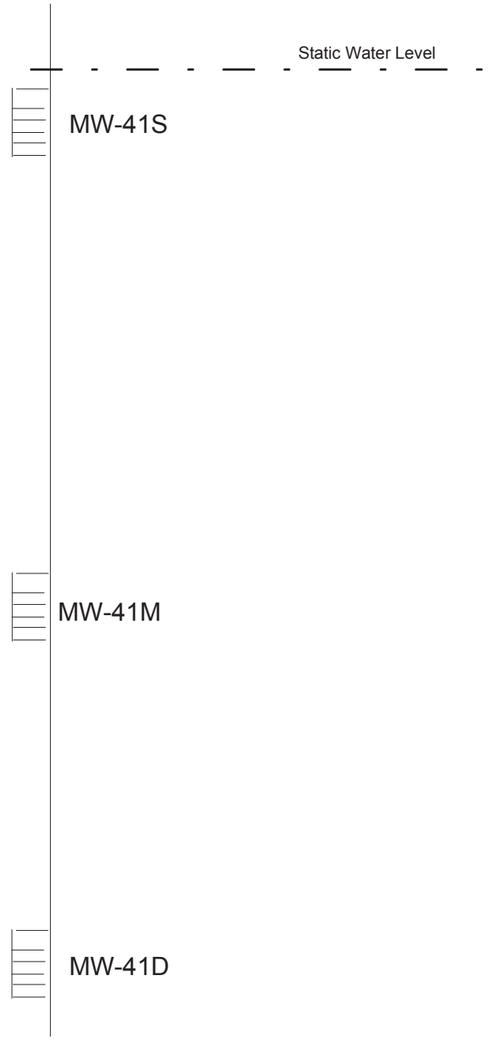
MW-41D Geophysical Logs



Cased Well Geophysical Log November 5, 2004

Log Units: Gamma Ray (API units), Induction Resistivity (ohm/m), Induction Conductivity (µS/cm)

MW-41 Well Cluster

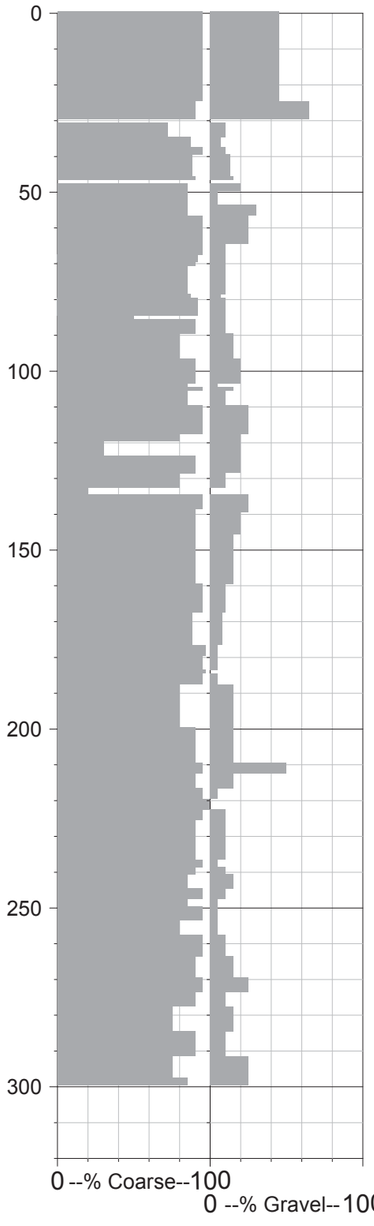


APPENDIX C-1D
SUMMARY OF HYDROGEOLOGIC LOGGING FOR MW-41 WELL CLUSTER
RCRA FACILITY INVESTIGATION/
REMEDIAL INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

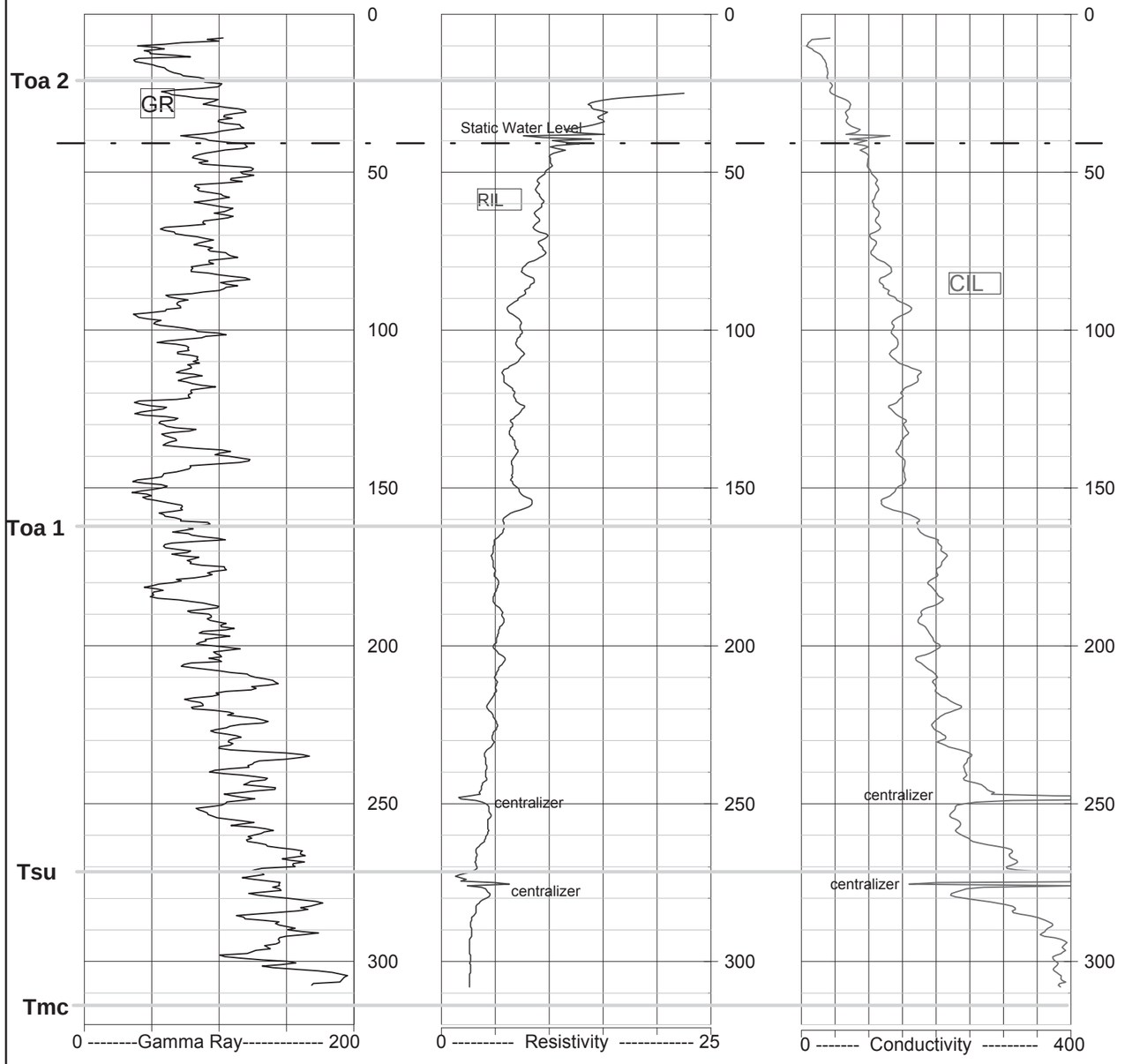
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MW-41D Core Log



Plots show percentages of coarse sediment (> No. 200 sieve) and gravel-size fragments logged in MW-41D core.

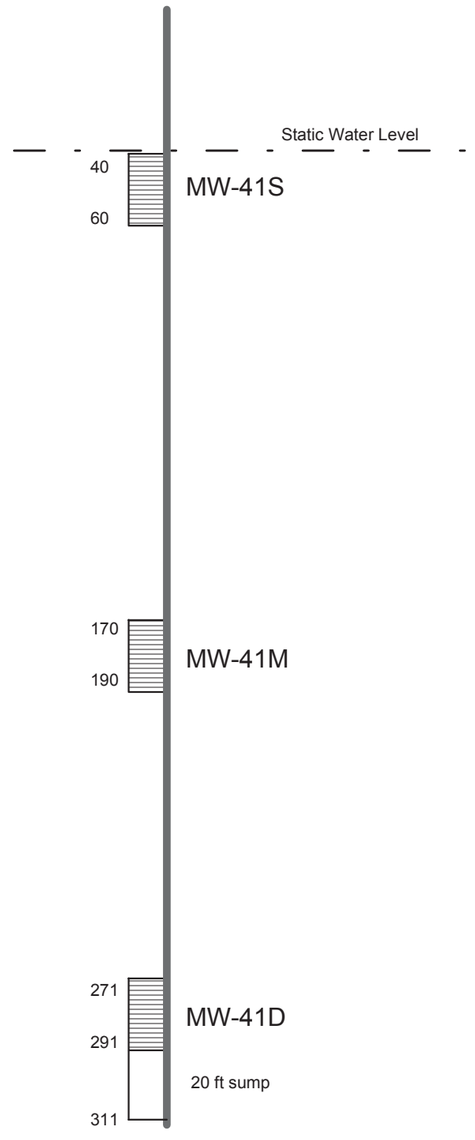
MW-41D Cased Well Geophysical Logs



Cased Well Geophysical Log November 5, 2004

Log Units: Gamma Ray (API units), Induction Resistivity (ohm/m), Induction Conductivity (µS/cm)

Monitoring Well Cluster MW-41



APPENDIX C-2A
SUMMARY OF HYDROGEOLOGIC LOGGING FOR MW-41 WELL CLUSTER

RCRA FACILITY INVESTIGATION/
REMEDIAL INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

SHEET 1 of 6	**PROJECT NUMBER:** 315024.IM.02	**BORING NUMBER:** TW-2

SOIL BORING LOG

PROJECT NAME: PG&E Topock IM Investigation (Phase 1 2004)		**HOLE DEPTH (ft):** 180.0	**DRILLING CONTRACTOR:** WDC Exploration and Wells, Montclair, CA	
SURFACE ELEVATION: 497.0 ft. MSL	**NORTHING (CCS NAD 27 Z 5):** 2,102,633.34	**EASTING (CCS NAD 27 Z 5):** 7,615,861.57	**DATE AND TIME STARTED:** 03/30/2004	**DATE AND TIME COMPLETED:** 04/01/2004
DRILLING METHOD: Mud Rotary		**WATER LEVEL (ft):** ---	**DRILLING EQUIPMENT:** Speedstar 30K Rig with 94-mm Punch Core	
LOCATION: MW-20 Bench			**LOGGED BY:** J. Sarabia	

DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/ NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.	COMMENTS DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.
5					No core	AM activities: rig-up, set conductor casing to 17' bgs with air rotary. P.M. activities: set up mud circulation system, drill direct 17'-40' bgs. 15:30 begin first core run
10						
15						
20						
25						
30						
35						

CH2MHILL

PROJECT NUMBER:	BORING NUMBER:
315024.IM.02	TW-2

SOIL BORING LOG

PROJECT NAME: PG&E Topock IM Investigation (Phase 1 2004)		**HOLE DEPTH (ft):** 180.0	**DRILLING CONTRACTOR:** WDC Exploration and Wells, Montclair, CA
SURFACE ELEVATION: 497.0 ft. MSL	**NORTHING (CCS NAD 27 Z 5):** 2,102,633.34	**EASTING (CCS NAD 27 Z 5):** 7,615,861.57	**DATE AND TIME STARTED:** 03/30/2004 / **DATE AND TIME COMPLETED:** 04/01/2004
DRILLING METHOD: Mud Rotary		**WATER LEVEL (ft):** ---	**DRILLING EQUIPMENT:** Speedstar 30K Rig with 94-mm Punch Core
LOCATION: MW-20 Bench			**LOGGED BY:** J. Sarabia

DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/ NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.	COMMENTS DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.
					No core	
40						
		CC124	0.75	SW	**WELL GRADED SAND WITH GRAVEL (SW)** - brn 10YR4/3, well graded sand, c silt, f gravel up to 3/4, subang to ang.	
		CC125	0.5	ML	**SILT WITH GRAVEL (ML)** - brn 10YR4/3, sand fraction nearly absent.	very slow coring
		CC126	3.5	SW	**WELL GRADED SAND WITH GRAVEL (SW)** - brn 10YR4/3, 80% well graded c silt to f gravel, m gravel up to 2, ang.	very slow - rig maxed out hard coring
45						
		CC127	0.5			very hard coring
		CC128	2			
		CC129	0.5	SM	**SILTY SAND WITH GRAVEL (SM)** - brn 10YR4/3, well graded c silt to 0.75 gravel, subang to ang, slight plasticity.	
50		CC130	2.25			
		CC131	0.75	SW	**WELL GRADED SAND WITH GRAVEL (SW)** - brn 10YR4/3, c silt, gravel up to 1, subang to subrnd.	
		CC132	3.5			moderate to hard coring, core is less dense/consolidated-remains intact after extraction from core barrel
55						
		CC133	0.5			
		CC134	1.5			very hard coring
		CC135	0			very hard coring, obstruction at 57' - will try to drill through with bit
		CC136	1.5			drill ahead to try to get through obstruction
60					- 1/8 to 1 ang gravel, subrnd cobbles to 2.5	attempt to core- no recovery hard coring
						cannot core, will drill ahead and attempt to core at 62' bgs
						attempted to core at 62'bgs - too many rocks, will drill to 65' bgs
65						
						attempted to core at 65'bgs - too many rocks, will drill ahead to 67' bgs and attempt to core
						attempted to core at 67'bgs - too many rocks, will drill ahead to 70' bgs and attempt to core
70						

CH2MHILL

PROJECT NUMBER:	BORING NUMBER:
315024.IM.02	TW-2

SOIL BORING LOG

PROJECT NAME: PG&E Topock IM Investigation (Phase 1 2004)		**HOLE DEPTH (ft):** 180.0	**DRILLING CONTRACTOR:** WDC Exploration and Wells, Montclair, CA	
SURFACE ELEVATION: 497.0 ft. MSL	**NORTHING (CCS NAD 27 Z 5):** 2,102,633.34	**EASTING (CCS NAD 27 Z 5):** 7,615,861.57	**DATE AND TIME STARTED:** 03/30/2004	**DATE AND TIME COMPLETED:** 04/01/2004
DRILLING METHOD: Mud Rotary		**WATER LEVEL (ft):** ---	**DRILLING EQUIPMENT:** Speedstar 30K Rig with 94-mm Punch Core	
LOCATION: MW-20 Bench			**LOGGED BY:** J. Sarabia	

DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/ NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.	COMMENTS DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.
				SW	**WELL GRADED SAND WITH GRAVEL (SW)** - brn 10YR4/3, c silt, gravel up to 1, subang to subrnd.	attempted to core at 70'bgs - refusal, will drill ahead
75						rig chatter significant in this zone, becomes progressively harder to drill with depth, and impossible to core (possible basal conglomerate)
80						at ~79.5 bgs, rig chatter subsides (possible lith, contact), will attempt to core at 80'bgs attempted to core at 80' bgs, could not advance the core barrel - will continue to attempt to get core.
85						attempted to core - could not advance core, will drill forward and attempt to core when lithology changes or 90' bgs (which ever comes first)
90						
					SILTY SAND WITH GRAVEL (SM) - brn 10YR4/3, silt.	core barrel cannot be advanced (too many rocks/ cobbles. Will continue to drill direct with tricone bit and attempt to core every 3-5 feet.
95						continued strong rig chatter. Still unable to advance core barrel
100				GM		
105						

CH2MHILL

PROJECT NUMBER:	BORING NUMBER:
315024.IM.02	TW-2

SOIL BORING LOG

PROJECT NAME: PG&E Topock IM Investigation (Phase 1 2004)		**HOLE DEPTH (ft):** 180.0	**DRILLING CONTRACTOR:** WDC Exploration and Wells, Montclair, CA
SURFACE ELEVATION: 497.0 ft. MSL	**NORTHING (CCS NAD 27 Z 5):** 2,102,633.34	**EASTING (CCS NAD 27 Z 5):** 7,615,861.57	**DATE AND TIME STARTED:** 03/30/2004 / **DATE AND TIME COMPLETED:** 04/01/2004
DRILLING METHOD: Mud Rotary		**WATER LEVEL (ft):** ---	**DRILLING EQUIPMENT:** Speedstar 30K Rig with 94-mm Punch Core
LOCATION: MW-20 Bench			**LOGGED BY:** J. Sarabia

DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/ NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.	COMMENTS DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.
					SILTY SAND WITH GRAVEL (SM) - brn 10YR4/3, silt.	
110						
		CC137	2.75		**WELL GRADED SAND WITH GRAVEL (SW)** - reddish brn 2.5YR4/4, well graded c silt, gravel up to 2, subang to ang, massive.	lithology still causing rig chatter, but will attempt core run.
115						partial core recovery; core color implies geologic contact
		CC138	1.75	SW		poor core recovery, punch coring bit has been chewed up due to cobbles/rocks. Well put on another bit. Very hard coring
120						
		CC139	1			
		CC140	1.75			hard to very hard coring
		CC141	2			very hard coring
125						
		CC142	0.5		**SILTY SAND (SM)** - reddish brn 2.5YR4/4, increasing silts and clays, ang gravel clasts, variable mineralogy, massive.	very hard coring
		CC143	4			hard coring - good core recovery and competence (less very large stones/cobbles, more cohesion in lithology)
130						
		CC144	2.5	SM		alternating moderate to hard coring
135						stones/cobbles stuck on both ends of returned core preventing better recovery
		CC145	2			moderate to easy coring
		CC146	2			
140						moderate coring difficulty

PROJECT NUMBER:	BORING NUMBER:
315024.IM.02	TW-2

SOIL BORING LOG

PROJECT NAME: PG&E Topock IM Investigation (Phase 1 2004)		**HOLE DEPTH (ft):** 180.0	**DRILLING CONTRACTOR:** WDC Exploration and Wells, Montclair, CA
SURFACE ELEVATION: 497.0 ft. MSL	**NORTHING (CCS NAD 27 Z 5):** 2,102,633.34	**EASTING (CCS NAD 27 Z 5):** 7,615,861.57	**DATE AND TIME STARTED:** 03/30/2004 / **DATE AND TIME COMPLETED:** 04/01/2004
DRILLING METHOD: Mud Rotary		**WATER LEVEL (ft):** ---	**DRILLING EQUIPMENT:** Speedstar 30K Rig with 94-mm Punch Core
LOCATION: MW-20 Bench			**LOGGED BY:** J. Sarabia

DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/ NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.	COMMENTS DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.
		CC147	3		**CLAYEY GRAVEL WITH SAND (SC)** - dk reddish brn 2.5YR3/4, well graded vf sand to 0.125, 20% gravel up to 2.	
		CC148	3			very easy coring
145				SC		
		CC149	3			very hard coring
		CC150	2			very hard coring, probable geologic contact at 150' very dense/tough material
150						
		CC151	0.5		**SILTY SAND WITH GRAVEL (SC)** - dk reddish brn 2.5YR3/4, well graded vf sand, 20% gravel 0.125 up to 2.	extremely hard coring
		CC152	1.5		- dark red, geologic contact, dense, lithified, stiff, rock-like	extremely hard coring, will drill 2.5'
						drill ahead due to difficult or impossible coring
155						
		CC153	2			extremely hard coring
		CC154	0.4			extremely hard core refusal
						drill ahead due to core refusal, will attempt to core again at 162' bgs
160						
						very slow drill with abundant rig chatter
		CC155	0.3			extremely hard core refusal at 6
						drill ahead due to core refusal, will attempt to core again at 167' bgs
165				SM		
						lots of rig chatter, very slow drilling
		CC156	0.5			extremely hard core, refusal at 6
						drill ahead due to core refusal
170						
						extremely slow drilling, abundant rig chatter, will attempt core run at 172'
		CC157	0.25			attempted core run, refusal at 3, will drill ahead
175						

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SHEET 6 of 6	**PROJECT NUMBER:** 315024.IM.02	**BORING NUMBER:** TW-2

SOIL BORING LOG

PROJECT NAME: PG&E Topock IM Investigation (Phase 1 2004)		**HOLE DEPTH (ft):** 180.0	**DRILLING CONTRACTOR:** WDC Exploration and Wells, Montclair, CA	
SURFACE ELEVATION: 497.0 ft. MSL	**NORTHING (CCS NAD 27 Z 5):** 2,102,633.34	**EASTING (CCS NAD 27 Z 5):** 7,615,861.57	**DATE AND TIME STARTED:** 03/30/2004	**DATE AND TIME COMPLETED:** 04/01/2004
DRILLING METHOD: Mud Rotary		**WATER LEVEL (ft):** ---	**DRILLING EQUIPMENT:** Speedstar 30K Rig with 94-mm Punch Core	
LOCATION: MW-20 Bench			**LOGGED BY:** J. Sarabia	

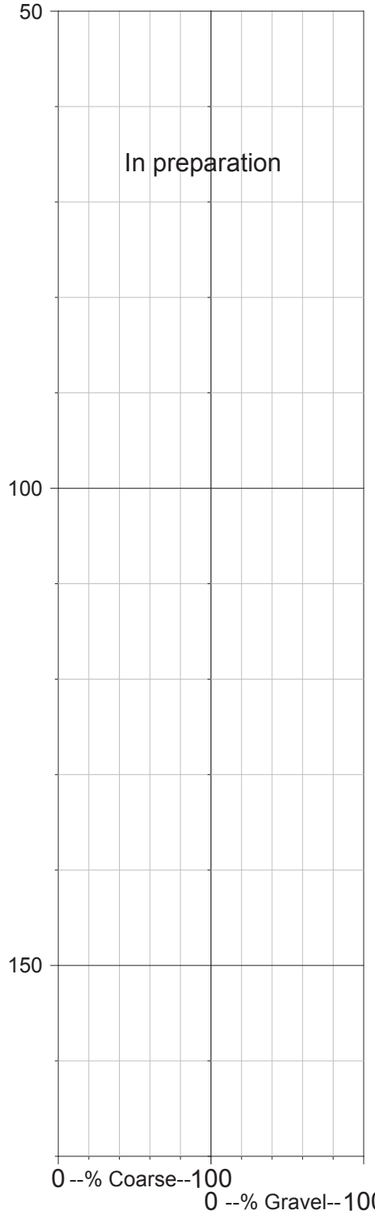
DEPTH BGS (feet)	SAMPLE INTERVAL	SAMPLE TYPE/ NUMBER	SAMPLE RECOVERY (ft)	USCS CODE	SOIL DESCRIPTION SOIL NAME, USCS SYMBOL, COLOR, PERCENT COMPOSITION, GRADING, GRAIN SHAPE, MINERALOGY, DENSITY/CONSISTENCY, STRUCTURE, MOISTURE.	COMMENTS DRILLING OBSERVATIONS AND OPERATIONS, DAILY START AND END TIMES , DRILL RATE, REFUSALS, SAMPLING AND TESTING NOTES.
180					**SILTY SAND WITH GRAVEL (SC)** Yellowish brown (10YR5/4), clayey silt and clasts, trace gravel, well graded vf sand, 20% gravel 0.125 up to 2.	extremely hard drilling to 180' bgs
					Boring Terminated at 180 ft	

ABBREVIATIONS

cc = continuous core run
brn = brown
lt = light
dk = dark
vf = very fine-grained
f = fine-grained
m = medium-grained
c = coarse-grained
vc = very coarse-grained
ang = angular
subang = subangular
subrnd = subrounded
rnd = rounded
br = bedrock formation
ss = sandstone
conglom = conglomerate
comptd = compacted
qtz = quartz

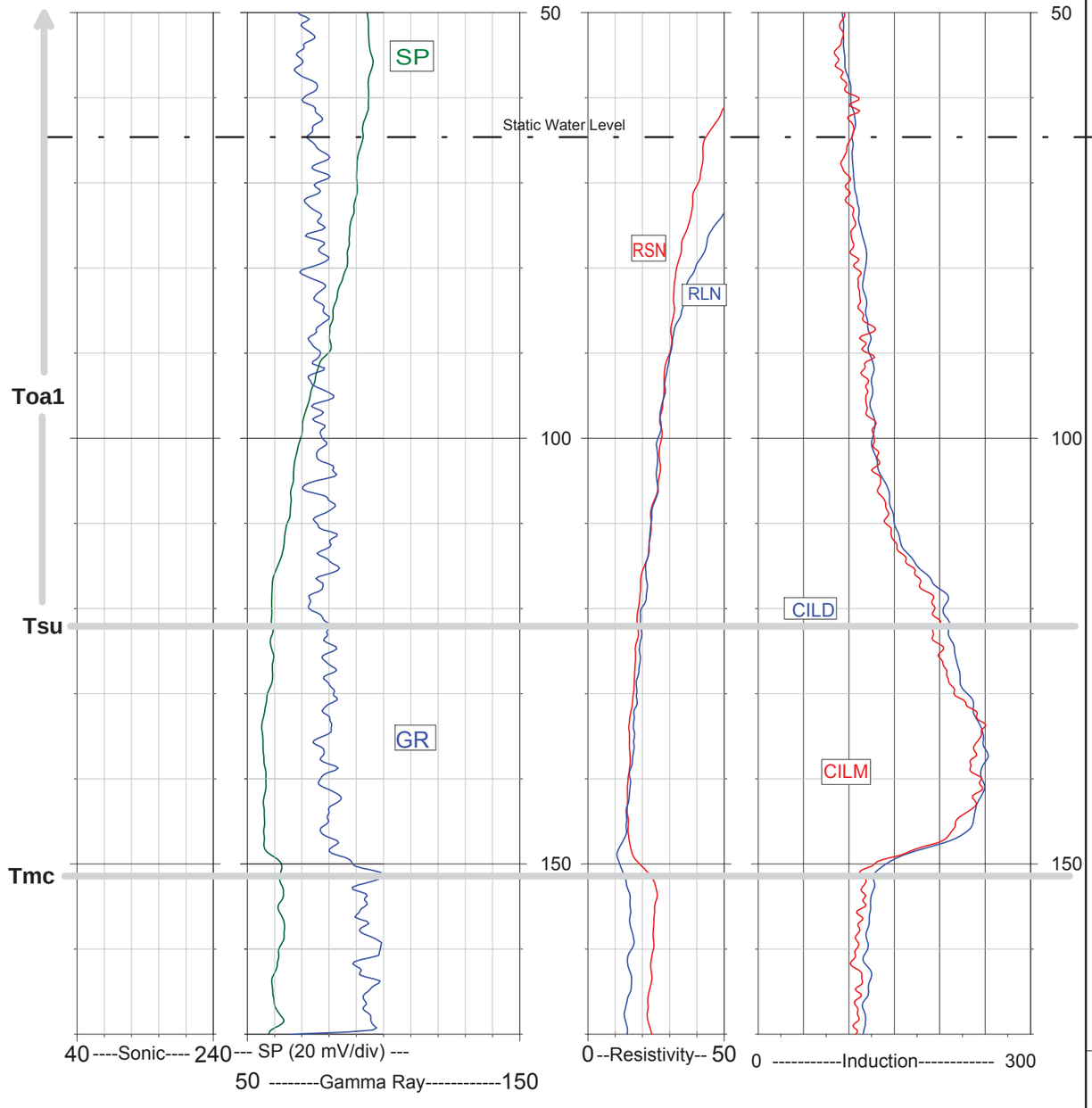
CH2MHILL

TW-2 Core Log



Plot shows percentages of coarse sediment (> No. 200 sieve) and gravel-size fragments logged in OW corehole adjacent to IW location. Core log depths adjusted to match ground surface datum for IW logs.

TW-2 Geophysical Logs

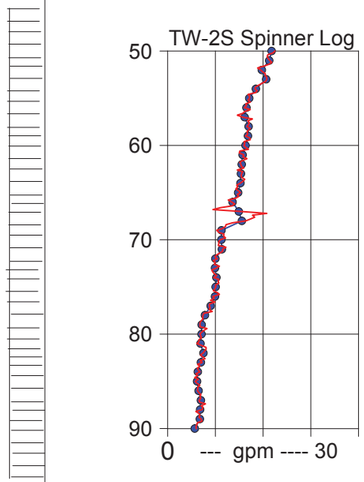


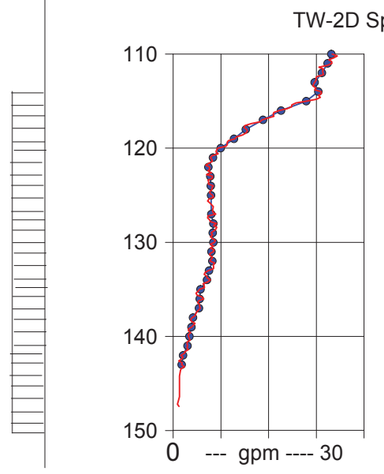
Cased Well Geophysical Log April 1, 2004

Log Units:
Sonic (µsecs/ft), SP (mV/div.), Gamma Ray (API units), Resistivity (RLN = 64" Normal (ohm/m), RSN = 16" Normal (ohm/m)), Induction (µS/m)

Well TW-2 Production Spinner Log

Log Date: May 10, 2004





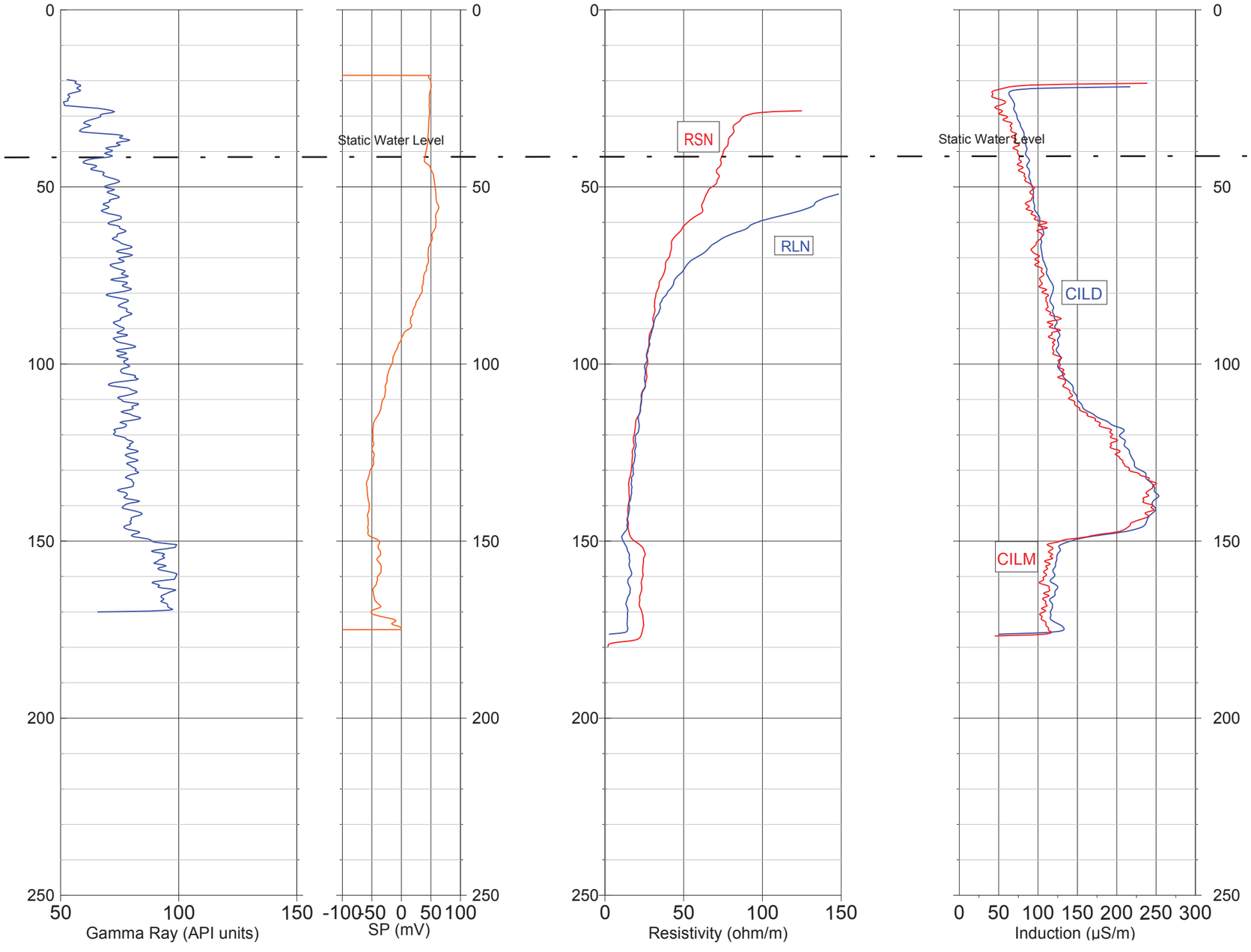
Spinner Logs Represent a combination of data from two Spinner tests.
One in TW-2S and one in TW-2D

TW-2S (screen 42-93 ft bgs) pumped at 18 pgm, pump at about 50 feet bgs
TW-2D (screen 113-148 ft bgs) pumped at 33 gpm, pump at about 80 ft bgs

APPENDIX C-1I
SUMMARY OF HYDROGEOLOGIC LOGGING AND TESTING FOR WELL TW-2

RCRA FACILITY INVESTIGATION/
REMEDIAL INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL



APPENDIX C-1J
TW-2 GEOPHYSICAL LOGS
RCRA FACILITY INVESTIGATION/
REMEDIAL INVESTIGATION REPORT (VOLUME 2)
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

ES102007005BAO_Appendix_C_figures.indd_022708_lho

PROJECT NUMBER:	BORING NUMBER:
326128.01.19.EW	*TW-3D*

SOIL BORING LOG

PROJECT NAME: PG&E Topock Interim Measures Extraction Well		**HOLE DEPTH (ft):** 157.0	**DRILLING CONTRACTOR:** Prosonic Corp., Phoenix, AZ	
SURFACE ELEVATION: 497.0 ft. MSL	**NORTHING (CCS NAD 83):** Approx. 2,102,627.34	**EASTING (CCS NAD 83):** Approx. 7,615,874.57	**DATE STARTED:** 10/20/2005 09:00	**DATE COMPLETED:** 10/24/2005 14:15
DRILLING METHOD: Rotosonic		**DRILLING EQUIPMENT:** Standard Rotosonic Rig		
LOCATION: MW-20 bench, approx. 13 ft. west and 6 ft. south of TW-2D		**LOGGED BY:** J. Piper		

DEPTH BGS (feet)	SAMPLE: INTERVAL	SAMPLE: RECOVERY (ft)	SAMPLE: PID (PPM)	SAMPLE: SOIL SAMPLE	USCS CODE	SOIL DESCRIPTION SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY
						- start coring at 9:00 AM 10/20/05 **Note:** TW-3D pilot boring (7") diameter) continuously cored using sonic core barrel system. No analytical sampling conducted during drilling.
5					SW	**GRAVELLY SAND WITH SILT (SW)** - dk yellowish brn (10YR4/2 to 5/4), 65% poorly sorted f-m sand, 30% rnd quartz, limestone, and vesicular basaltic gravel up to 15 cm (minor portion reworked? subang mm clasts), 5% silt, moist.
						- dry
10					SP	**POORLY GRADED SAND (SP)** - dk yellowish orange (10YR7/4 to 6/6), 95% well sorted f sand, 5% gravel up to 1 cm, loose, moist
15					SW	**GRAVELLY SAND (SW)** - dk yellowish brn (10YR4/2), 55% sand, 40% rnd qtz, limestone, and jasper gravel up to 4-5 cm, 5% fines
20						- 60% sand, no fines (coarsening downwards), rounded chert and limestone clasts up to 12 cm
25					GW	**WELL GRADED SANDY GRAVEL (GW)** - 10YR4/2, 60% rnd (fluvial) gravel up to 15 cm (diverse rock types), 40% sand
30					SW/GW	**GRAVELLY SILTY SAND (SW/GW)** - med brn (5YR4/4), 50% sand, 40% subang mm gravel with weathered rinds, 10% fines, weakly cemented
35						

PROJECT NUMBER: 326128.01.19.EW

BORING NUMBER: *TW-3D*

SOIL BORING LOG

PROJECT NAME: PG&E Topock Interim Measures Extraction Well		**HOLE DEPTH (ft):** 157.0	**DRILLING CONTRACTOR:** Prosonic Corp., Phoenix, AZ
SURFACE ELEVATION: 497.0 ft. MSL	**NORTHING (CCS NAD 83):** Approx. 2,102,627.34	**EASTING (CCS NAD 83):** Approx. 7,615,874.57	**DATE STARTED:** 10/20/2005 09:00 / **DATE COMPLETED:** 10/24/2005 14:15
DRILLING METHOD: Rotosonic		**DRILLING EQUIPMENT:** Standard Rotosonic Rig	
LOCATION: MW-20 bench, approx. 13 ft. west and 6 ft. south of TW-2D		**LOGGED BY:** J. Piper	

DEPTH BGS (feet)	SAMPLE: INTERVAL	SAMPLE: RECOVERY (ft)	SAMPLE: PID (PPM)	SAMPLE: SOIL SAMPLE	USCS CODE	SOIL DESCRIPTION SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY
					SW/GW	**GRAVELLY SILTY SAND (SW/GW)** - med brn (5YR4/4), 50% sand, 40% subang mm gravel with weathered rinds, 10% fines, weakly cemented
40					SW/SM	**GRAVELLY SILTY SAND (SW/SM)** - med brn (5YR4/4), 45% sand, 40% gravel up to 5 cm, 15% fines, slightly cohesive - weakly cemented, dry to moist
45					SM/GM	**SILTY GRAVEL WITH SAND (SM/GM)** - 45% gravel up to 9 cm, 40% sand, 20% fines
50					SM	- saturated conditions encountered at 47 ft. **GRAVELLY SILTY SAND (SM)** - med brn (5YR4/4), 55% sand, 30% fines, 15% gravel up to 3 cm, slightly plastic
55						- 55% sand, 25% gravel up to 5 cm, 20% fines, coarsening downwards
60					SW	**GRAVELLY SAND (SW)** - 5YR4/4-3/4, 55% poorly sorted sand, 40% subang weathered mm gravel up to 15 cm, 5% fines
65						- increasing sand and less fines, gravel up to 4 cm
					SM	**GRAVELLY SILTY SAND (SM)** - 45% sand, 30% gravel up to 7 cm, 25% clayey fines
					SW	**SAND WITH GRAVEL AND SILT (SW)** - 60% poorly sorted f-c sand, 25% mm gravel, 15% fines
70					GW	**SANDY GRAVEL (GW)** - 5YR5/2 - 10YR6/2, 70% fluvial (and some reworked? mm) gravel up to 8 cm, 27% sand, 3% fines

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PROJECT NUMBER: 326128.01.19.EW

BORING NUMBER: *TW-3D*

SOIL BORING LOG

PROJECT NAME: PG&E Topock Interim Measures Extraction Well		**HOLE DEPTH (ft):** 157.0	**DRILLING CONTRACTOR:** Prosonic Corp., Phoenix, AZ
SURFACE ELEVATION: 497.0 ft. MSL	**NORTHING (CCS NAD 83):** Approx. 2,102,627.34	**EASTING (CCS NAD 83):** Approx. 7,615,874.57	**DATE STARTED:** 10/20/2005 09:00 / **DATE COMPLETED:** 10/24/2005 14:15
DRILLING METHOD: Rotosonic		**DRILLING EQUIPMENT:** Standard Rotosonic Rig	
LOCATION: MW-20 bench, approx. 13 ft. west and 6 ft. south of TW-2D		**LOGGED BY:** J. Piper	

DEPTH BGS (feet)	SAMPLE: INTERVAL	SAMPLE: RECOVERY (ft)	SAMPLE: PID (PPM)	SAMPLE: SOIL SAMPLE	USCS CODE	SOIL DESCRIPTION SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY
75					GW	**SANDY GRAVEL (GW)** - 5YR5/2 - 10YR6/2, 70% fluvial (and some reworked? mm) gravel up to 8 cm, 27% sand, 3% fines - 65% ang to subang mm gravel up to 3 cm, 35% sand - 5YR4/4, 65% gravel up to 3 cm, 25% sand, 10% fines
80					SW	- end of drilling on 10/20/05 **SAND (SW)** - 60% sand, 30% gravel up to 9 cm, 10% fines, gradational contact (grades finer) - start of drilling at 8:45 10/21/05
85					SM	**GRAVELLY SAND WITH SILT AND CLAY (SM)** - 55% sand, 25% gravel up to 5 cm, 20% fines
90					SW	**SAND (SW)** - 55% m-c sand, 25% gravel up to 13 cm, 20% fines (clay increasing with depth), becoming slightly plastic - 50% sand, 35% gravel, 15% fines
95					GW	**SANDY GRAVEL (GW)** - 65% gravel up to 3 cm, 35% sand, 5% fines
100					GM/SM	**SILTY SAND AND GRAVEL (GM/SM)** - 5YR4/4, 40% sand, 40% mm gravel up to 13 cm, 20% fines
105					SW	**GRAVELLY SAND (SW)** - 52% well sorted m-c sand, 45% f gravel up to 2 cm, 3% fines - 62% gravel up to 15 cm, 35% sand, 3% fines
					GW	**GRAVEL WITH SAND (GW)** - 50% sand, 45% gravel up to 4 cm (90% of gravel is subang mm clasts, 10% is reworked? subrnd mm clasts), 5% fines

PROJECT NUMBER: 326128.01.19.EW

BORING NUMBER: *TW-3D*

SOIL BORING LOG

PROJECT NAME: PG&E Topock Interim Measures Extraction Well		**HOLE DEPTH (ft):** 157.0	**DRILLING CONTRACTOR:** Prosonic Corp., Phoenix, AZ	
SURFACE ELEVATION: 497.0 ft. MSL	**NORTHING (CCS NAD 83):** Approx. 2,102,627.34	**EASTING (CCS NAD 83):** Approx. 7,615,874.57	**DATE STARTED:** 10/20/2005 09:00	**DATE COMPLETED:** 10/24/2005 14:15
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DEPTH BGS (feet)	SAMPLE: INTERVAL	SAMPLE: RECOVERY (ft)	SAMPLE: PID (PPM)	SAMPLE: SOIL SAMPLE	USCS CODE	SOIL DESCRIPTION SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY
110					GW	**GRAVEL WITH SAND (GW)** - 50% sand, 45% gravel up to 4 cm (90% of gravel is subang mm clasts, 10% is reworked? subrnd mm clasts), 5% fines - 57% gravel up to 4 cm, 40% sand, 3% fines - 50% sand, 40% gravel, 10% fines
115					SW/SM	**GRAVELLY SILTY SAND (SW/SM)** - 5YR3/4, 55% sand, 25% gravel up to 3 cm, 20% fines
120					SM	**SILTY SAND (SM)** - 65% sand, 25% fines (clayey), 10% gravel, slightly plastic - clayey - clayey
125					SW	**GRAVELLY SAND (SW)** - 60% gravel up to 4 cm, 25% well sorted m-c sand, 15% fines
130					GW	**GRAVEL WITH SAND AND SILT (GW)** - 50% sand, 40% gravel up to 15 cm, 10% fines
					SM	**SILTY SAND (SM)** - 55% sand, 25% gravel (mm cobble), 20% fines
135					SW	**SAND WITH GRAVEL AND SILT (SW)** - 5YR4/4, 60% sand, 25% gravel up to 4 cm, 15% silty fines - maximum clast size decreasing
140					SM	**GRAVELLY SILTY SAND (SM)** - 50% sand, 40% gravel up to 3 cm, 10% fines
					SW	**GRAVELLY SAND (SW)** - 45% sand, 40% gravel up to 3 cm, 15% fines

PROJECT NUMBER:	BORING NUMBER:
326128.01.19.EW	*TW-3D*

SOIL BORING LOG

PROJECT NAME: PG&E Topock Interim Measures Extraction Well		**HOLE DEPTH (ft):** 157.0	**DRILLING CONTRACTOR:** Prosonic Corp., Phoenix, AZ	
SURFACE ELEVATION: 497.0 ft. MSL	**NORTHING (CCS NAD 83):** Approx. 2,102,627.34	**EASTING (CCS NAD 83):** Approx. 7,615,874.57	**DATE STARTED:** 10/20/2005 09:00	**DATE COMPLETED:** 10/24/2005 14:15
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LOCATION: MW-20 bench, approx. 13 ft. west and 6 ft. south of TW-2D		**LOGGED BY:** J. Piper		

DEPTH BGS (feet)	SAMPLE: INTERVAL	SAMPLE: RECOVERY (ft)	SAMPLE: PID (PPM)	SAMPLE: SOIL SAMPLE	USCS CODE	SOIL DESCRIPTION SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY
					GW	**SANDY GRAVEL (GW)** - 50% gravel up to 12 cm, 45% sand, 5% fines, grading finer downwards
145					SM	**GRAVEL WITH SAND AND SILT (SM)** - 60% gravel up to 15 cm, 35% sand, 5% fines - becoming stiff - transition to weathered bedrock
150						- stronger white CO3 cemented zones, mm clasts very weathered - 45% sand, 45% gravel up to 12 cm, 10% fines, weathered bedrock with (mm clasts), stiff, competent, moist - drilling becomes harder below 150 ft.
155					BR	**BEDROCK (BR)** - consolidated Miocene conglomerate, 45% gravel up to 15 cm, 40% sand, 15% fines, competent, dry, dark reddish brown - shattered, moist - shattered, dry bedrock - End of boring 16:30 10/21/05 - Enlarged borehole to 10.7" for installing extraction well TW-3D. See TW-3D installation report.
						Total Depth = 157 ft bgs

ABBREVIATIONS

brn = brown
lt = light
dk = dark
vf = very fine-grained
f = fine-grained
m = medium-grained
c = coarse-grained
ang = angular
subang = subangular
subrnd = subrounded
rnd = rounded
mm = metamorphic

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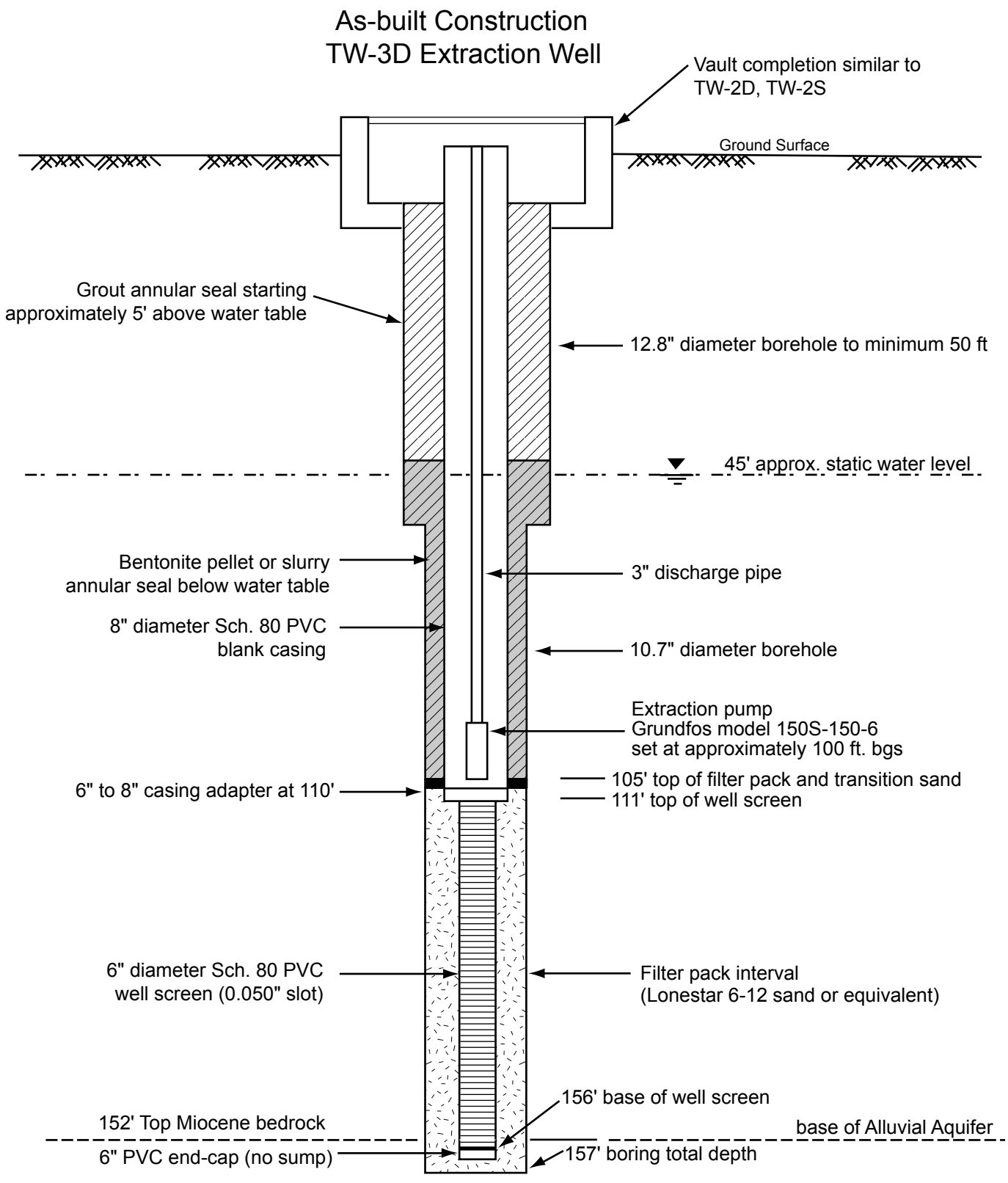


DIAGRAM NOT TO SCALE

Well screen selection reviewed with DTSC 10/21/05

Well TW-3D installed 10/26-27/05

FIGURE 3
WELL CONSTRUCTION DIAGRAM
TW-3D EXTRACTION WELL
IM NO. 3 GROUNDWATER EXTRACTION SYSTEM
PG&E TOPOCK COMPRESSOR STATION

CH2MHILL

ALISTO ENGINEERING GROUP
WALNUT CREEK, CALIFORNIA

LOG OF BORING XMW-9

SEE SITE PLAN

ALISTO PROJECT NO: *10-320-06* DATE DRILLED: *06/25/97*

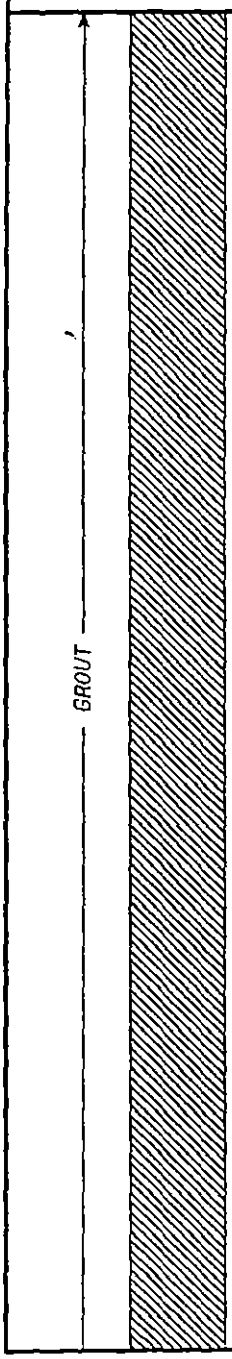
CLIENT: *Pacific Gas and Electric Company*

LOCATION: *Topock Compressor Station, Needles, CA*

DRILLING METHOD: *Resonant Sonic, Continuous Core*

DRILLING COMPANY: *Boart Longyear* CASING ELEVATION:

LOGGED BY: *Dan Salaices/ Dan Birch* APPROVED BY: *Dan Salaices*



DEPTH feet	SOIL CLASS	GEOLOGIC DESCRIPTION
	GP	GRAVEL: pinkish gray, yellowish gray, light medium gray; 4-70 mm, subangular.
		At 2 feet, sandy GRAVEL: light medium gray; 80% gravel, 4-8 mm; 40% sand, fine to coarse grained.
	SP	At 3 feet, GRAVEL: pinkish yellow, light medium gray; 80% gravel, 4-70 mm; 40% cobbles, fractured.
	GP/GC	ALLUVIUM/OLDER ALLUVIUM CONTACT AT 4 FEET. gravelly SAND: dark yellowish brown; 70% sand, fine to medium grained; 30% gravel, subangular to angular, various grays and browns.
10		sandy clayey GRAVEL: mottled olive gray to dark yellowish brown; 60-70% gravel, 4-40 mm, subangular to angular; 15-20% sand, fine to coarse grained; 10-25% fines; slightly moist.
	SP	gravelly SAND: dark yellowish brown; 70% sand, fine grained, minor coarse grained; 30% gravel, light medium gray, subangular, 4-20 mm; occasional fractured cobbles.
20		
	GP/GC	sandy clayey GRAVEL: mottled light olive gray to dark yellowish brown; 60% gravel, 4-20 mm, subangular, 0-15% cobble fragments; 20-30% sand, fine to coarse grained; 5-15% fines; slightly moist; slight to low plasticity.
30		
40		At 42 feet, 70-85% gravel.
	GP	sandy GRAVEL: light olive brown; 60% gravel, 4-30 mm, subangular, fractured cobbles; 20% sand, fine grained with minor coarse grained; slightly moist.
50		
	GP/GM	sandy silty GRAVEL: mottled dark yellowish brown to olive gray; 80% gravel, 4-30 mm, subangular and fractured; 10% sand, fine grained; 10% fines, moist.
60		
	CL	sandy CLAY: moderate brown; 40% sand, very fine; occasional fine gravel; low plasticity; moist.
	GP	Fractured cobbles.
	GM	sandy silty GRAVEL: light olive gray to moderate brown; 80% gravel, 4-50 mm, subangular to fractured; 10% sand, fine grained; 10% fines; moist.
	GP	RED FANGLOMERATE
		GRAVEL: moderate reddish brown; 90% gravel, 4-50 mm, appears crushed by drill bits, very angular; less than 10% sand/fines; dry.
		At 89 feet, color change to pale red.

ALISTO ENGINEERING GROUP
WALNUT CREEK, CALIFORNIA

LOG OF BORING XMW-9

BORING DIAGRAM	DEPTH feet	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
GROUT	80		GP	At 73 feet, color change to dark yellowish brown; material is very crushed and powdered; rock fragments are up to 100 mm and olive gray with dark reddish brown mineral coating on fractures.
				CHEMEHUEVI FORMATION: olive gray; very hard; old fracture surfaces with dark reddish brown mineral coating.
				Total depth of boring is 77.5 feet.
	90			
	100			
	110			
	120			
	130			
	140			
	150			

Geotechnical Investigation Report, Topock Compressor Station, Water Treatment Plant (CH2M HILL 2004)

Geotechnical Investigation Report
Topock Compressor Station
Water Treatment Plant

Prepared for

Pacific Gas & Electric Company

September 2004

CH2MHILL

9193 South Jamaica Street
Englewood, Colorado
80112

The following individuals have participated in the preparation and/or have completed quality review of this geotechnical report for the *Geotechnical Investigation Report, Topock Compressor Station Water Treatment Plant.*

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Exp. 12/31/05
GEOTECHNICAL
STATE OF CALIFORNIA

Contents

Page

Contents i

1.0 Introduction 1

1.1 Project Description 1

1.2 Objectives and Scope 1

1.3 Limitations 2

2.0 Technical Data 3

2.1 Field Exploration 3

2.1.1 Current Investigation 3

2.1.2 Previous Investigations 4

2.2 Laboratory Testing Program 4

3.0 Interpretation 5

3.1 Regional and Local Geology 5

3.2 Site Conditions 5

3.2.1 Surface 5

3.2.2 Subsurface 5

3.2.3 Engineering Parameters 6

3.3 Groundwater 7

3.4 Liquefaction 7

3.5 Expansion/Collapse 8

3.6 Settlement 8

3.7 Corrosion Conditions 8

3.8 Solubility 9

3.9 Seismicity 9

3.10 Frost Depth 10

4.0 Discussions and Recommendations 11

4.1 General 11

4.2 Water Treatment Plant 11

4.2.1 Facility Description 11

4.2.2 Recommendations 11

5.0 Construction Considerations 13

5.1 Trenching and Temporary Excavations 13

5.2 Pipeline Design 13

5.2.1 Pipe Zone Backfill 14

5.2.2 Trench Backfill 14

5.3 Roadways 14

5.4 Fill Placement and Compaction 15

5.5 Site Drainage 15

5.6 Geotechnical Observation 15

5.7 Review of Construction Plans and Specifications 15

6.0 References 16

Appendixes

A Soil Boring Logs
B Existing Monitoring Well Logs
C Laboratory Test Results

Tables

2-1 Soil Boring Summary
3-1 Generalized Subsurface Soil Profile and Design Strength Parameters
3-2 Summary of Laboratory Corrosion Tests
3-3 Summary of Laboratory Solubility Tests

Figures

1 General Location Map
2 Exploration Location Map

1.0 Introduction

1.1 Project Description

This report describes the results of a geotechnical investigation regarding construction of a new water treatment plant (WTP) for remediating contaminated groundwater at Pacific Gas and Electric Company's (PG&E's) Topock compressor station. The Topock site is located in eastern San Bernardino County, approximately 15 miles to the southeast of Needles, California. Figure 1 shows the Topock site and the location of WTP, while Figure 2 shows a detailed layout of the WTP and soil borings drilled during this investigation. The main purpose of this investigation was to provide site-specific data regarding geotechnical properties for foundation design and excavation in the existing ground, and to develop appropriate geotechnical design recommendations.

The water treatment plant is situated on Metropolitan Water District of Southern California (MWD) property and permission was required from MWD, as well as the Bureau of Land Management (BLM), to conduct the geotechnical investigation.

1.2 Objectives and Scope

The primary objective of CH2M HILL's geotechnical services was to provide appropriate geotechnical information for the foundation design of the water treatment plant. The geotechnical design criteria and recommendations described here were developed based on evaluation of available subsurface information, field exploration, laboratory testing, and engineering analyses.

The scope of work for this study includes the following tasks:

Task 1. Compile and Review Existing Information

This task involved compilation and review of available geologic and geotechnical information in the vicinity of the WTP. The following information was reviewed:

- Area geologic data
- Area monitoring well installation logs

Task 2. Field Exploration

This task included drilling four (4) soil borings within the treatment plant footprint. This task also included planning the field investigation, arranging for a drilling subcontractor, obtaining the necessary utility clearances for the work, and coordinating with the various parties involved.

Task 3. Laboratory Testing

A laboratory testing program was conducted on selected soil samples as required to determine pertinent engineering properties and to aid in soil classification.

Task 4. Engineering Evaluation

Engineering evaluations were carried out to aid in the development of geotechnical design and construction recommendations for the WTP.

Task 5. Geotechnical Report Preparation

This geotechnical report was prepared to document the methods and results of the field and laboratory investigations, and to provide geotechnical design criteria for various project facilities.

1.3 Limitations

This report has been prepared according to generally accepted principles and practices of geotechnical engineering applicable at the time of the work. No other warranty, express or implied, is made. This report is for the exclusive use of PG&E and CH2M HILL for specific application to the Topock water treatment plant project.

The analyses and recommendations contained in this report are based on the results of field exploration, laboratory testing, and engineering evaluation. The soil explorations indicate subsurface conditions only at specific locations and times, and only to the depths penetrated. They do not necessarily reflect strata variations that may exist between or outside such locations. If variations in subsurface conditions from those described are noted during construction, the recommendations in this report must be reevaluated.

If any significant changes in the nature, design, or location of the facilities are planned, the conclusions and recommendations contained in this report should not be considered valid unless the changes are reviewed and the conclusions of this report are modified or verified in writing by CH2M HILL. CH2M HILL is not responsible for any claims, damages, or liability associated with interpretation of subsurface data or reuse of the subsurface data or engineering analyses without the express written authorization of CH2M HILL.

We recommend that CH2M HILL be provided the opportunity to review the project plans and specifications to confirm that the intent of the geotechnical recommendations provided in this report has been appropriately incorporated.

2.0 Technical Data

2.1 Field Exploration

The geotechnical field exploration program conducted at the Topock water treatment plant site included site reconnaissance and drilling soil borings. The reconnaissance was performed to locate onsite utilities and to identify locations of soil borings.

2.1.1 Current Investigation

CH2M HILL conducted a field exploration at the project site on August 13, 2004. Four borings were advanced to depths ranging from 11.5 to 36.5 feet below existing ground surface. Approximate boring locations are shown on Figure 2. Locations were determined by measuring from existing site reference features.

Boring locations were selected to provide site-specific information below the proposed structure. Before drilling began, utility locates were requested so boring locations would avoid underground utility lines.

Kleinfelder, Inc. of Las Vegas, Nevada mobilized a truck-mounted B-61 drill rig to the site. Soil borings were advanced using 6-inch outside diameter hollow stem auger techniques.

Soil samples were obtained in borings by driving 1.4-inch ID split spoon samplers. The 1.4-inch ID sampler was driven by a 140-pound autohammer with a 30-inch drop in accordance with standard penetration test (SPT) procedures described in ASTM Standard D1586. Recovered soil samples obtained with the split spoon samplers were sealed in double plastic bags with locking tops to preserve the natural moisture content. Soil samples were typically obtained at 5-foot intervals throughout each boring. One sample was also obtained using a modified California sampler, but this method was abandoned due to the difficulty in obtaining a full sample in the sample liner.

Bulk samples were also obtained from each boring by taking a grab sample directly from the auger stem.

A CH2M HILL geotechnical engineer supervised drilling and sampling operations, and also logged soil borings and obtained representative soil samples. The soils encountered during drilling were visually classified in the field according to the Unified Soil Classification System (USCS). Table 2-1 provides a summary of the depth of the soil borings. Logs of the soil borings drilled during this study are included in Appendix A. A key sheet explaining terms used on the logs is also included in Appendix A.

All borings were terminated above the groundwater table; therefore, no groundwater levels were recorded. At the completion of drilling, all borings were backfilled with drill cuttings back to ground surface.

Table 2-1
Soil Boring Summary
Topock Water Treatment Plant

Soil Boring	Approximate Ground Surface Elevation (ft msl)	Depth Explored (ft bgs)
B-01	508	36.5
B-02	505	11.5
B-02A	505	15.0
B-03	508	31.5

2.1.2 Previous Investigations

Several monitoring wells have been installed throughout the Topock site to characterize and monitor the groundwater. The new water treatment plant is located north of the compressor station and Interstate 40, and west of Bat Cave Wash (see Figure 1). The closest monitoring well to the WTP site is approximately 400 feet away to the southeast (MW-13). The discussion of existing subsurface information will focus on three wells that have been installed near the WTP site (MW-13, MW-14, and MW-37D). These boring logs are included in Appendix B.

The logs for MW-13 and MW-14 indicate that the area consists of alternating layers of gravelly sand and sandy gravel down to an approximate elevation of 435 feet above mean sea level (msl). The log for MW-37D revealed gravelly sand with clay and sandy clay layers starting at an elevation of approximately 465 feet msl underlying the sandy gravel. The difference in material in this boring can be attributed to the fact that it was located in a wash that transports the finer material from higher elevations.

Groundwater elevations encountered during drilling range from 455 to 459.5 feet msl.

2.2 Laboratory Testing Program

Laboratory tests to determine pertinent geotechnical index and engineering properties on selected soil samples were performed by Kleinfelder, Inc. of Las Vegas, Nevada. Tests were conducted to confirm field classifications and provide additional data needed for geotechnical engineering analyses. Laboratory tests were conducted in accordance with American Society for Testing and Materials (ASTM) standards as follows:

- Moisture Content (ASTM D2216)
- Grain-size Analyses (ASTM D422 and D1140)
- Corrosion Potential (pH, resistivity, sulfates, chlorides)
- R-value (ASTM D2844)
- Solubility (AWWA test methods)

Laboratory test results are presented in Appendix C.

3.0 Interpretation

3.1 Regional and Local Geology

The Topock site is located in the Mojave Desert area southeast of Needles, CA and west of the Colorado River. The surficial soils consist of nonmarine sedimentary rocks and alluvial deposits of the Cenozoic period (California Geologic Survey, 2002). Volcanic rocks may also be present.

Logs from current borings and installation of monitoring wells indicate that the surficial soils consist of silty sands, sandy gravels and gravelly sands at depths of over 50 feet below ground surface. There is also evidence of sandy clay layers.

3.2 Site Conditions

The interpretation of site and subsurface conditions presented here has been developed from the soil borings, laboratory testing, and review of previous investigations.

3.2.1 Surface

The topography of the site is relatively flat with an elevation ranging between 505 and 510 feet above mean sea level (msl). Historic Route 66 runs north of the site. Bat Cave Wash runs east of the site into the Colorado River.

3.2.2 Subsurface

3.2.2.1 Soil Classification

In the preparation of this report, soil has been classified using the USCS per ASTM Standards D2487 and D2488. The relative consistency of the soil, used in the soil description, relies on the standard penetration test (SPT) blow count (N) that was obtained during the subsurface investigation.

3.2.2.2 General

A total of four borings (B-01 to B-03) were drilled across the site ranging in depth from 11.5 to 36.5 feet. Boring B-01 was drilled down to a depth of 36.5 feet near the southeast corner of the WTP footprint. Boring B-02 was located near the northwest corner of the WTP site and hit refusal at 11.5 feet. The drill rig was moved approximately 12 feet west where boring B-02A was drilled and the auger hit refusal at 15 feet. The driller stated that boulders were probably the cause of refusal in both borings. Boring B-03 was drilled at the center of the WTP site down to 31.5 feet. The soils encountered can be grouped into two general categories. These categories are silty sand with gravel, and poorly graded sand with silt and gravel. Not all soil categories are present at each location drilled. Discussions of individual soil categories, including locations encountered, are presented below.

3.2.2.3 Silty Sand with Gravel

The entire site appears to be underlain by a layer of silty sand with gravel ranging from 11.5 to 31.5 feet thick as identified in the borings. The consistency of the material ranged from medium dense to very dense, according to SPT blow counts. The sand was fine to coarse grained and the amount of gravel was estimated to range from 10 to 30 percent of the sample. The percentage of gravel increased with depth and the gravel sizes ranged from 1/8 to 2 inches.

The driller noted the presence of cobbles and boulders. In the deeper holes, there was no sample recovery after 15 feet, most likely due to the presence of cobbles obstructing the sampling tip. Boring B-02 and B-02A probably encountered large boulders at depths of 11.5 and 15 feet, respectively, causing auger refusal.

3.2.2.4 Poorly Graded Sand with Silt and Gravel

A 1.5 feet thick layer of poorly graded sand with silt and gravel was identified below the silty sand with gravel layer in Boring B-03 at a depth of 20 feet. The consistency of the material was very dense containing approximately 40 to 50 percent gravels ranging in size from 1/8 to 1/2 inch.

3.2.3 Engineering Parameters

Current and previous investigations and laboratory test results were used to develop the engineering properties of the subsurface materials. In addition to laboratory tests, SPT blow counts from various test borings were used to estimate equivalent friction angles for granular soils based on established correlations in the literature (Federal Highway Administration [FHWA], 1996).

The generalized soil profiles and material properties used for engineering analyses are presented in Table 3-1.

TABLE 3-1
Generalized Subsurface Soil Profile and Design Strength Parameters
Topock Water Treatment Plant

Geologic Unit	Approx. Elevation of Layer[1] (± feet)	Soil Type	Average Corrected[2] SPT N-Values (blows per foot)	Total Unit Weight [lbs/ft^3]	Friction Angle (degree)
		Boring B-01			
Alluvium	508 – 498	SMg	20	120	32
Alluvium	498 – 493	SMg	>50	120	35
Alluvium	493 – 474	SW-SM	>50	120	35
Alluvium	<474	SMg	>50	120	35
		Boring B-02			
Alluvium	505 – 495	SMg	46	120	32
Alluvium	<495	SMg	>50	120	35

TABLE 3-1
Generalized Subsurface Soil Profile and Design Strength Parameters
Topock Water Treatment Plant

Geologic Unit	Approx. Elevation of Layer[1] (± feet)	Soil Type	Average Corrected[2] SPT N-Values (blows per foot)	Total Unit Weight [lbs/ft^3]	Friction Angle (degree)
		Boring B-02A			
Alluvium	505 – 495	SMg	63	120	32
Alluvium	<495	SMg	>50	120	35
		Boring B-03			
Alluvium	508 – 498	SMg	44	120	32
Alluvium	498 – 488	SMg	>50	120	35
Alluvium	<488	SP-SM	>50	120	35

Notes:
1. Bottom of footing elevation for the proposed slab on grade at the treatment plant is approximately 2 feet below grade.
2. SPT blow counts corrected for overburden and efficiency.
3. Groundwater table was not encountered during current investigation.

3.3 Groundwater

The groundwater table was not encountered during the current investigation. The deepest boring (Boring B-01) was terminated at a depth of 36.5 feet below ground surface, or approximately elevation 471.5 feet msl. There was no surface flow in washes at the time the borings were performed. The groundwater table may fluctuate due to seasonal variation, nearby construction, irrigation, vegetation, and other man-made influences. Groundwater elevations in the monitoring wells nearby ranged from 455 to 459.5 feet msl.

3.4 Liquefaction

The term liquefaction, as used herein, describes a phenomenon in which a cohesionless saturated soil loses strength during an earthquake and acquires a degree of mobility sufficient to permit movements ranging from settlement to lateral spreading. The factors known to influence liquefaction potential include grain size, relative density, groundwater conditions, effective confining pressures, and intensity and duration of ground shaking. Saturated, loose and medium dense, near-surface cohesionless soils exhibit the highest liquefaction potential, while dry, dense cohesionless soils, and cohesive soils exhibit low to negligible liquefaction potential.

Generally, medium dense to very dense, silty sands and poorly graded silty sands underlie the proposed treatment plant site. Blow counts in the dry, silty sands were generally in the range of 20 to greater than 50. Therefore, liquefaction potential of the site soils is estimated to be low, especially where the groundwater is greater than 50 feet bgs.

3.5 Expansion/Collapse

Based on the medium dense to very dense granular material encountered at the project site, expansion and collapse potential is regarded as low.

3.6 Settlement

Primary consolidation settlement occurs when a load is applied to saturated compressible materials, causing an increase in pore water pressure (in excess of the static groundwater conditions) that results in a reduction in volume due to the expulsion of water from the pores of the soil (Fang, 1991). Based on the medium dense to very dense granular material encountered at the project site (above and below the proposed/existing footing elevation), and the relatively deep groundwater table (>45 feet), consolidation settlement is not considered an issue.

Secondary compression settlement is not a result of a reduction in volume due to the expulsion of water from the pores of the soil. It is the result of compression of bonds between individual particles after excess hydrostatic pressure is zero (Fang, 1991). Secondary compression settlement has been determined to be negligible.

3.7 Corrosion Conditions

Two samples collected at the site were tested for minimum soil resistivity, soil pH, water soluble sulfate content, and chloride content. The results of those laboratory tests are presented in Appendix C. Caltrans Bridge Memo to Designers 3-1 (Caltrans, 1998), regarding deep foundations, defines a corrosive environment as being a site where the soil has electrochemical resistivity of less than 1,000 ohm-centimeters (ohm-cm), a sulfate content greater than 2,000 parts per million (ppm), or chloride content of greater than 500 ppm. Comparison between the laboratory test results and the Caltrans corrosion criteria indicates that the onsite soils are considered to be corrosive to concrete structures. The results of the laboratory corrosion testing are summarized in Table 3-1. The Caltrans corrosion criteria should not be applied to piping and other metal structures. A corrosion engineer should review the test results and make recommendations for any metal structures.

Concrete in contact with onsite soil shall be batched using Type V cement in accordance with the 2001 California Building Code (CBC, 2001). Adequate concrete cover over reinforcing steel should be provided in accordance with good construction practices and design standards.

TABLE 3-2
Summary of Laboratory Corrosion Tests
Topock Water Treatment Plant

Boring	Sample Depth (ft)	Soil Type	Minimum Resistivity (ohm-cm)	pH	Sulfate Content (ppm)	Chloride Content (ppm)
B-01	6.5 – 8.0	SM	370	8.63	2,888	1,025
B-02	6.5 – 8.0	SM	725	8.67	3,988	350

3.8 Solubility

Due to the highly corrosive nature of the granular soil at the site, two soil samples were tested for solubility. Solubility refers to the potential for soluble particles to be present (i.e. salts, gypsum) that appear to be sand/gravel, but will dissolve when wet and cause excessive settlement. The results are shown in Table 3-3 and included in Appendix C.

TABLE 3-3
Summary of Solubility Tests
Topock Water Treatment Plant

Boring	Sample Depth (ft)	Soil Type	Solubility (%)
B-01	6.5 – 8.0	SM	0.79
B-03	5.0 – 6.5	SM	0.33

Local practice dictates that solubility results greater than 1.0 % require remedial efforts. Remedial efforts include mixing non-soluble soil with the soluble soil or pre-wetting the soluble soil. The solubility results are low at this site, so it is not expected to be an issue.

3.9 Seismicity

The proposed site is located in a seismically active region. The nearest faults that are considered capable of producing strong ground shaking are the Chemehuevi Graben Fault, Pahrump-Stateline Fault, and the Pisgah-Bullion Fault. The Chemehuevi Graben Fault, approximately 18.8 kilometers from the project site, is the controlling fault at the project site. The Chemehuevi Graben Fault is a normal style fault with a maximum credible earthquake (MCE) moment magnitude (M_w) of 6.0. The fault is classified as Seismic Source Type C, the project site lies in Seismic Zone 3, and the soil profile is classified as type S_D as defined in the California Building Code (CBC, 2001).

There are no Alquist-Priolo Fault-Rupture Hazard Zones in proximity to the project site, and no active faults are known to transect the proposed site. Therefore, the possibility of primary surface rupture or deformation at the site is considered low.

Site-specific probabilistic and deterministic analyses of ground motion were performed for active faults within the region using the computer programs EQFAULT and FRISKSP published by Thomas Blake (1998). The deterministic ground-motion analysis requires information regarding the fault geometry, maximum credible earthquake (MCE) magnitude of the fault, and a regional attenuation equation, which relates the relevant seismic parameters to the magnitude source and the source-site distance. Fault geometry was based on the CGS fault database for the State of California. Using the attenuation curves of Sadigh et al. (see Blake, 1998), probabilistic analyses indicate that a horizontal peak ground acceleration (HPGA) of 0.07g may be used for a 10 percent probability of exceedance in 50 years. Deterministic analyses indicate a peak ground acceleration (PGA) of 0.20g at the project site.

In order to verify the deterministic analysis, the results were compared to the California Seismic Hazard Map (Caltrans, 1996). Using this map, the peak bedrock acceleration at the site was estimated to be 0.20g. Additionally, the attenuation equation by Sadigh (Sadigh et al., 1997), which accounts for fault style and proximity, also estimated a peak bedrock acceleration of 0.20g based on distance to fault and fault MCE data from the Caltrans Seismic Hazard Map.

3.10 Frost Depth

According to a figure in NAVFAC DM 7.01-42 (1986), the depth of extreme frost penetration in the Needles, CA area is approximately 8 to 10 inches. Structures should be founded below this depth to mitigate frost heave potential.

4.0 Discussions and Recommendations

4.1 General

The soils at the Topock water treatment plant site consist primarily of alluvial deposits of silty sand with gravel and some poorly graded sand with silt and gravel. Groundwater was not encountered in any of the borings.

4.2 Water Treatment Plant

4.2.1 Facility Description

The water treatment plant consists of a prefabricated metal building with dimensions of approximately 50 feet by 140 feet built on a 6-inch concrete slab. The slab has a thickened edge that acts as a footing embedded approximately 2 feet below ground surface with a width of 2 feet. Tanks, compressors, and reactors will be installed inside the building and will sit on individual concrete footings also embedded 2 feet below ground surface with widths between 2 and 8.5 feet. There is also one area that will be excavated down to 12 feet bgs to accommodate a drain sump.

The existing ground will be leveled to build the WTP. One side will be cut and the other filled to make a level pad with a net fill of approximately 72 cubic yards. An access road with a ditch will surround the treatment plant facility. Site access will come from historic Route 66 at the north end of the site.

4.2.2 Recommendations

Shallow foundations are recommended for support of the water treatment plant. The depth of foundation support should be down to a minimum of 2 feet bgs.

The slab and footings should be set on a minimum 6-inch thick layer of granular base leveling course. The granular material should consist of well-graded sand and gravel with a maximum particle size of 3 inches and no more than 6 percent passing the No. 200 sieve. The granular material should be placed in 6-inch lifts and compacted to 95 percent of maximum dry density per ASTM D1557.

The native soil under the granular base course should be well compacted down to a depth of 12-inches to a minimum of 95 percent of maximum dry density per ASTM D1557 to provide a firm, unyielding surface. If the native soil under the granular course cannot be compacted to a minimum of 95 percent of maximum dry density per ASTM D1557, it should be removed to a maximum depth of 1 foot and replaced with competent granular backfill compacted in 6-inch lifts.

The foundation design should be based on an evaluation of the allowable bearing capacity, settlement, and sliding coefficient of friction.

4.2.2.1 Bearing Capacity

The allowable bearing capacity was determined, using soil parameters determined based on SPT blow counts and laboratory test results, for the soil at the proposed bottom of footing elevation. Calculations were based on methods proposed by Meyerhoff (1965), Bowles (1977), and Peck et al. (1974). All three methods are based on SPT blow counts in sandy soils, and all take into account an allowable settlement. For the purpose of design, an allowable settlement of 1 inch was used in the calculations. Based on the calculations, it was determined that the subgrade at or near the bottom of the proposed footings will have an allowable bearing capacity of 2,000 psf.

4.2.2.2 Sliding Coefficient of Friction

An ultimate sliding coefficient of friction equal to 0.45 may be used for foundation design. The recommended sliding coefficient of friction was estimated for mass concrete on silty medium to coarse sand through the use of a correlation table given in NAVFAC DM 7.2-63 (1986).

4.2.2.3 Cut and Fill Slopes

Cut slopes in the native soil are recommended to be 2H:1V or flatter. The native soil was classified as medium dense to very dense in the borings. In fill areas, the native soil should be placed in 6-inch lifts and compacted to 95 percent of maximum dry density per ASTM D1557.

Excavation of the overburden can be accomplished using conventional heavy earth-moving equipment. According to the boring logs, boulders and cobbles may be encountered in the excavation for the drain sump. The contractor should be aware of this possibility and be suitably prepared. All excavations should conform to OSHA, state, and local standards. Using OSHA criteria (CCH, 2000), the overburden soil would be classified as Type B.

5.0 Construction Considerations

5.1 Trenching and Temporary Excavations

The design of all temporary excavations (either braced or sloped) and work safety should be the responsibility of the contractor. Temporary excavations should be designed in accordance with the Occupational Safety and Health Administration's (OSHA) most recent revised standard for excavations. Adequate provisions should be made to protect the slopes from raveling and sloughing during construction. The design of the excavation wall support system is the responsibility of the contractor. The contractor should develop their own means and methods, based on experience and availability of materials, for constructing the required elements. Performance of the temporary construction must conform to the requirements stated in the contract documents. The analysis of the stability of the excavation and design of appropriate sheeting or shoring may require the contractor to hire a qualified professional engineer. Existing structures near the excavations shall be monitored during the excavation to detect any movement due to the excavations.

Soil types may mandate different types/styles of bracing or excavation support. However, regardless of soil type, excavation depth and configuration drive the requirement to brace or not to brace.

If groundwater is encountered in an excavation, instability may be created as a result of upward seepage of water into the cut if the water level inside the cut is lowered below the groundwater table. The design of the dewatering systems should consider these factors. It shall be the contractor's responsibility to install an appropriate dewatering system to achieve a proper working base for the subgrade of the excavation.

Temporary excavation bracing should be designed to protect adjacent traffic, utilities, and construction personnel. Suitable factors of safety should be used in the contractor's sheeting and bracing design.

During excavation, all equipment should be stored at a distance from the edge of the excavation equal to at least the depth of the excavation, so as not to produce a surcharge load, which could affect the stability of the slope. Temporary stockpiles of excavated materials should be stored well away from any settlement-sensitive utilities and pipelines.

5.2 Pipeline Design

It is our understanding that PVC or HDPE pipe will be used in the buried pipelines. The performance of the pipe is highly dependent on the support provided by the soils around it. Flexible pipe, such as PVC, normally is designed to transmit the load of the backfill over the pipe to the soil at the sides of the pipe. As the vertical load increases on the pipe, the vertical diameter of the pipe decreases and the horizontal diameter increases due to deformation of the pipe (i.e., the pipe becomes more elliptical). The increase in horizontal diameter is resisted by the soil at the sides of the pipe. The side soil must support the load without the pipe deflecting beyond acceptable limits. Thus, adequate soil support at the sides of the pipe is essential for the structural integrity of the pipe.

Along with depth of fill, unit weight of fill, and compaction of fill, the modulus of soil reaction, E', of the soil surrounding the trench is a parameter in flexible pipe design, because it controls the lateral support provided by the soil and, therefore, the deformation of the pipe. For the soils found along the project, an E' value of 1,000 pounds per square inch (psi) is recommended for pipe design. For the purposes of design, a total unit weight of 120 pounds per cubic foot (pcf) may be used for the fill above the pipeline.

5.2.1 Pipe Zone Backfill

The pipe zone backfill material placed surrounding the pipe from 6 inches below the invert to 1 foot above the top of pipe should be composed of sand, gravel, or crushed rock, that is reasonably well graded from coarse to fine with a maximum particle size of ½-inch, and free from excessive clay, organic material, and other deleterious substances.

Pipe zone backfill should be placed and spread in layers, not to exceed 6 inches loose thickness and compacted to at least 90 percent of the maximum dry density as determined by ASTM D1557, within 2 percent of the optimum moisture content. Compaction of the pipe zone backfill should be increased to 95 percent relative compaction (RC) in areas that are sensitive to surficial settlement. The contractor should be responsible for verifying that the pipe strength is adequate to withstand the weight and energy delivered by a compactor during the pipe backfill operation.

Although unanticipated, areas where weaker soil (e.g., soft clay or loose sand) is encountered during construction of the pipeline should be overexcavated a minimum depth of 1 foot below the proposed trench bottom and replaced with granular fill in 6-inch lifts compacted to 95 percent of the maximum dry density as determined by ASTM D1557.

5.2.2 Trench Backfill

Backfill material around structures and more than 1 foot above the top of the pipe (above the pipe zone backfill) may consist of excavated onsite soil. However, all topsoil, organic material, rubbish, debris, rock, and broken concrete larger than 2 inches in diameter and other unsuitable material should be removed prior to use as backfill. Rocks greater than 6 inches in any dimension should not be permitted in backfill placed within 1 foot of pavement subgrade.

Backfill should be placed and spread in layers, not to exceed 8 inches loose thickness and compacted to at least 90 percent of the maximum dry density as determined by ASTM D1557. Moisture conditions of backfill soils shall be at or above the optimum moisture content. Increased compaction is advised where greater sensitivity to surficial settlements may exist, so long as it does not damage or cause excessive deflections of the pipe.

5.3 Roadways

It is our understanding that the roadway around the WTP will consist of graded aggregate base course. No asphalt or Portland cement concrete pavement will be laid.

5.4 Fill Placement and Compaction

Native on-site materials may be considered for use as backfill if they have an expansion index (EI) less than 50, and contain less than 8 percent fines as determined in accordance with ASTM D4829 and D422, respectively. If native materials are considered, they should be tested for verification. The granular base course material shall be imported. The geotechnical engineer should approve the imported material prior to placement.

All fill soil should be placed in thin, loose lifts; moisture-conditioned, as necessary, to near optimum moisture content; and compacted to a minimum 95 percent relative compaction beneath structures as determined by ASTM D1557.

5.5 Site Drainage

Drainage is an important key to successful performance of any foundation or pavement scheme. Good surface drainage should be established prior to construction and maintained afterward to prevent water from ponding within or adjacent to the structures, or pavement areas. During and after construction, positive drainage should be provided to direct surface water away from structures and all excavations towards suitable, non-erosive drainage devices. Final grading should slope away from structures.

5.6 Geotechnical Observation

A geotechnical engineer or a technician under the supervision of a geotechnical engineer should observe the preparations for footing subgrades and backfill. Variations in soil and geologic conditions are possible and may be encountered during construction. To permit correlation between the exploration data and the actual conditions encountered during construction, a qualified geotechnical engineer should perform onsite reviews during construction.

5.7 Review of Construction Plans and Specifications

The geotechnical recommendations in this report are based on preliminary construction plans. The geotechnical designer should review construction plans and specifications to verify that the geotechnical recommendations have been incorporated into the design. If the nature, design, or location of the proposed facilities vary from those used to develop the recommendations provided in this report, then the recommendations should be re-evaluated.

6.0 References

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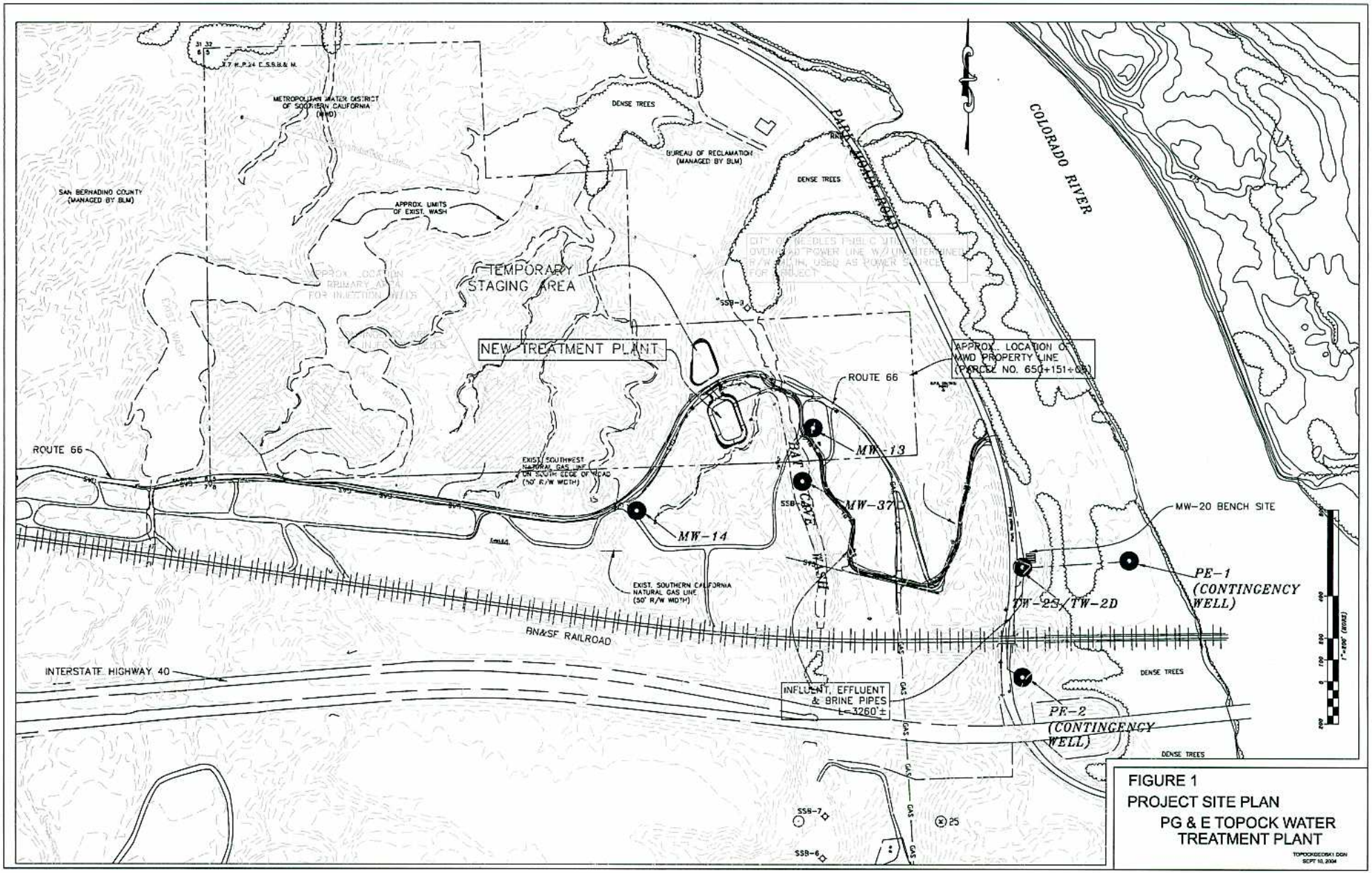


FIGURE 1
PROJECT SITE PLAN
PG & E TOPOCK WATER TREATMENT PLANT

TOPOCKDECDSK1.DGN
SEPT 10, 2004

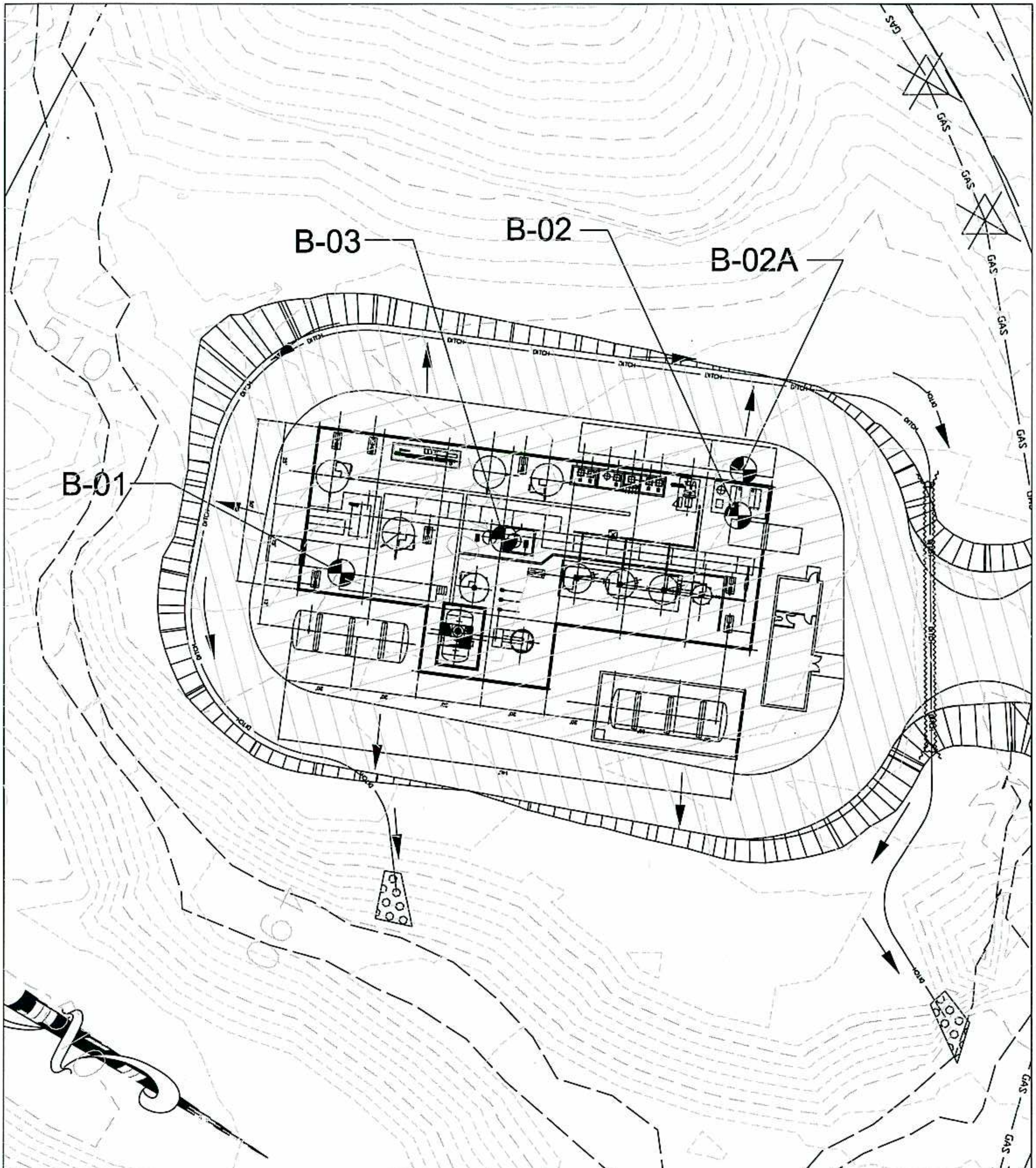


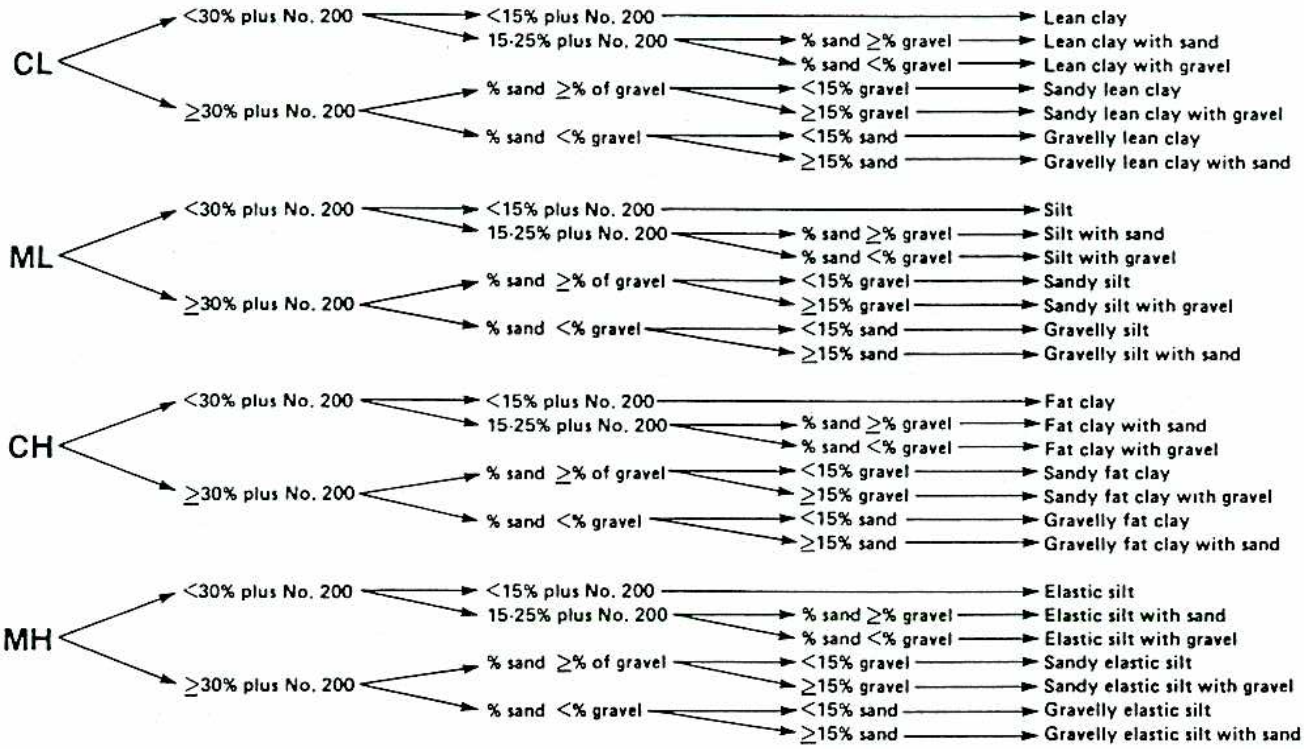
FIGURE 2
BORING LOCATIONS
PG & E TOPOCK WATER TREATMENT PLANT

TOPOCKGEOSK2.DGN
08/23/04

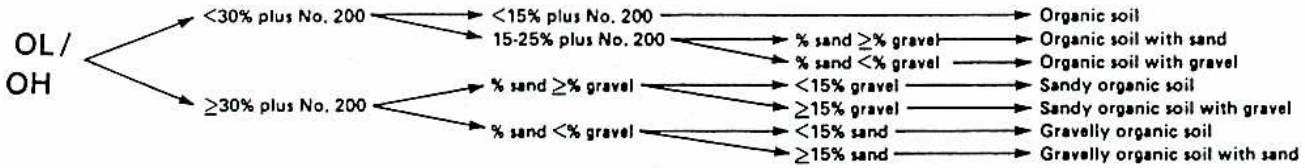
APPENDIX A

Soil Boring Logs

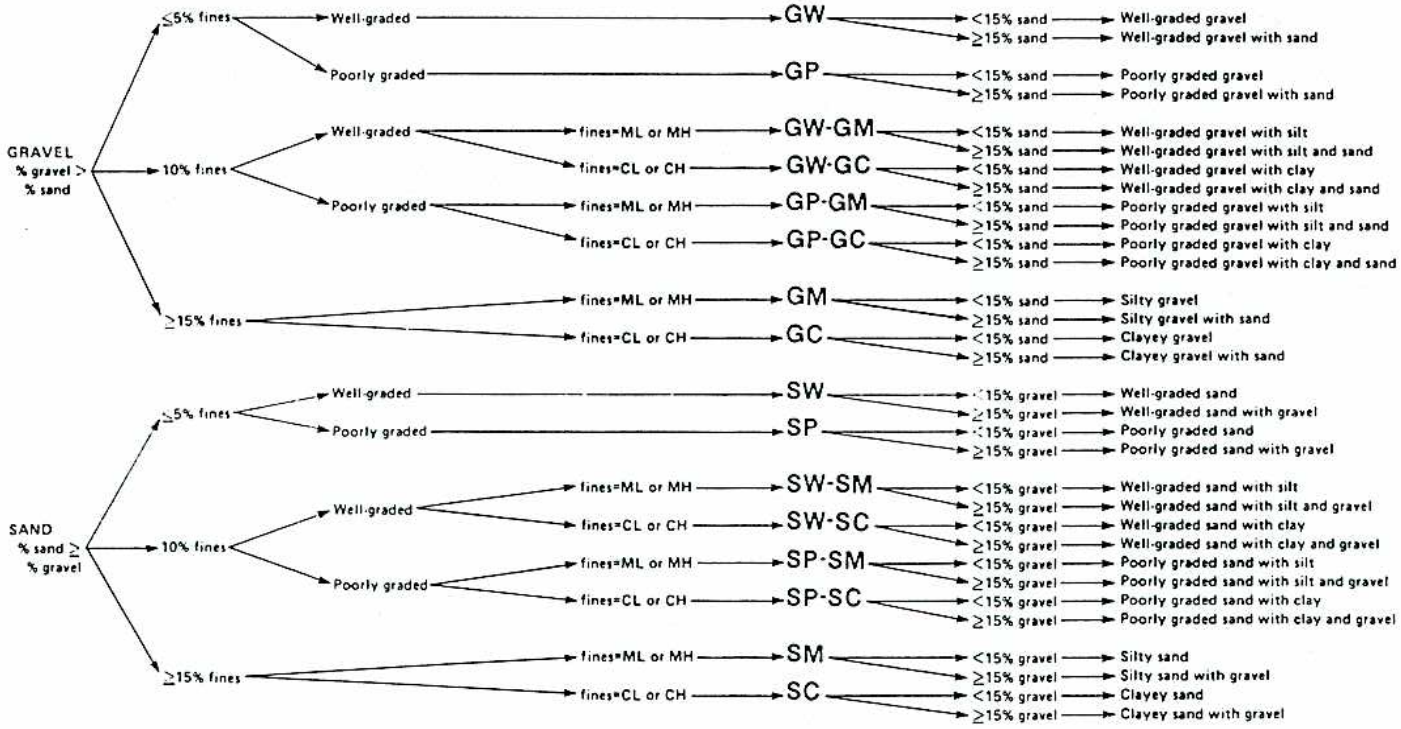
FLOW CHART FOR IDENTIFYING INORGANIC FINE–GRAINED SOIL (50% OR MORE FINES)



FLOW CHART FOR IDENTIFYING ORGANIC FINE–GRAINED SOIL (50% OR MORE FINES)



FLOW CHART FOR IDENTIFYING COARSE–GRAINED SOILS (LESS THAN 50% FINES)



ANC10.51 SoilCla NO
Rev 0 11/5/93

CH2MHILL

Soil Classification System Used on Logs (From ASTM D2488, Based on Unified Soil Classification System)

TERMS USED ON LOGS

Criteria for Describing Moisture Condition

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp, but no visible water
Wet	Visible free water, usually soil is below water table

Relative Density of Coarse-Grained Soil

Blows/ Foot*	Description	Approximate Relative Density (%)	Field Test
0-4	Very loose	0-20	Easily penetrated with 1/2-inch steel rod pushed by hand
5-10	Loose	20-40	Easily penetrated with 1/2-inch steel rod pushed by hand
11-30	Medium	40-70	Easily penetrated with 1/2-inch steel rod driven with 5-pound hammer
31-50	Dense	70-90	Penetrated a foot with 1/2-inch steel rod driven with 5-pound hammer
50	Very Dense	90-100	Penetrated only a few inches with 1/2-inch steel rod driven with 5-pound hammer

Consistency of Fine-Grained Soil

Blows/ Foot*	Consistency	Pocket Penetrometer (TSF)	Torvane (TSF)	Field Test
<2	Very soft	<0.25	<0.12	Easily penetrated several inches by fist
2-4	Soft	0.25-0.50	<0.12-0.25	Easily penetrated several inches by thumb
5-8	Firm	0.50-1.0	0.25-0.5	Can be penetrated several inches by thumb with moderate effort
9-15	Stiff	1.0-2.0	0.5-1.0	Readily indented by thumbnail, but penetrated only with great effort
16-30	Very stiff	2.0-4.0	1.0-2.0	Readily indented by thumbnail
30	Hard	>4.0	>2.0	Indented with difficulty by thumbnail

*The number of blows on a 2-inch OD, split-spoon sampler by a 140-pound hammer falling 30 inches required to drive the sampler a distance of 1 foot from 6 to 18 inches (Standard Penetration Test, ASTM D1586). Actual sampler/hammer characteristics and actual field blow counts are noted on the boring logs.

Source: Sowers, 1979.

CH2MHILL

PROJECT NUMBER:	BORING NUMBER: SHEET 1 OF 1

BORING LOG EXPLANATION

PROJECT : LOCATION :

ELEVATION : DRILLING CONTRACTOR :

DRILLING METHOD AND EQUIPMENT :

WATER LEVELS : START : END : LOGGER :

DEPTH BELOW GROUND SURFACE (ft)	DEPTH BELOW GROUND SURFACE (m)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
		1.0				Sample Interval: Top/Bottom (ft. bgs) Amount of Sample Recovered (ft)	Comments
		2.5	1.5				Comments and observations regarding drilling or sampling made by the driller or field personnel.
	1	3.5				Sample Type - Sample Number	Test
5		5.0		S-1		(S) Standard split-spoon drive sampler, 2.0-inch (51-mm) outside diameter, 1.4-inch (35-mm) inside diameter (without liners)	Field and Laboratory tests include the following:
	2					(M) Modified split-spoon drive sampler, 2.5-inch (64-mm) outside diameter, 2.0-inch (51-mm) inside diameter (with liners)	WC Moisture Content (ASTM D-2216)
10	3					(MC) Modified California split-spoon drive sampler, 3.0-inch (76-mm) outside diameter, 2.4-inch (64-mm) inside diameter (with liners)	UW Dry Unit Weight (ASTM D-2937) in pounds per cubic foot (pcf) or kilonewtons per cubic meter (kN/m3)
	4					(ST) Thin-walled Shelby tube sampler, 3.0-inch (76-mm) outside diameter, 2.9-inch (74-mm) inside diameter	SA Seive analysis (ASTM D-1140) See appropriate laboratory data sheets for gradation curve
15		15.0				(G) Grab sample collected from drill cuttings	p200 Percentage of soil particles passing the No.200 sieve (ASTM D-422)
	5	16.5			3-5-6 (11)	Standard Penetration Test Results	HD Standard hydrometer analysis
						Number of blows required to advance driven sampler over three 6-inch (152-mm) increments. Number in parenthesis is the total number of blows required to advance the sampler 12-inch (305 mm) beyond the first 6-inch (152-mm) interval. Drive samplers advanced using a 140 lb (63.5 kg) Hammer with the 30-inch (762-mm) drop. The blow counts given have not been modified to account for field and/or depth conditions.	LL Atterberg Limits (ASTM D-4318) PL LL = Liquid Limit, PL = Plastic Limit, PI PI = Plasticity Index
20	6						PP Unconfined Compressive Strength in tons per square foot (tsf) or kilopascals (kPa) measured using a pocket penetrometer device
	7					General Notes	TV Unconfined Compressive Strength in tsf or kPa measured using a torvane device
25						1) Soil classifications are based on the Unified Soil Classification System. Classifications and descriptions made in the field have been modified based on the results of laboratory testing.	TX-UU Unconsolidated Undrained Triaxial Shear Strength in pounds per square foot (psf) or kPa as measured in the laboratory (ASTM D-2850). Confining pressure given in parenthesis
	8					2) Boring logs depict subsurface conditions only at the specific locations and times the boring was made. Logs do not necessarily reflect strata variations that may exist between boring locations.	TX-CU Consolidated Undrained Triaxial Shear Strength in psf or kPa as measured in the laboratory (ASTM D-4767). Confining pressure given in parenthesis
							CONSOL One-Dimensional Consolidation (ASTM D-2435)
							PERM Triaxial, Falling Head Permeability (ASTM D-5084)
30	9						OC Organic content (ASTM D-2974)
							CA Corrosion Analysis

CH2MHILL

PROJECT NUMBER: 315994.PS.07.GE	BORING NUMBER: B-01	SHEET 1 OF 2

SOIL BORING LOG

PROJECT : PG&E Topock Compressor Station, Needles, CA

LOCATION : Proposed Water Treatment Plant - Southeast Corner

ELEVATION : Approximately 508 to 510 feet mean sea level

DRILLING CONTRACTOR : Kent Groover/Klienfelder/Las Vegas, NV

DRILLING METHOD AND EQUIPMENT : Hollow Stem Auger, B-61 Mobile Truck-Mounted, 140-lbs 30-in Drop Hammer with Cathead/Rope, 6-in OD and 3 1/4-in ID Auger

WATER LEVELS : Not Encountered

START : 08/13/2004 08:20

END : 08/13/2004 14:30

LOGGER : P.Srinavakul

DEPTH BELOW GROUND SURFACE (ft)	DEPTH BELOW GROUND SURFACE (m)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
							Driller notes easy to drill between 0 and 3.5 ft below ground surface (bgs)
	1						
							Driller notes dense soils and small gravels from 3.5 ft bgs.
5		5.0					
		6.5	0.9	S-1	3-8-12 (20)	SILTY SAND WITH GRAVEL (SM), light brown, dry, medium dense, fine grained, with subrounded gravels (1/8 to 1 inch diameter)	WC = 1%; 29.6% gravel; 42.4% sand; 28.0% fines
	2						CA; PI = Non Plastic
		8.0	Bulk	B-2	Bulk	SILTY SAND (SM), similar to above, with approximately less than 10% gravels	
10	3	10.0					
		11.5	0.7	MC-3	45-50/1" (>50)	SILTY SAND WITH GRAVEL (SM), similar to above, very dense, fine to medium grained, with approximately 30% subangular gravels (1/8 to 2 inches diameter)	
							Driller notes gravelly soils and some cobbles between 11.5 and 15 ft bgs
	4						
15		15.0					
		16.5	1.0	S-4	21-38-50/5" (>50)	WELL-GRADED SAND WITH SILT AND GRAVEL (SW-SM), brown and gray, dry, very dense, fine to coarse grained, with subangular gravels (1/8 to 1/2 inch diameter)	WC = 1%; 34.2% gravel; 57.0% sand; 8.8% fines
	5						
		20.0					
20	6						
		21.5	NR	MC-5	50/1" (>50)		No Recovery Driller notes small cobbles and rocks while driving sample MC-5
	7						
25		25.0					
		26.5	NR	S-6	50/1" (>50)		No Recovery Driller notes gravels and cobbles with occasional big cobbles
	8						
	9						
30							

CH2MHILL

PROJECT NUMBER:	BORING NUMBER:	
315994.PS.07.GE	B-01	SHEET 2 OF 2

SOIL BORING LOG

PROJECT : PG&E Topock Compressor Station, Needles, CA
LOCATION : Proposed Water Treatment Plant - Southeast Corner
ELEVATION : Approximately 508 to 510 feet mean sea level
DRILLING CONTRACTOR : Kent Groover/Klienfelder/Las Vegas, NV
DRILLING METHOD AND EQUIPMENT : Hollow Stem Auger, B-61 Mobile Truck-Mounted, 140-lbs 30-in Drop Hammer with Cathead/Rope, 6-in OD and 3 1/4-in ID Auger
WATER LEVELS : Not Encountered
START : 08/13/2004 08:20
END : 08/13/2004 14:30
LOGGER : P.Srinavakul

DEPTH BELOW GROUND SURFACE (ft)	DEPTH BELOW GROUND SURFACE (m)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
		30.0					No Recovery Driller notes gravelly and rocky soils
		31.5	NR	S-7	50/5" (>50)		
	10						
		34.0					
35		35.0	Bulk	B-8	Bulk	SILTY SAND WITH GRAVEL (SM), brown and dark brown, moist, fine to coarse grained, with approximately 20% subangular to subrounded gravels (1/8 to 1 inch diameter), more silty than above	
	11	36.5	NR	S-9	50/3" (>50)		No Recovery
							Hole backfilled with drill cuttings 8/13/04 14:30
	12						
40						Bottom of Hole at 36.5 ft below ground surface 08/13/2004 10:00 Groundwater Not Encountered	
	13						
45							
	14						
	15						
50							
	16						
55							
	17						
	18						
60							

CH2MHILL

PROJECT NUMBER:	BORING NUMBER:	
315994.PS.07.GE	B-02	SHEET 1 OF 1

SOIL BORING LOG

PROJECT : PG&E Topock Compressor Station, Needles, CA LOCATION : Proposed Water Treatment Plant - Northwest Corner

ELEVATION : Approximately 505 to 507 feet mean sea level DRILLING CONTRACTOR : Kent Groover/Klienfelder/Las Vegas, NV

DRILLING METHOD AND EQUIPMENT : Hollow Stem Auger, B-61 Mobile Truck-Mounted, 140-lbs 30-in Drop Hammer with Cathead/Rope, 6-in OD and 3 1/4-in ID Auger

WATER LEVELS : Not Encountered START : 08/13/2004 10:10 END : 08/13/2004 11:10 LOGGER : P.Srinavakul

DEPTH BELOW GROUND SURFACE (ft)	DEPTH BELOW GROUND SURFACE (m)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
5	1	5.0					
		6.5	1.2	S-1	16-25-21 (46)	SILTY SAND WITH GRAVEL (SM), brown and gray, dry, dense, fine to medium grained, with lots of gravels at bottom 6 inches of sample, subangular and flat gravels (1/8 to 2 inches diameter)	WC = 1%; 35.6% gravel; 50.7% sand; 13.7% fines
	2	8.0	Bulk	B-2	Bulk	SILTY SAND WITH GRAVEL (SM), similar to above, with subangular gravels (up to 3 inches diameter)	CA; PI = Non Plastic; R-Value = 83
10	3	10.0					Driller notes big cobbles, drill chatter, between 8 and 10 ft bgs
		11.5	NR	S-3	50/0" (>50)		No Recovery
15	4						Auger refusal at 11.5 ft bgs
	5					Bottom of Hole at 11.5 ft below ground surface (Auger Refusal) 08/13/2004 11:00 Groundwater Not Encountered	Moved 12 ft to the west to drill B-02A
20	6						Hole backfilled with drill cuttings 8/13/04 11:10
	7						
25	8						
30	9						

CH2MHILL

PROJECT NUMBER: 315994.PS.07.GE	BORING NUMBER: B-02A	SHEET 1 OF 1

SOIL BORING LOG

PROJECT : PG&E Topock Compressor Station, Needles, CA

LOCATION : Proposed Water Treatment Plant - Northwest Corner (12 ft west of B-02)

ELEVATION : Approximately 505 to 507 feet mean sea level

DRILLING CONTRACTOR : Kent Groover/Klienfelder/Las Vegas, NV

DRILLING METHOD AND EQUIPMENT : Hollow Stem Auger, B-61 Mobile Truck-Mounted, 140-lbs 30-in Drop Hammer with Cathead/Rope, 6-in OD and 3 1/4-in ID Auger

WATER LEVELS : Not Encountered

START : 08/13/2004 11:15

END : 08/13/2004 14:40

LOGGER : P.Srinavakul

DEPTH BELOW GROUND SURFACE (ft)	DEPTH BELOW GROUND SURFACE (m)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
							Light brown, dry, fine silty sand in cuttings between 1 and 5 ft bgs
5	1						
	2						Becoming gravelly sand at 5 ft bgs
							Driller notes big cobbles, drill chatter, at 8 ft bgs, then, easy to drill between 9 and 10 ft bgs
10	3	10.0					
		11.5	1.0	S-1	22-29-34 (63)	SILTY SAND WITH GRAVEL (SM), orange-brown with gray and dark gray, dry, very dense, fine to medium grained, with subangular to angular gravels (1/8 to 2 inches diameter)	WC = 1%; 37.3% gravel; 48.5% sand; 14.2% fines
	4						
15							Auger refusal at 15 ft bgs
	5						Hole backfilled with drill cuttings 8/13/04 14:40
						Bottom of Hole at 15 ft below ground surface (Auger Refusal) 08/13/2004 11:30 Groundwater Not Encountered	
20	6						
	7						
25							
	8						
30	9						

CH2MHILL

PROJECT NUMBER:	BORING NUMBER:	
315994.PS.07.GE	B-03	SHEET 1 OF 2

SOIL BORING LOG

PROJECT : PG&E Topock Compressor Station, Needles, CA
LOCATION : Proposed Water Treatment Plant - Middle

ELEVATION : Approximately 508 to 510 feet mean sea level
DRILLING CONTRACTOR : Kent Groover/Klienfelder/Las Vegas, NV

DRILLING METHOD AND EQUIPMENT : Hollow Stem Auger, B-61 Mobile Truck-Mounted, 140-lbs 30-in Drop Hammer with Cathead/Rope, 6-in OD and 3 1/4-in ID Auger

WATER LEVELS : Not Encountered
START : 08/13/2004 11:50
END : 08/13/2004 14:00
LOGGER : P.Srinavakul

DEPTH BELOW GROUND SURFACE (ft)	DEPTH BELOW GROUND SURFACE (m)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
							Fine silty sand, easy to drill, between 0 and 5 ft bgs
5	1	5.0					
		6.5	0.8	S-1	12-16-13 (29)	SILTY SAND WITH GRAVEL (SM), brown and gray, dry, medium dense, fine to coarse grained, with approximately 20% subangular to subrounded gravels (1/8 to 1 1/2 inches diameter)	
	2						Gravelly sand in cuttings between 5 and 10 ft bgs
10	3	10.0					
		11.5	0.9	S-2	19-27-31 (58)	SITLY SAND WITH GRAVEL (SM), similar to above, very dense	WC = 1%; 22.8% gravel; 64.0% sand; 13.2% fines
	4	13.0	Bulk	B-3	Bulk	SILTY SAND WITH GRAVEL (SM), similar to above, brown, with approximately 15% to 20% flat and subangular gravels (1/8 to 3 inches diameter)	
15		15.0					
	5	16.5	NR	S-4	50/0" (>50)		No Recovery Gravelly soils and large cobbles in cuttings between 16.5 and 20 ft bgs
20	6	20.0					
		21.5	0.3	S-5	30-50/5" (>50)	POORLY GRADED SAND WITH SILT (SP-SM), brown and light gray, dry, very dense, fine to coarse grained, with subangular and flat gravels (1/8 to 1/2 inch diameter)	WC = 4%; 13.9% gravel
	7						Driller notes gravelly soils with large cobbles between 21.5 and 25 ft bgs
25		25.0					
	8	26.5	NR	S-6	50/0" (>50)		No Recovery
30	9						

CH2MHILL

PROJECT NUMBER: 315994.PS.07.GE	BORING NUMBER: B-03	SHEET 2 OF 2

SOIL BORING LOG

PROJECT : PG&E Topock Compressor Station, Needles, CA

LOCATION : Proposed Water Treatment Plant - Middle

ELEVATION : Approximately 508 to 510 feet mean sea level

DRILLING CONTRACTOR : Kent Groover/Klienfelder/Las Vegas, NV

DRILLING METHOD AND EQUIPMENT : Hollow Stem Auger, B-61 Mobile Truck-Mounted, 140-lbs 30-in Drop Hammer with Cathead/Rope, 6-in OD and 3 1/4-in ID Auger

WATER LEVELS : Not Encountered

START : 08/13/2004 11:50

END : 08/13/2004 14:00

LOGGER : P.Srinavakul

DEPTH BELOW GROUND SURFACE (ft)	DEPTH BELOW GROUND SURFACE (m)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
		30.0 31.5	NR	S-7	50/0" (>50)		No Recovery
							Hole backfilled with drill cuttings 8/13/04 14:00
35	10					Bottom of Hole at 31.5 ft below ground surface 08/13/2004 13:10 Groundwater Not Encountered	
	11						
40	12						
	13						
45	14						
	15						
50	16						
55	17						
	18						
60							

APPENDIX B

Existing Monitoring Well Logs

SEE SITE PLAN

ALISTO PROJECT NO: *10-320-08* DATE DRILLED: *07/09/97*

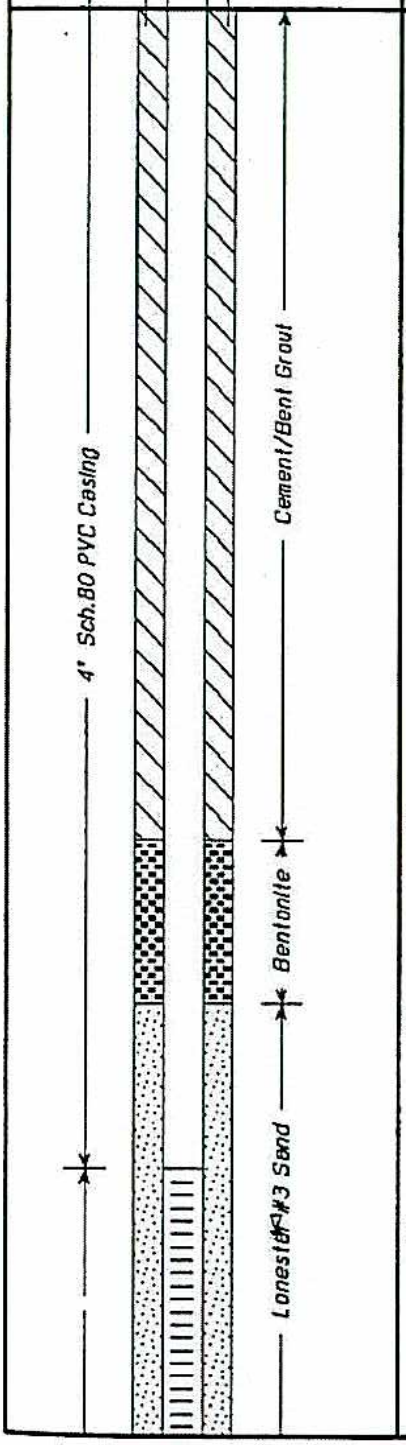
CLIENT: *Pacific Gas and Electric Co.*

LOCATION: *Topock Compressor Station*

DRILLING METHOD: *Resonant Sonic, Continuous Coring*

DRILLING COMPANY: *Boart Longyear* CASING ELEVATION: *488.19*

LOGGED BY: *Ted Molse/Dan Birch* APPROVED BY: *Dan Salaices*



DEPTH feet	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
0		SP	gravelly SAND: yellowish gray; 50% sand, fine to coarse grained; 45% gravel, 4-50 mm, subangular, occasional cobbles; minor fines; dry.
5			color change to light olive gray
10			
15		GP	sandy GRAVEL: light gray; 60% gravel, 4-75 mm, subangular; 40% sand, fine to medium grained; dry.
			at 19 feet, 150 mm cobble.
20			at 19.5 feet, color change to pale yellowish brown; 70% gravel; 30% sand, fine to medium grained. Possibly older alluvium.
25			at 28.5 feet, 60% gravel, 40% sand.
30			Wet at 30 feet.
		SP	gravelly SAND: pale brown; 60% sand, fine to coarse grained;

ALISTO ENGINEERING GROUP
WALNUT CREEK, CALIFORNIA

LOG OF WELL MW-13

SEE SITE PLAN

ALISTO PROJECT NO: 10-320-06 DATE DRILLED: 07/09/97

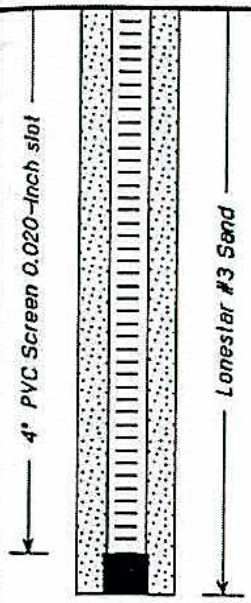
CLIENT: Pacific Gas and Electric Co.

LOCATION: Topock Compressor Station

DRILLING METHOD: Resonant Sonic, Continuous Coring

DRILLING COMPANY: Boart Longyear CASING ELEVATION: 488.19

LOGGED BY: Ted Moise/Dan Birch APPROVED BY: Dan Salalces



DEPTH feet	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
		SP	35% gravel, 4-40 mm, subangular; wet.
40			At 40 feet, color change to pale red; 70% sand, fine to coarse grained; 30% gravel, 4-25 mm, subangular.
			At 43 feet, color change to light brownish gray, cobble to 100 mm.
45			
50			Total depth of borehole is 49.5 feet.
55			
60			
65			

ALISTO ENGINEERING GROUP
WALNUT CREEK, CALIFORNIA

LOG OF WELL MW-14

SEE SITE PLAN

ALISTO PROJECT NO: 10-320-06 DATE DRILLED: 07/14-15/97

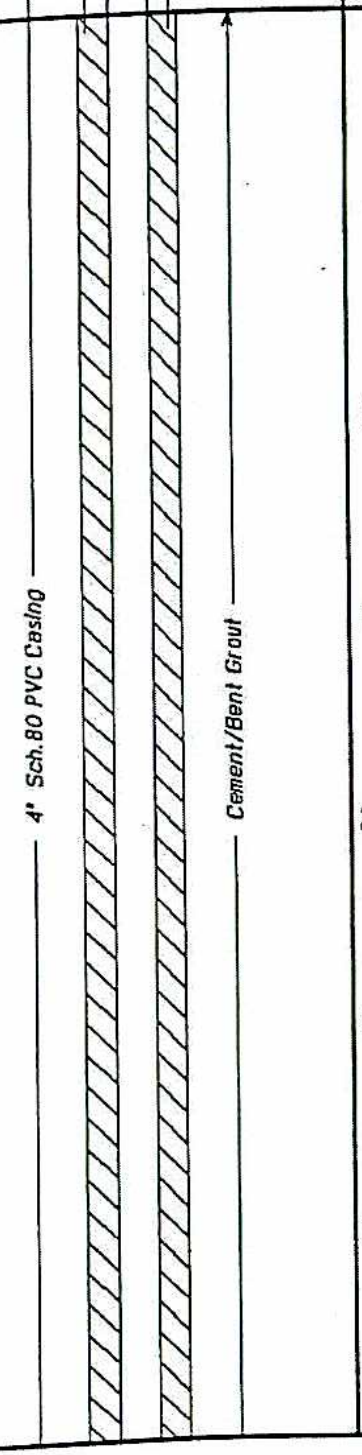
CLIENT: Pacific Gas and Electric Co.

LOCATION: Topock Compressor Station

DRILLING METHOD: Resonant Sonic, Continuous Coring

DRILLING COMPANY: Boart Longyear CASING ELEVATION: 570.54

LOGGED BY: Ted Moise/Ken Simas APPROVED BY: Dan Salaices



DEPTH feet	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
0		GP	sandy GRAVEL: grayish orange pink; 70% gravel, 4-75 mm, rounded to subangular; 30% sand, fine to coarse grained; dry.
5		SP	gravelly SAND: pale yellowish brown; 80% sand, fine to coarse grained; 20% gravel, 4-50 mm, subangular; dry.
			At 8 feet, 60% sand, fine to coarse grained; 40% gravel, 4-70 mm, subangular.
10			
15		GP	sandy GRAVEL: pale yellowish brown; 60% gravel, 4-35 mm; subangular; 40% sand, fine to coarse grained, dry.
		SP	gravelly SAND: pale yellowish brown; 80% sand, fine to coarse grained; 10% gravel, 4-20 mm, subangular, dry.
20			At 20 feet, 55% sand, fine to coarse grained; 45% gravel, 4-50 mm.
			At 22 feet, color change to light gray; 60% sand, fine to coarse grained; 40% gravel, 4-50 mm, angular to subrounded.
25			At 25 feet, color change to light olive gray; 40% gravel, 4-25 mm, subangular.
30			At 30 feet, color change to pale yellowish brown; 75% sand, fine to coarse grained; 25% gravel, 4-80 mm, subangular; dry.

ALISTO ENGINEERING GROUP
WALNUT CREEK, CALIFORNIA

LOG OF WELL MW-14

SEE SITE PLAN

ALISTO PROJECT NO: *10-320-08* DATE DRILLED: *07/14-15/97*

CLIENT: *Pacific Gas and Electric Co.*

LOCATION: *Topock Compressor Station*

DRILLING METHOD: *Resonant Sonic, Continuous Coring*

DRILLING COMPANY: *Boart Longyear* CASING ELEVATION: *570.54*

LOGGED BY: *Ted Moise/Ken Simas* APPROVED BY: *Dan Salaices*

WELL DIAGRAM	DEPTH feet	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
4" Sch.80 PVC Casing; Cement/Bent Grout	40		SP	At 38 feet, gravel, 4-40 mm, subangular. At 38 feet, color change to light olive gray; 60% sand, fine to coarse grained; 40% gravel, 4-75 mm, subrounded to subangular; dry.
	45		GP SP	sandy GRAVEL/gravelly SAND: Pale yellowish brown; 50% sand, fine to coarse grained; 50% gravel, 4-75 mm, subangular to subrounded; dry.
	50		SP	gravelly SAND: Pale yellowish brown; 70% sand, fine to coarse grained; 30% gravel, 4-75 mm, subangular. At 50 feet, 60% sand, fine to coarse grained; 40% gravel, 4-65 mm, subrounded to subangular; dry. At 54 feet; color change to light gray, 55% sand, fine to coarse grained; 40% gravel, 4-35 mm, subangular to subrounded; 5% fines; dry. At 57 feet, 65% sand, fine to coarse grained; 30% gravel, subangular to subrounded, 4-75 mm; 5% fines.
	65		GP	sandy GRAVEL: light gray; 60% gravel, subangular to subrounded, 4-75 mm; 40% sand, fine to coarse grained.

ALISTO ENGINEERING GROUP
WALNUT CREEK, CALIFORNIA

LOG OF WELL MW-14

SEE SITE PLAN

ALISTO PROJECT NO: 10-320-06 DATE DRILLED: 07/14-15/97

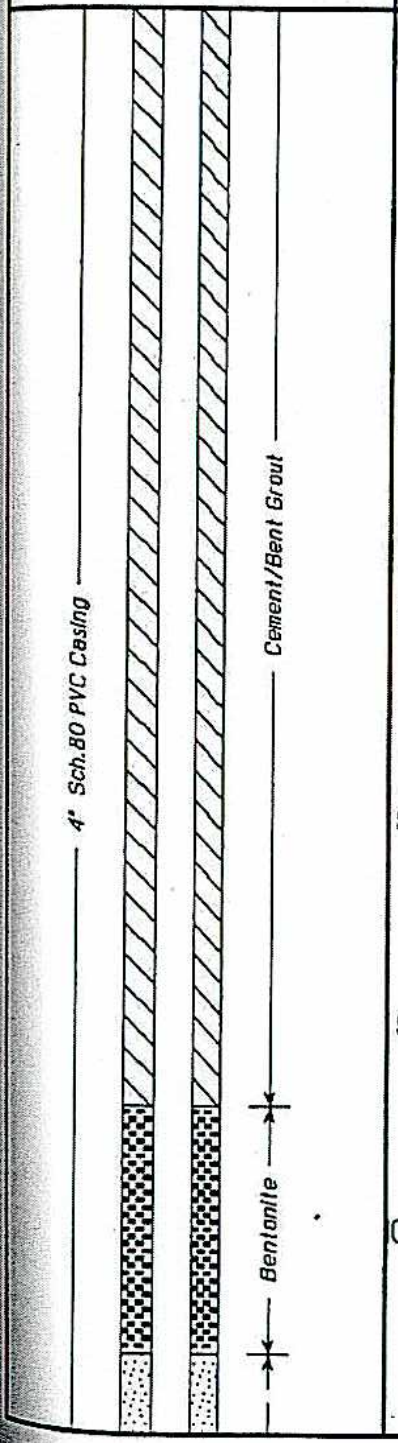
CLIENT: Pacific Gas and Electric Co.

LOCATION: Topock Compressor Station

DRILLING METHOD: Resonant Sonic, Continuous Coring

DRILLING COMPANY: Boart Longyear CASING ELEVATION: 570.54

LOGGED BY: Ted Moise/Ken Simas APPROVED BY: Dan Salaices



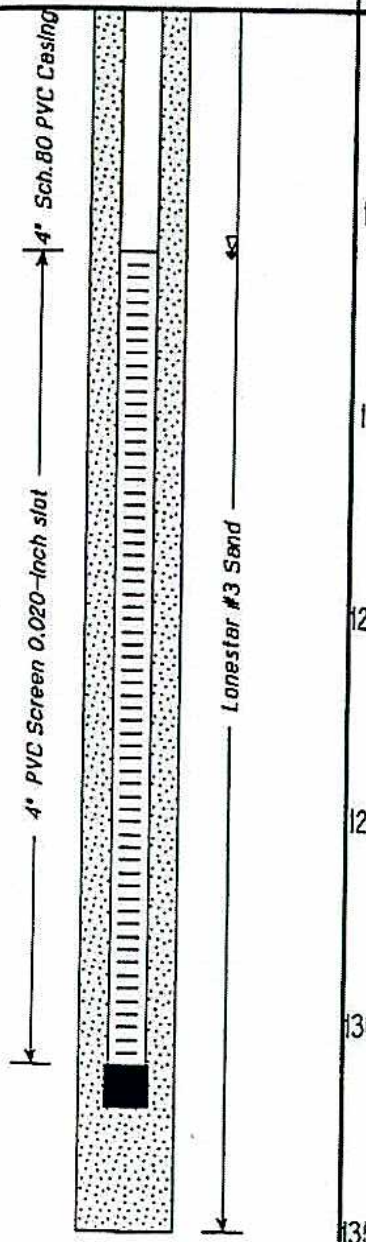
DEPTH feet	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
		GP	Same
75		SP	gravelly SAND: pale yellowish brown; 60% sand, fine to coarse grained; 40% gravel, 4-50 mm, subangular.
		GP SP	sandy GRAVEL/gravelly SAND: light olive brown; 50% sand, fine to coarse grained; 50% gravel, 4-50 mm, subangular.
80			At 78.5 feet, 1.5 foot long boulder core, 8-inches wide. Rock flour is light gray.
		SP	gravelly SAND: light olive gray; 60% sand, fine to coarse grained; 40% gravel, 4-50 mm, subangular.
85			
90			
		GP SP	sandy GRAVEL/gravelly SAND: light olive gray, 50% sand, fine to coarse grained; 50% gravel, 4-50 mm, subangular.
95			
		SP	gravelly SAND: light gray; 60% sand, fine to coarse grained; 20% gravel, 4-50 mm, subangular.
00			
		GP	sandy GRAVEL: light gray; 75% gravel, 4-50 mm, subangular to subrounded; 25% sand, fine to coarse grained, dry.
		GP SP	

ALISTO ENGINEERING GROUP
WALNUT CREEK, CALIFORNIA

LOG OF WELL MW-14

SEE SITE PLAN

ALISTO PROJECT NO: 10-320-06 DATE DRILLED: 07/14-15/97
CLIENT: Pacific Gas and Electric Co.
LOCATION: Topock Compressor Station
DRILLING METHOD: Resonant Sonic, Continuous Coring
DRILLING COMPANY: Boart Longyear CASING ELEVATION: 570.54
LOGGED BY: Ted Moise/Ken Simas APPROVED BY: Dan Salalces



DEPTH feet	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
		GP SP	sandy GRAVEL/gravelly SAND: moderate brown; 50% gravel, 4-75 mm, subrounded to subangular; 50% sand, fine to coarse grained; damp.
		SP	gravelly SAND: light olive brown; 60% sand, fine to coarse grained; 40% gravel, subangular, 4-40 mm; moist to wet.
110		GP	sandy GRAVEL: light olive gray; 60% gravel, subangular to subrounded, 4-75 mm; 40% sand, fine to coarse grained; wet at 111 feet.
115			At 118 feet, color change to light brown; gravel 4-75 mm.
			At 117.5 feet, 140 mm cobble, light gray rock flour.
		SP	gravelly SAND: pale yellowish brown; 65% sand, fine to coarse grained, 30% gravel, subangular, 4-75 mm; 5% fines; wet.
120			
125		GP GM	sandy silty GRAVEL: pale yellowish brown; 55% gravel, subangular, 4-50 mm, occasional cobble to 80 mm; 35% sand, fine to coarse grained; 10% fines; wet.
		SP	gravelly SAND: pale yellowish brown; 60% sand, fine to coarse grained; 35% gravel, subangular, 4-20 mm; 5% fines; wet.
130		SM	gravelly silty SAND: pale yellowish brown; 60% sand, fine to coarse grained; 20% gravel, subangular, 4-30 mm; 20% fines; wet.
		SP	gravelly SAND: light olive gray; 65% sand, fine to coarse grained; 30% gravel, subangular, 4-25 mm; 5% fines; wet.
135			Total depth of the boring is 135 feet.

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET	OF
315024.JM.01	MW37D	1	8

SOIL BORING LOG

PROJECT PG&E Topock LOCATION Back Cave Wash North of I40

ELEVATION 482 DRILLING CONTRACTOR WDC Drilling & Exploration

DRILLING METHOD AND EQUIPMENT Sonic

WATER LEVELS 30.81' BTOC 4/23/04 START 4/13/04 1400 FINISH 4/21/04 LOGGER Stacy Cooper

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION	Core Liner
0					0-8' Lost in setting conductor pipe.		
5							
10			5'/10'			1500 - Drillers lost 8'-13' Dropped Drilling is Soft	
15		①		13-14 GW-GC	Well Graded Sandy Gravel (GW-GC) Dark Gray (2.5Y 4/1), wet, high dry strength, no plasticity. 50% well-graded, angular to subangular gravel, 40% well-graded sand, subangular, 10% Fines. Becomes drier @16'	MW37D-15' (CrG)	1
				SC	(Gravelly Sand w/ Clay (SC) (2.5Y 5/2) Grayish brown, dry, low dry strength 30% Gravel, well graded, subangular, 50% well-graded sand, subangular, 20% Fines no plasticity	1600	2
20			20/20		slightly moister layer @ 18 to 19' then the same as above.		3
		②		GW	22-23' well-graded Gravel with Sand (GW) Dry, Gray (2.5Y 5/1), 70% Gravel, Cobbles to 3", course to fine, Subrounded to Subangular. 25% Sand, angular to Subangular, course to medium, quartz, gneiss, feldspar 5% Fines-Clay.		4
25				SC	23-25 Gravelly Sand with Clay (SC) (2.5Y 4/1) Dark Gray, moist, high dry strength, 30% Gravel, Subangular, well-graded, course to fine. 50% sand well graded, Subangular, 20% fines clay	26-28 - Becomes more Sandy, Besides that, same as above	5

CH2MHILL

PROJECT NUMBER	BORING NUMBER		
315024.JM.01	MW-37D	SHEET 2	OF 8

SOIL BORING LOG

PROJECT PG&E Topock LOCATION Bat Cave Wash North of I-40

ELEVATION 482 DRILLING CONTRACTOR WDC Drilling & Exploration

DRILLING METHOD AND EQUIPMENT Sonic

WATER LEVELS START 4/13/04 1400 FINISH 4/21/04 LOGGER S. Cooper

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
30			20/20'		Sandy Clay w/Gravel (SC) Dark Grayish Brown (10YR 4/2) 20% well-graded gravel, subrounded, moist, Medium Plasticity, high dry strength, 40% well graded, subangular sand, 40% clay fines.	
35		②		SC		
40		③	10/10'	SC	Clayey Sand w/Gravel (SC) Dark Gray (10YR 4/1), moist, High dry strength, Low Plasticity, 30% round to subround, well-graded gravel, Medium Plasticity, 40% sand, 30% clay fines. well-graded to poorly subround	
45						
50		④	10/10'	SC	Sandy Clay with Gravel (SC) Dark Gravish Brown (10YR 4/2), moist, high dry Strength, medium plasticity, 30% well-graded gravel, subangular, 30% sand, well graded, subround to subangular, 40% clay fines.	MW-37D-50 CROT 0814
55					Gravelly Sand with clay (SC) Color Change @ 55' - 7.5YR (4/2) Brown more sand, 40% angular gravel-well-graded 45% subangular to subround well-graded course to medium sand, 15% Fines. Becomes a little less consolidated @ 60'	MW-37D-55 CROT 0816
		⑤		0737 4/14/04		

(8.30) REV 9/96 FOR

CH2MHILL

PROJECT NUMBER	BORING NUMBER		
315024.JM.01	MW-37D	SHEET 3	OF 8

SOIL BORING LOG

PROJECT PG&E Topock LOCATION Bat Cave wash North of I-40

ELEVATION 482 DRILLING CONTRACTOR WDC Drilling

DRILLING METHOD AND EQUIPMENT Sonic

WATER LEVELS START 4/13/04 FINISH 4/21/04 LOGGER S. Cooper

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION	Core Box
60			60'/10'		a little less sandy, more clay to 62'	0945 Drilling is Hard MW-37D-60 CrGt 0930	13
		(5)			Becomes more Gravelly, unconsolidated	ve	
65				GW-GC	Well-graded Sandy Gravel (GW-GC) Dark Brown (10YR 3/3) - moist, 60% well-graded, angular, subangular Gneiss, Quartz, Feldspar, 30% angular, Subangular Sand, 10% Fines, No Plasticity	MW-37D-65 CrGt 0935	14
				SC	Same as 48'-60' Clayey Sand w/Gravel. moist. High dry strength.		
70			10'/10'		70-72 Slightly more clay, less Gravel. Still very Sandy	MW-37D-70 CrGt 1030	15
		(6) 1300		GC	Sandy Gravel w/Clay (GC) (2.5Y 6/3) Light Yellowish Brown, Dry, Unconsolidated, medium plasticity 50% Gravel, Cobbles to 3", Gneiss mostly, Subangular, well-graded, 20% Subangular well-graded, Course to Medium Sand. Feldspar, Quartz, Gneiss, 20% clay Fines.	MW-37D-75 CrGt 1035	16
75			1300				17
				CL	Sandy lean clay with Gravel (CL) (2.5Y 4/3) olive Brown, Moist, high plasticity High dry strength, 15% Subround, fine, to medium, well graded Gravel. 35% Sand, Subround, well graded. 65% clay Fines.	MW-37D-80 1405 CrGt	18
80			15'/15'				
		(7) 1345		GC	Sandy Gravel w/clay (GC) (2.5Y 4/3) olive Brown, Dry to moist, 50% Subangular to Subround gravel, well-graded-metamorphics. 30% well graded Sand, Subangular to Subround. 20% clay fines. Low plasticity. Unconsolidated Low dry Strength.	MW-37D-85 1410 CrGt	19
85							20
				SC	See Next Page		21

CH2MHILL

PROJECT NUMBER	BORING NUMBER		
315024. IM.01	MW37-D	SHEET 4	OF 8

SOIL BORING LOG

PROJECT PG & E Topock LOCATION Bat Cave Wash

ELEVATION 482 DRILLING CONTRACTOR WDC Drilling & Exploration

DRILLING METHOD AND EQUIPMENT Sonic

WATER LEVELS START 4/13/04 FINISH 4/21/04 LOGGER S. Cooper

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
90				SC	Clayey Sand w/Gravel (SC) (10YR 4/3) Brown, moist, medium dry strength 25% subangular to subround well graded Gravel. 40% well-graded medium to fine Sand, subangular to sub round. 35% clay fines. Becomes a little Sandier @ 93'. Also becomes wet.	MW-37D-90 1415
95				CL	Lean clay w/Sand (CL) (2.5Y (5/2)) Grayish Brown, wet, medium plasticity low dry strength... mush. 10% Gravel, well graded, to 1", subangular, MM, 20% course to medium Sand. 70% clay fines	MW-37D-95 (crot) 1630 MM=metamorphic
		(8) 1560	15'/15'		Becomes more Sandy & Gravelly with depth.	
100						MW-37D-100 1635 crot
105				SC	Gravelly Sand w/Clay (SC) (7.5YR 4/2) Brown, has some reddish mottles & clasts. 40% fine gravel, 40% course to medium Sand, well-graded, subangular to angular Quartz, Gneiss, green minerals. 20% fines-clayey. Gravel & Sands has thin interlayes of clay.	Hard Drilling MW-37D-105 1640 crot
110		(9) 0800 4/15/04	10'/15'	SC	Gravelly Sand w/Clay (SC) Dark Grayish Brown (10YR 4/2), moist, 40% well-graded angular gravel, metamorphic, Gneiss, 40% well-graded angular to subangular Sand. Same mineralogy as above. 20% clay fines. Gravel to 2" Uncosolidated at top of run.	MW-37D-110 0845 crot
115					116-118'- more Gravelly than @ top - a little more reddish in color, multicolored mineralogy with some red staining, still moist, but a little drier.	MW-37D-115 0850 crot

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET	OF
315024.JM.01	MW37D	5	8

SOIL BORING LOG

PROJECT PG&E Topock LOCATION East Cave Wash

ELEVATION 482 DRILLING CONTRACTOR WDC Drilling & Exploration

DRILLING METHOD AND EQUIPMENT Sonic

WATER LEVELS START 4/13/04 FINISH 4/21/04 LOGGER S. Cooper

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION	(inches)
120					Clayey Sand w/Gravel (SC) Brown (10YR 4/3), wet, medium Plasticity 20% angular to subangular gravel, to 3" well-graded, 60%, well-graded, subangular Sand, quartz, mm gneiss, green MM mineral, 20% clay fines,	MW-37D-120 1145 crot	29
125		(10) 1200 4/20/04	20/20	SC	126'-128' - same, but wetter. Same as above to 130'	MW-37D-125 1145 crot	30
130						MW-37D-130 1150 crot	31
135				SC	Gravelly Sand w/clay (SC) (10YR 4/3) Brown, moist, low plasticity 25% well-graded, subangular gravel to 2", 60% Sand, subangular, same mineralogy as above, 15% clay fines.	MW-37D-135 1155 crot	32
140		(11) 1500	20/20	SW-SC	Gravelly Sand w/clay (SW-SC) Brown (10YR 4/3), wet, low plasticity, 40% well-graded, subangular gravel, 50% well-graded, angular to subangular sand, 10% clay fines. Becomes more clayey w/depth	Some heaving gravels @138' gneiss, green MM mineral, feldspar, quartz MW-37D-140 crot 1445	33
145				CL	Sandy Lean clay (CL) Brown (10YR 5/3), wet, medium plasticity, 10% well-graded, subangular gravel, 40% well-graded, subangular Sand, 50% clay fines.	MW-37-145 crot 1450	34
							35
							36

CH2MHILL

PROJECT NUMBER 315024. IM.01 | BORING NUMBER MW 37D | SHEET 6 OF 8

SOIL BORING LOG

PROJECT PG&E Topock LOCATION Bat Cave Wash

ELEVATION 482 DRILLING CONTRACTOR WDC Drilling & Exploration

DRILLING METHOD AND EQUIPMENT Sonic

WATER LEVELS START 4/13/04 FINISH 4/21/04 LOGGER S. Cooper

DEPTH BELOW SURFACE (FT)	SAMPLE: INTERVAL	SAMPLE: NUMBER AND TYPE	SAMPLE: RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION	Core Box
150					Clayey Sand w/Gravel (SC) (10YR 4/2) Dark Grayish Brown, wet, medium plasticity, 10% well-graded subangular gravel, 60% well-graded subangular sand, 30% clay fines.	MW-37D-150 1455 crct	
		(11) 1500	20'/20'	SC	150 - 156' - slightly drier → moist not wet		37
155						wet ↑ MW-37D-155 1500	
				GC	Sandy Gravel w/Clay (GC) Dark Grayish Brown (10YR 4/2), moist, low plasticity, some reddish arkose, 40% well-graded subangular, 40% well-graded angular to subangular sand, 20% clay fines. Reddish staining, multi-colored gravels, more consolidated than above.	Drilling got harder here	38
				CL	Gravelly Lean Clay w/Sand (CL) (10YR 4/3) Dark Grayish Brown, moist, medium plasticity, 30% well-graded, subangular gravel, green mineralogy, 20% well-graded, subangular sand, 50% clay fines.	Gravel, → Reworked red Flanglomerate MW-37D-160 1630 Fairly Hard drilling	39
160							
		(12) 1630	20'/20'				40
165						MW-37D-165 1635 crct	
				SC	Gravelly Sand w/Clay (SC) (10YR 4/2) Dark Grayish Brown, wet, medium plasticity, 25% well-graded, angular to subangular, gravel, 50% well-graded, subangular sand (qtz., amphibole), gneiss, 25% clay fines.		41
170					more clay w/depth to 174'	MW-37D-170 crct 1640	42
175						MW-37D-175 crct 1645	43
				GC	Sandy Gravel w/Clay (GC) (10YR 4/3) Dark Grayish Brown, moist to dry, medium plasticity, 50% well-graded, subangular gravel, 30% well-graded, subangular sand, same mineralogy as above, 20% clay fines.		44

CH2MHILL

PROJECT NUMBER	BORING NUMBER		
315024.IN.01	MW37D	SHEET 7	OF 8

D, P

SOIL BORING LOG

PROJECT PGT/E Topock LOCATION Bat Cave Wash

ELEVATION 482 DRILLING CONTRACTOR WDC Drilling & Exploration

DRILLING METHOD AND EQUIPMENT Sonic

WATER LEVELS START 4/13/04 FINISH 4/21/04 LOGGER S.Cooper

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
180					Clayey Sand w/ Gravel (SC) (2.5YR 4/3) Brown, moist, medium plasticity, 30% well-graded, subangular gravel, gneiss, 40% subangular, well-graded sand, quartz, gneiss, amphiboles, 30% clay fines, Reddish stains, matrix supported,	gravels to 3"
185		(13) 1830	20'/20'	SC		
190					190-194 - more wet than above, slightly more sand & gravel than above, but the same otherwise.	
195					194-198' back to moist but same as 190 to 194' otherwise. (not quite as wet) Brown, but reddish tone throughout this run.	
200		(14) 1215	20'/20' 4/21/04	SC	Gravelly Sand w/ clay (SC) (5.5YR 4/4) Brown, moist, low plasticity 25% well-graded, subangular to angular gravel, 60% well graded course to fine, subangular to angular sand, 15% clay fines. matrix supported. High dry strength	MW-37D-200' 1300 cgr Fractures obliquely re-worked red fanglomerate
					204-208' Becomes more gravelly w/ depth. Cobbles to 3" Still mostly sand.	MW-37D-205 cgr 1305
					208-214 - less gravel again - as above.	

44 45 46 47 48

CH2MHILL

PROJECT NUMBER	BORING NUMBER	SHEET	OF
315624.IM.01	MW37D	8	8

SOIL BORING LOG

PROJECT PG&E Topock LOCATION Bat Cave Wash

ELEVATION 482 DRILLING CONTRACTOR WDC Drilling & Exploration

DRILLING METHOD AND EQUIPMENT Sonic

WATER LEVELS START 4/13/04 FINISH 4/21/04 LOGGER

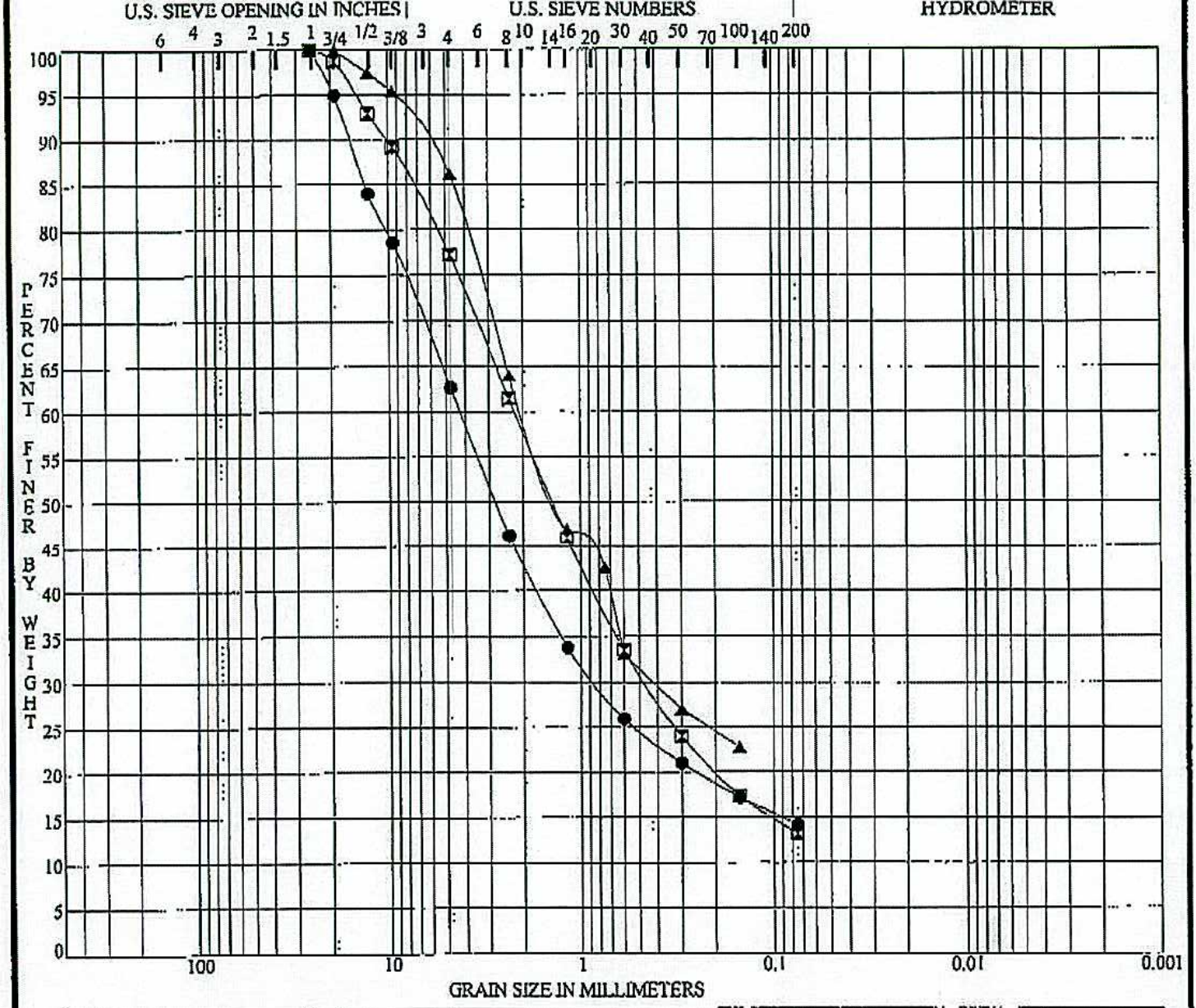
DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
210						MW-37D-210 1310 crot
		(14) 1245	20'/20'	SC		Still Fractures obliquely
215					214-218' more consolidated here - harder, still moist, high dry strength. More gravelly (30%). Whole run is Brown, but reddish tone.	MW-37D-215 1315 CR GT
220		(15) 1600	10'/10'	SC	Gravelly Sand w/clay (SC) Brown (7.5 YR 4/3), moist, low plasticity Same as @ 198'. Looser than 214-218'. Grades to 2".	
225					At 222', some bright red, brick red material color is (5YR 4/4) reddish Brown. Material is same as above just redder in color.	226' Digital photo of oblique Fracture in Red Conglomerate, Photo #4 & #5.
					226-228' A little more consolidated. Otherwise, as above.	
					EOB	
230					TD=228'	
235						

APPENDIX C

Laboratory Test Results

Moisture Test Results

Exploration Number	Sample Depth (ft.)	Moisture Content (%)
B-1	5	1%
B-1	15	1%
B-3	20	4%
B-2	5	1%
B-3	10	1%
B-2A	10	1%



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Exploration No.	Depth(ft)	Classification	LL	PL	PI	Cc	Cu
●	B-2a	10.0	()					
⊠	B-3	10.0	0					
▲	B-3	20.0	0					

	Exploration No.	Depth(ft)	D100 (mm)	D60 (mm)	D30 (mm)	D10 (mm)	%Gravel	%Sand	%Silt	%Clay
●	B-2a	10.0	25.40	4.24	0.852		37.3	48.5	14.2	
⊠	B-3	10.0	25.40	2.21	0.466		22.8	64.0	13.2	
▲	B-3	20.0	19.00	2.01	0.422		13.9			

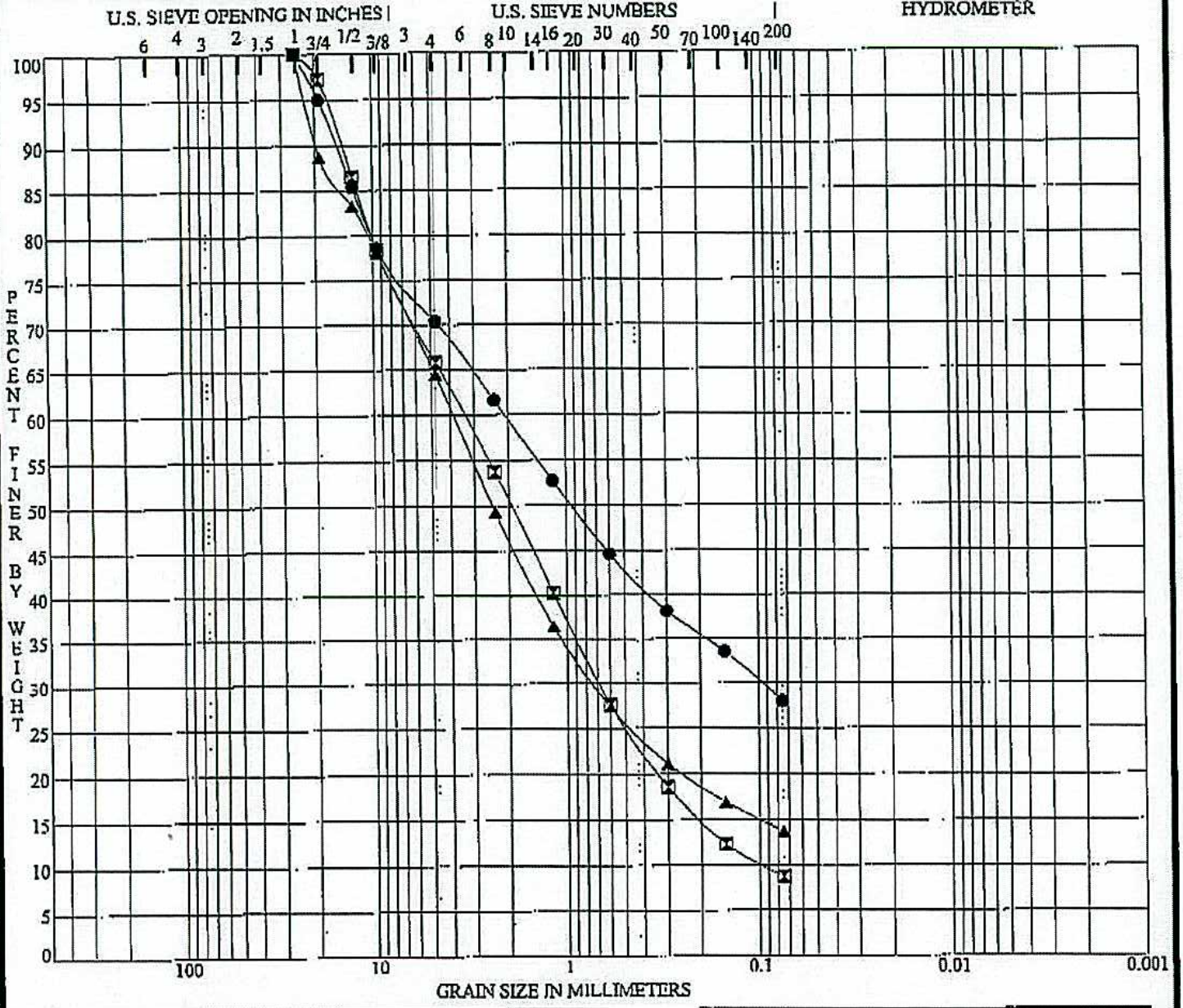
KLEINFELDER
GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS
SOILS AND MATERIALS TESTING

PROJECT NO. 48294

PROJECT: Needles Improvements

GRAIN SIZE ANALYSES

PLATE
B-2



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Exploration No.	Depth(ft)	Classification	LL	PL	PI	Cc	Cu
●	B-1	5.0	()					
⊠	B-1	15.0	()				1.44	35.5
▲	B-2	5.0	()					

	Exploration No.	Depth(ft)	D100 (mm)	D60 (mm)	D30 (mm)	D10 (mm)	%Gravel	%Sand	%Silt	%Clay
●	B-1	5.0	25.40	2.08	0.096		29.6	42.4	28.0	
⊠	B-1	15.0	25.40	3.39	0.682	0.0953	34.2	57.0	8.8	
▲	B-2	5.0	25.40	3.87	0.732		35.6	50.7	13.7	

KLEINFELDER
GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS
SOILS AND MATERIALS TESTING

PROJECT NO. 48294

PROJECT: Needles Improvements

GRAIN SIZE ANALYSES

PLATE
B-1

Atlas Consultants, Inc.

6000 S. Eastern Avenue, Suite 10J • Las Vegas, Nevada 89119
(702) 383-1199 • Fax (702) 383-4983

member of
AMERICAN SOCIETY FOR TESTING MATERIALS

LABORATORY NO: 12541(c)
SAMPLE: Soil
MARKED: 48294
SUBMITTED BY: Kleinfelder, Inc.

DATE: August 19, 2004
P.O.:
LAB ID: 27468
SOIL SIEVE = -10

REPORT OF DETERMINATION

BORING NUMBER	B-01	B-02				
SAMPLE NO.	27468-B2A	27468-B2B				
DEPTH (feet)	6.5-8.0	6.5-8.0				
pH VALUE	8.63	8.67				
RED-OX (mv)	+646	+668				
SULFATE (mg/Kg)	2,888	3,988				
SULFIDE (mg/Kg)	Nil	Nil				
TOTAL SALTS (mg/Kg)	7,890	6,574				
CHLORIDE (mg/Kg)	1,025	350				
RESISTIVITY (Ohm-cm)	370	725				

Respectfully submitted,

Robert L. Summers
Analytical Chemist

NOTES:

1. The soil:water extract ratio was 1:5, the results are in mg/Kg in the soil.
2. The standard methods used for the determinations are AWWA 4500 H pH Value, ASTM D 1498 Red-Ox, AWWA 4500-SO_4 E Turbidimetric, AWWA 4500-S D Methylene Blue, AWWA 2510 Electrical Conductivity, AWWA 4500-Cl B Argentometric and ASTM G 57.
3. Nil is less than 1.0 mg/Kg.

Job # => 48294
Project => PG & E TOPOCK
Client => CH2M HILL
Phase =>
Sample Location => Boring B-02, Sample B-2 @ 6.5 - 8.0

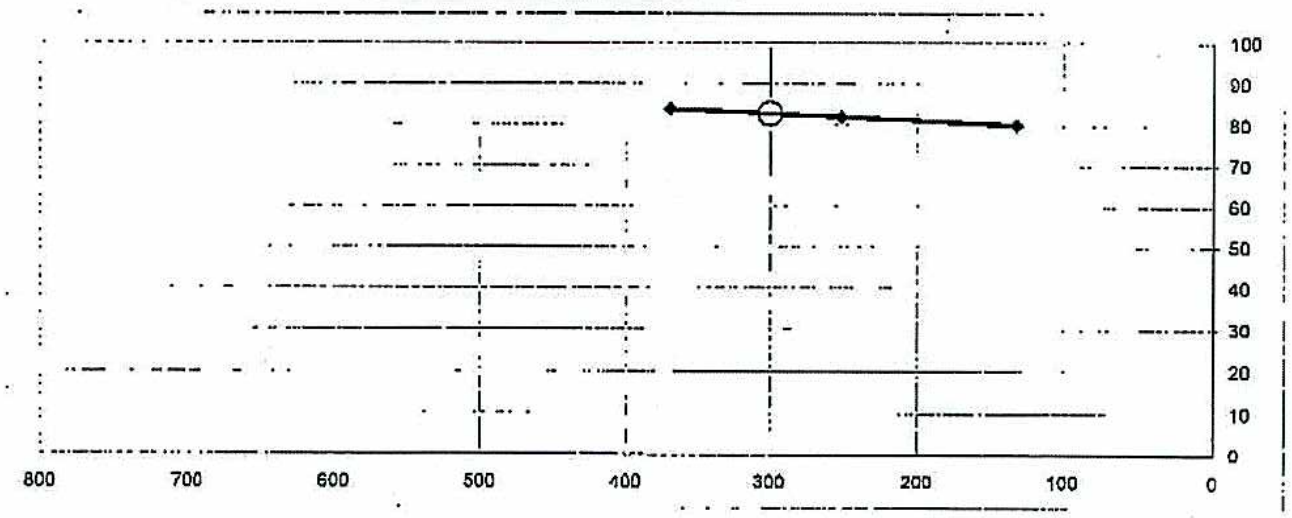
Lab Number => 27468
Date Sampled =>
Date Received => 23-Aug-04
Sampled By => Client
Tested By => J Wallis
Reviewed By => W Henshaw

Mold Label:	A	B	C
Moisture Content:	4.2%	5.0%	4.6%
Weight of Material used,gms:	1200.0	1200.0	1200.0
Water Added,gms:	50.0	60.0	55.0
Height of Specimen:	2.40	2.40	2.50
Weight of Specimen & mold:	3241.4	3293.8	3265.7
Weight of Mold,gms:	2098.4	2126.7	2110.3
Specimen Weight,gms:	1143	1167.1	1155.4
Exudation Pressure,lbs:	4636	1670	3150
Exudation Load Psi.:	369	133	251
Expansion Dial Reading:	0.0001	-0.0005	-0.0003
Stabilometer Reading @ 1000			
Stabilometer Reading @ 2000	16	27	21
Turns of Displacement:	4.05	2.94	3.63
Un-Corrected R-Value:	85	81	82
Correction from Chart:	-1	-1	
Corrected R-Value:	84	80	82
R-Value @ 300 psi. Exudation:			83
Dry Density PCF.:	138.6	140.5	134.0

Initial Moisture

Pan Number:	
Wet Wt of Sample + Pan:	2.0
Dry Wt of Sample + Pan:	2.0
Weight of Water:	
Weight of Pan:	1.0
Dry Weight of Sample:	1.0
Moisture content:	

Remarks and observations



Atlas Consultants, Inc.

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member of
AMERICAN SOCIETY FOR TESTING MATERIALS

ACT LAB NO: 12594(e) **DATE:** September 13, 2004

PROJECT NO: 48294 **P.O.:**

ANALYZED BY: Robert L. Summers **LAB ID:** 26468

WATER SOLUBLE SALT ANALYSIS IN SOIL

1:5 (soil:water) Aqueous Extraction
AWWA 3500-Na D, AWWA 4500 E
AWWA 2540 C

SOIL SIEVE SIZE = -10 MESH

Sample No.	Location	Depth (feet)	Sodium (Percent)	Water Soluble Sulfate (SO_4) (Percent)	Total Available Water Soluble Sodium Sulfate (Na_2SO_4) (Percent)
	B-01-B-2	6.5-8.0	0.07	0.20	0.21
Solubility = 0.79%					
	B-03-S-1	5.0-6.5	0.04	0.03	0.04
Solubility = 0.33%					

Robert L. Summers

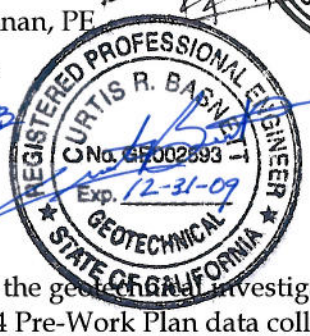
LABORATORY MANAGER

Notes: The results for each constituent denote the percentage of that analyte, at a 1:5 (soil:water) extraction ratio, which is present in the soil. Sodium was determined by flame photometry, sulfate turbidimetrically, and sodium sulfate by calculation.

Geotechnical Investigation, Topock AOC 4 Remediation – Pre-Work Plan Data Collection Activities, PG&E Compressor Station, Needles, California (CH2M HILL 2009)

Geotechnical Investigation, Topock AOC 4 Remediation – Pre-Work Plan Data Collection Activities, PG&E Compressor Station, Needles, California





PREPARED FOR:	Pacific Gas & Electric Company
PROJECT NO:	382653.FP.03.01
SUBMITTED BY:	CH2M HILL
PREPARED BY	Karthik Radhakrishnan, PE
REVIEWED BY:	Mike Cavaliere, PG Curt Basnett, GE
DATE:	October 9, 2009

Summary

This memorandum presents a summary of the geotechnical investigation conducted for the PG&E's Topock Compressor Station AOC 4 Pre-Work Plan data collection activities, including the field logs and laboratory test results. The purpose of this memorandum is to summarize the field investigation program, laboratory tests performed to evaluate the strength parameters of the subsurface materials, and present the findings from the stability analyses performed to assist with the planning of construction activities. This memorandum includes descriptions of the field investigation program and laboratory tests performed on collected samples including strength characteristics of the subsurface soils.

Four geotechnical borings were drilled in the areas on top of the ravine slopes in the AOC4 area. The scope of the geotechnical investigation did not include evaluation of fill along the slope face and at the bottom of the slope. The four borings were drilled until the augers refused on possible rock or other obstructions. Soil samples were obtained from the borings and tested for index properties, strength, and compaction characteristics. Profiles were developed based on the subsurface data and laboratory results. Slope stability analyses were also performed to evaluate the maximum slope ratio that can be maintained during construction activities, based on the estimated material strengths of the subsurface materials encountered.

Based on the subsurface exploration conducted, all the borings indicated fill material to depths of 5 feet below the existing ground surface. Based on results of the slope stability analyses, a 35 foot tall cut-slope with a 1 Horizontal (H): 1 Vertical (V) slope ratio is expected to be globally stable during construction and remediation activities. A factor of safety (FOS) for slope failure of over 1.2 was computed for this condition considering a surcharge of about 500 pounds per square foot (psf) on top of the slope. A factor of safety of 1.1 or greater is normally considered adequate for temporary slopes during construction activities.

Field Explorations

To characterize the subsurface conditions at the project site, a geotechnical field exploration was conducted at the truck-accessible locations in a nearly level area within the primary debris area of AOC4. The geotechnical field investigation included drilling four hollow stem auger (HSA) soil borings. Figure 1 shows the boring locations relative to the existing ravine, slopes, and the AOC4 area at the plant site. The figure also shows the existing grading at 1-foot contour intervals. Table 1 summarizes the field exploration.

Table 1 Summary of Field Exploration

Exploration Number	Approximate Location (NAD 83 Lat. /Lon.)	Approximate Ground Surface Elevation (feet)	Type of Boring	Depth to Auger Refusal (feet)	Groundwater Depth (feet)
AOC4-GEO1	34°42'47" N; 114°29'37" W	611.0	HSA	38.5	NE
AOC4-GEO2	34°42'47" N; 114°29'38" W	611.0	HSA	56	NE
AOC4-GEO3	34°42'46" N; 114°29'37" W	612.0	HSA	26	NE
AOC4-GEO4	34°42'46" N; 114°29'36" W	612.0	HSA	8.5	NE

NE – Not Encountered
NAD – North American Datum
Lat. – Latitude
Lon. – Longitude

Cascade Drilling, Inc., of La Habra, California, was contracted by CH2M HILL to drill the soil borings using a truck-mounted CME 85 drill rig equipped with an 8-inch-diameter HSA. The soil borings, B-1 and B-2, were drilled and sampled to the depth of 38.5 and 56 feet below ground surface (bgs), and borings B-3 and B-4 were drilled and sampled to the depth of 26 and 8.5 feet bgs. The borings were drilled until augers refused to advance either due to potential top of hard bedrock or due to hard cobbles. Groundwater was not encountered in the borings during drilling. A CH2M HILL geotechnical specialist specified the locations, depths, and sampling intervals of the borings, logged materials encountered, and observed the drilling and sampling operations.

Hand augering was performed for the first 5 feet in each of the boring to avoid possible underground utilities. Soil samples were collected at 5-foot intervals using the standard penetration test (SPT) and modified California ring (ring) samplers. The SPT and ring samplers were driven using a down-hole hydraulic hammer, 140-pound, free falling from a height of approximately 24 inches, for a total penetration of 18 inches into the ground. The blow counts were recorded for every 6 inches of penetration. The blow counts presented in parentheses on the boring logs are the blow counts for the last 12 inches of penetration and represent the field N-value.

Relatively intact soil samples were collected from the borings using the ring sampler. Sampling procedures generally followed SPT and split-barrel sampling of soils (American Society for Testing and Materials [ASTM] D1586). In addition, representative bulk samples

were collected from the borings at shallow depths from the hand auger cuttings. Each soil sample collected was examined and classified in accordance with the Unified Soils Classification System (USCS) per ASTM D2488. Following drilling, sampling, and logging, the borings were grouted with a Sodium Bentonite slurry mix. The soil boring logs are included in Attachment A of this memorandum.

Laboratory Testing

A laboratory testing program was conducted using the soils collected during the surface sampling program, as discussed in the previous section. These samples were used to perform index testing, strength testing, and compaction testing.

Index, Strength, and Compaction Testing

Index testing was performed to properly classify the soil obtained from the field exploration program in accordance with the Unified Soil Classification System (USCS). Compaction characteristics were also determined including the maximum dry density and optimum moisture content of a surface sample. Direct-shear tests were performed to evaluate the strength characteristics of the fill and native soil materials. Confining pressures were used corresponding to the depth from which the sample is obtained.

The laboratory testing was conducted by Environmental Geotechnology Laboratories of Arcadia, California, under subcontract to CH2M HILL. Test assignment and coordination were provided by CH2M HILL. Laboratory testing included the following ASTM standard test methods:

- ASTM D422 – Test Method for Particle-Size Analysis of Soils (grain size and hydrometer analyses)
- ASTM D4318 – Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
- ASTM D1557 – Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort
- ASTM D3080 – Test Method for Direct-Shear Test of Soils Under Consolidated Drained Conditions

Laboratory Test Results

The results of the laboratory testing programs are summarized in Tables 1 and 2 below. Laboratory testing is also summarized in Table B-1 provided in Attachment B. Detailed test results are presented in Attachment B.

The results of the index testing are presented in Table 2. Results of the index testing indicate that the grain size analyses for soil samples have predominantly granular components with fines content up to 32 percent. The results also indicate that all the tested samples had amounts of gravel ranging from 24 to 55 percent.

TABLE 2
Results of Index Testing

Boring Location	Sample Depth (ft)	% Gravel	% Sand	% Fines	LL (%)	PL (%)	PI (%)
AOC4-GEO1	1	-	-	-	17	16	1
	5	24	44	32			
	25	51	31	18			
	35	33	47	20			
AOC4-GEO2	15	37	41	22	19	18	1
	35	55	33	12			
	45	40	42	18			
AOC4-GEO3	1	44	35	21			
	15	33	38	29			
AOC4-GEO4	1	40	45	15			

ft = feet
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index

The results of strength testing are presented in Table 3. The in situ (field) moisture content of the native samples varied from 0.5 percent to 3.7 percent.

TABLE 3
Results of Direct Shear Strength Testing

			Peak Strength		Ultimate Strength	
Boring Location	Sample Depth (ft)	Sample Condition	Cohesion, C (psf)	Friction Angle, ϕ^o	Cohesion, C (psf)	Friction Angle, ϕ^o
AOC-GEO1	10	Relatively Intact	366	48	342	48
	20	Relatively Intact	6	40	0	40
AOC-GEO2	1	Remolded to 90% RC	185	36	86	34
	20	Relatively Intact	15	45	13	45
	30	Relatively Intact	301	44	307	44
AOC-GEO3	10	Remolded to 90% RC	534	31	112	33

psf = pound per square foot
RC = relative compaction

Subsurface Conditions

Based on the subsurface exploration conducted in AOC 4, the depth of debris fill materials is approximately 5 feet in the nearly level area and consists of silty sands and gravel mixed with debris, including some trash, roots, and peaty materials. These depths correspond to elevations of 606 feet and 607 feet, respectively, above mean sea level on the west and east side of the AOC4 area above the ravine. The debris and fill material is underlain by possible weakly cemented alluvium or weathered native materials. Boring AOC4-GEO2, located at the west edge of the existing slope above the ravine, encountered gravelly materials to approximately 35 feet bgs (El 577 feet). Based on the soil borings, the subsurface materials at the project site generally consist of gray to grayish brown, dry, medium dense to very dense, silty sand and silty gravel. The gravel sizes ranges from 0.5 to 3 inches. The uncorrected SPT N-values in this zone range from 17 for 12 inches of penetration to 50 for 6 inches of penetration.

Below the fill layer and alluvial sediments, weathered rock materials were encountered in some of the borings to the explored maximum depths overlying relatively unweathered metadiorite bedrock. The weathered rock generally consists of dense to very dense gravel and sand with silt. Gravel sizes varied from less than an inch up to 5 inches. In some areas broken cobbles or fragments of bedrock were present in the recovered samples. The uncorrected SPT N-values within the native soil zone were above 50. Detailed boring logs are presented in Attachment A.

Stability Analyses

Development of Stability Profiles

A critical cross section location was chosen passing through the existing slope at the point of maximum height. The section location is designated A-A'. CH2M HILL located the sections with respect to the existing grading plans, and the potential for overall impacts during slope excavations. As such, section A-A' is located along the western side of the AOC 4 area running north-south across the slope as shown in Figure 1.

Cross sections to develop stability profile models used in the stability analyses were generated from the most recent topographic map provided. The cross sections were developed manually using the topographic map. Section modifications were completed to demarcate estimated fill, alluvium, and the bedrock. The existing ravine slopes in the AOC 4 area are approximately 1.5H: 1V. Steeper slopes of varying grades ranging from 1H: 1V to less than 0.75H: 1V were modeled to represent the potential temporary slopes that may be maintained during remediation and construction operations. The material types within the slopes and below the slope subsurface were stratified, and their boundaries were demarcated based on materials encountered in the borings.

Design Soil Parameters

The strength parameters used in the stability analyses are developed based on the geotechnical exploration and laboratory testing data. Shear strength parameters of 100 psf of cohesion (C) and a friction angle (ϕ) of 38 degrees were used for the fill and alluvial

materials. For native materials consisting of very dense alluvium and weathered bedrock, a C of 100 psf and a ϕ of 40 degrees were used. The bedrock beneath the native soils is modeled using a C of 350 psf and a ϕ of 48 degrees.

Analyses Methodology

The slope stability analyses performed considers the overall (global) stability of slopes using circular and wedge-shaped failure planes. The slope stability analyses were performed using the Modified Bishop method for circular slip surfaces and Janbu Corrected method for wedge failures. The calculations were performed using the limit equilibrium computer program SLIDE v.5.0 (Rocscience, 2006). The method of slices estimates slope stability by assuming a failure surface and calculating the forces that would cause slope movement (driving forces) and the forces resisting slope movement (resisting forces) for the selected failure surface. The ratio of resisting forces to driving forces is known as the factor of safety. SLIDE 5.0 employs a searching routine to determine the failure surface with the minimum factor of safety. The critical slip surface for each major slope is shown on the analyses results.

Static slope stability analyses were conducted. A factor of safety of 1.1 or greater is normally considered adequate for temporary slopes during construction activities.

An equipment surcharge load of up to 500 psf is considered in the stability analyses to account for additional wheel loads on top of the slopes from vehicles and construction equipment. The following sections discuss the results and limitations of the analyses.

Stability Analyses Results

Cross section A-A' was analyzed for slope stability assuming global circular and block failure surfaces considering a 1H: 1V slope. The maximum slope height used is 35 feet. The lowest FOS obtained is 1.2. The results show a 35 foot tall slope with a 1H: 1V slope ratio is expected to be globally stable during construction and remediation activities. A steeper slope with 0.75H: 1V was also analyzed for global stability. The lowest FOS obtained considering circular and block failure surfaces is slightly less than 1.1.

The surficial stability of a localized side slope should be considered during the grading and other construction activities. Localized instabilities, if left unchecked, could lead to larger stability issues.

Conclusions, Recommendations, and Discussion

Based on the results of the field explorations, laboratory testing results, and stability analyses, the following can be inferred:

- The depth of debris fill materials encountered in the borings extends approximately 5 feet bgs on the nearly level area of AOC 4 and contains silty sand and gravel mixed with debris including some trash, roots and peaty materials. These depths correspond to elevations of 606 feet and 607 feet above mean sea level, respectively, on the west and east side of the AOC 4 area above the ravines.

- The debris fill is underlain by possible weakly cemented alluvium and weathered metadiorite bedrock. These materials consist of dense to very dense silty sand (SM) to silty gravels (GM). The gravel sizes ranges from 0.5 to 3 inches.
- Boring refusal, indicating bedrock or obstructions, was encountered at depths varying from 56 to 5 feet bgs. Boring AOC4-GEO2, located on the west edge of the existing slope, encountered refusal at EL 556 feet or about 56 feet bgs. Boring AOC4-GEO4, located on the east side of the existing slope, encountered refusal at EL 607 feet or at about 5 feet bgs. With respect to the exposed bedrock observed near the investigation site, boring refusal is interpreted as the surface of relatively unweathered bedrock.
- Based on the results of the slope stability analyses, a 35 foot tall slope with a 1H: 1V slope ratio is expected to be globally stable during construction and remediation activities. A FOS for slope failure of 1.2 was computed for this condition. An FOS of 1.1 or greater is normally considered adequate for temporary slopes during construction activities.
- It is recommended that temporary slopes be maintained no steeper than 1H: 1V and not higher than 35 feet. Shorter, steeper slopes may be achievable and should be evaluated if proposed.
- The surficial stability of a localized side slope should be considered during the grading and other construction activities. Localized instabilities, if left unchecked, could lead to larger stability issues

The scope of the geotechnical investigation and subsequent analyses noted above did not include evaluation of fill along the slope face and at the bottom of the slope. The fill thickness and engineering properties are unknown in these areas. Because of this, stability of the fill along the slope was not conducted. In addition, a detailed geologic assessment of bedrock conditions, including mapping of fractures and bedding planes, was not part of this scope of work. The analyses conducted assumed a homogeneous subgrade consisting of dense to very dense alluvial type materials underlain by bedrock, which was encountered in the borings.

Additional assessments are recommended during the removal phase of the slope. This may include, but may not be limited to, conducting test pits along the slope face and bottom of slope to determine fill thicknesses and engineering properties. Once obtained, this data should be reviewed by the removal contractor to provide further direction on the contractor's means and methods for fill removal.

Limitations

This memorandum has been prepared for the use of the PG&E for specific application to the Topock AOC 4 – Pre-Work plan data collection activities. This memorandum was prepared in accordance with generally accepted geotechnical engineering practice; no warranty, expressed or implied, is made.

The conclusions and recommendations contained in this memorandum are based on information from the current field exploration, laboratory testing, and analyses performed. These results reflect subsurface conditions only at specific locations, times, and to the depths explored. They do not necessarily reflect strata variations that might exist between exploration locations. The nature and extent of any variations in subsurface conditions might not become evident until construction. If conditions encountered during construction differ from those described in this memorandum, recommendations made in this memorandum will need to be re-evaluated by CH2M HILL.

If any changes in the nature, design, or locations of the facilities are planned, the conclusions and recommendations contained in this memorandum should not be considered valid unless the changes are reviewed and the conclusions of this memorandum are modified or verified in writing by CH2M HILL.

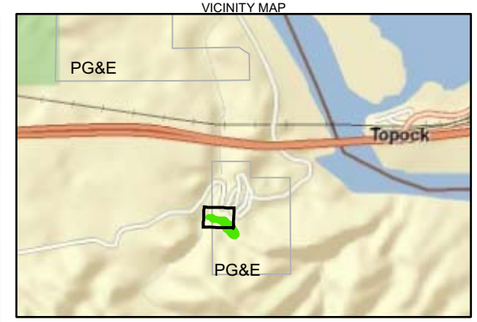
References

Rocscience, Inc. 2006. SLIDE V5.04, *User's Guide 1989-2003*

Figures



VICINITY MAP



LEGEND

- AOC-4 Geotech Borings
- AOC 4 Boundary
- AOC4 Area 1 ft contour

N

0 25 50 100
Feet

FIGURE 1
AOC 4 GEOTECHNICAL BORINGS GROUND SUFRACE ELEVATIONS
PG&E Topock Compressor Station
Needles, California

Attachments

Attachment A
Boring Logs

CH2MHILL

PROJECT NUMBER	BORING NUMBER:	
382653.FP.03.01	AOC4-GE01	SHEET 1 OF 2

SOIL BORING LOG

PROJECT : PG & E TOPOCK SITE REMEDIATION LOCATION : Topock, CA

ELEVATION : 611.0 DRILLING CONTRACTOR : Cascade Drilling, Inc.

DRILLING METHOD AND EQUIPMENT : CME 85, HSA Downhole Hammer (140 lbs., 24 inch drop)

WATER LEVELS : --- START: 7/29/2009 END: 7/30/2009 LOGGER : KR

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
0.0			B-1		SILTY SAND (SM), FILL, gray, dry, with fine to coarse gravel (1"-3"), trash, peat.	
5 5.0						
6.5	1.1	S-2		18-24-38 (62)	-- dense, fine sand, low plastic silt, no trash, no peat.	
10 10.0						
11.5	1.6	D-3		30-18-16 (34)	-- medium dense, medium to coarse gravel (1"-3"), low plastic silt.	
15 15.0						
16.5	1.4	S-4		15-18-24 (42)	-- dense, grayish brown.	
20 20.0						
21.5	1.0	D-5		38-27-37 (64)	-- gravel sizes from <0.5" to 2", coarse sand.	
25 25.0						
26.5	0.2	S-6		39-50/6" (50/6")	SILTY GRAVEL (GM), gray, dry, very dense, with coarse sand, fine gravel, low plastic silt.	
30						

CH2MHILL

PROJECT NUMBER	BORING NUMBER:	
382653.FP.03.01	AOC4-GE01	SHEET 2 OF 2

SOIL BORING LOG

PROJECT : PG & E TOPOCK SITE REMEDIATION LOCATION : Topock, CA

ELEVATION : 611.0 DRILLING CONTRACTOR : Cascade Drilling, Inc.

DRILLING METHOD AND EQUIPMENT : CME 85, HSA Downhole Hammer (140 lbs., 24 inch drop)

WATER LEVELS : --- START: 7/29/2009 END: 7/30/2009 LOGGER : KR

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
	30.0					
	31.5	0.6	D-7	50/6" (50/6")		
	32.0					
			B-8			
35	35.0					
	36.5	0.5	S-9	48-50/2" (50/2")	SILTY SAND (SM), gray, dry, very dense, with fine gravel, medium grained sand, low plastic silt. @36' - possible Bedrock, light gray, dry, weathered.	
40					Auger refusal @38.5'. Bottom of Hole @38.5'. No groundwater encountered. 7/30/09 8:00 AM	
45						
50						
55						
60						

CH2MHILL

PROJECT NUMBER	BORING NUMBER:	
382653.FP.03.01	AOC4-GE02	SHEET 1 OF 2

SOIL BORING LOG

PROJECT : PG & E TOPOCK SITE REMEDIATION LOCATION : Topock, CA

ELEVATION : 611.0 DRILLING CONTRACTOR : Cascade Drilling, Inc.

DRILLING METHOD AND EQUIPMENT : CME 85, HSA Downhole Hammer (140 lbs., 24 inch drop)

WATER LEVELS : --- START: 7/30/2009 END: 7/30/2009 LOGGER : KR

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
0	0.0		B-1		SILTY GRAVEL (GM), FILL, gray, moist, fine sand, low plastic silt, gravel sizes from <0.5" to 3", some waste debris.	Start @1:35 pm.
5	5.0	0.4	S-2	8-9-17 (26)	-- medium dense, no waste/debris.	
	6.5					
10	10.0	0.5	D-3	16-19-27 (46)		
	11.5					
15	15.0	0.6	S-4	18-19-24 (43)	SILTY SAND (SM), grayish-brown, with fine to medium gravel, fine sand, low plastic silt.	
	16.5					
20	20.0	1.0	D-5	19-27-31 (58)		
	21.5					
25	25.0	1.1	S-6	20-23-26 (49)	-- olive brown, dense.	
	26.5					
30						

CH2MHILL

PROJECT NUMBER	BORING NUMBER:	
382653.FP.03.01	AOC4-GE02	SHEET 2 OF 2

SOIL BORING LOG

PROJECT : PG & E TOPOCK SITE REMEDIATION — LOCATION : Topock, CA

ELEVATION : 611.0 — DRILLING CONTRACTOR : Cascade Drilling, Inc.

DRILLING METHOD AND EQUIPMENT : CME 85, HSA Downhole Hammer (140 lbs., 24 inch drop)

WATER LEVELS : --- — START: 7/30/2009 — END: 7/30/2009 — LOGGER : KR

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
	30.0					
	31.5	1.0	D-7	19-20-26 (46)	-- medium dense, turn into gray rock fragments/gravel @31'.	
35	35.0					
	36.5	0.8	S-8	20-24-27 (51)	POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM), olive-gray, dry, dense, gravel sizes (2" to 4"), fine sand, low plastic silt.	
40	40.0					
	41.5	1.0	D-9	50/6" (50/6")	-- very dense, broken rock fragments/cobble.	
45	45.0					
	46.5	0.8	S-10	27-50/6" (50/6")	SILTY SAND (SM), gray, dry, very dense, with fine to medium gravel, up to 1-5", coarse sand, low plastic silt.	
50	50.0					
	51.5	1.0	D-11	50/6" (50/6")		
55	55.0					
	56.5	0.7	S-12	39-50/2" (50/2")		
60					Auger refusal @56'. Bottom of Hole @56'. No groundwater encountered. Backfilled with Bentonite grout. 7/30/09 3:45 PM	

CH2MHILL

PROJECT NUMBER	BORING NUMBER:	
382653.FP.03.01	AOC4-GE03	SHEET 1 OF 1

SOIL BORING LOG

PROJECT : PG & E TOPOCK SITE REMEDIATION LOCATION : Topock, CA

ELEVATION : 612.0 DRILLING CONTRACTOR : Cascade Drilling, Inc.

DRILLING METHOD AND EQUIPMENT : CME 85, HSA Downhole Hammer (140 lbs., 24 inch drop)

WATER LEVELS : --- START: 7/30/2009 END: 7/30/2009 LOGGER : KR

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
0	0.0		B-1		SILTY SAND (SM), FILL, gray, dry, fine sand, with gravel size <0.2" to 4", low plastic silt, some debris.	
5	5.0	0.3	S-2	20-25-32 (57)	-- dense, no debris.	
	6.5					
10	10.0	0.3	D-3	12-15-17 (32)	-- medium dense.	
	11.5					
15	15.0	0.4	S-4	26-50/6" (50/6")	-- very dense.	
	16.5		B-5		SILTY GRAVEL (GM), gray to brown, dry, fine sand, low plastic silt, fine to medium gravel.	
20	20.0	0.5	D-6	16-21-19 (40)	-- medium dense.	
	21.5					
25	25.0	0.0	S-7	50/0" (50/0")	-- possible Bedrock or cobble.	
	26.5				Auger and spoon refusal @26'. Bottom of Hole @26'. No groundwater encountered. 7/30/09 12:00 PM	
30						

CH2MHILL

PROJECT NUMBER	BORING NUMBER:	
382653.FP.03.01	AOC4-GE04	SHEET 1 OF 1

SOIL BORING LOG

PROJECT : PG & E TOPOCK SITE REMEDIATION LOCATION : Topock, CA

ELEVATION : 612.0 DRILLING CONTRACTOR : Cascade Drilling, Inc.

DRILLING METHOD AND EQUIPMENT : CME 85, HSA Downhole Hammer (140 lbs., 24 inch drop)

WATER LEVELS : --- START: 7/30/2009 END: 7/30/2009 LOGGER : KR

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
0.0			B-1		SILTY SAND (SM), FILL, gray, dry, fine to coarse sand, with gravel size <0.2" to 2", some waste and debris.	Start @9:50 am.
5 5.0						
6.5	0.3	S-2		50/3" (50/3")	-- gray, Bedrock (possible), soft, weathered, no waste or debris.	
10					Bedrock @8.5'. Auger refusal @8.5'. Bottom of Hole @8.5'. No groundwater encountered. Backfilled with Bentonite grout. 7/30/09 11:00 AM	
15						
20						
25						
30						

Attachment B
Laboratory Testing Results

TABLE B-1
SUMMARY OF LABORATORY TEST RESULTS - PG E TOPOCK SITE REMEDIATION

Boring	Sample	Sample Depth (ft)	USCS Classification	Field Dry Density (pcf)	Field Moisture Content (%)	Compaction		Grain Size (GR:SD:FN)	Atterberg Limits			Direct Shear				Direct Shear			
												Undisturbed				Remolded to 90% RC			
						Max. Dry Density (pcf)	Opt. Moisture Content (%)		Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Peak C (psf)	Peak Phi (deg)	Ultimate C (psf)	Ultimate Phi (deg)	Peak C (psf)	Peak Phi (deg)	Ultimate C (psf)	Ultimate Phi (deg)
A0C4-GEO1	B1	1 - 5	SM		1.8				17	16	1								
	S2	5 - 6.5	SM		1.4			24:44:32											
	D3	10 - 11.5	SM									366	48	342	48				
	S4	15 - 16.5	SM		1.2														
	D5	20 - 21.5	SM									6	40	0	40				
	S6	25 - 26.5	GM		2.0			51:31:18											
	D7	30 - 31.5	GM		1.5														
	S9	35 - 36.5	SM		1.9			33:47:20											
A0C4-GEO2	B1	1 - 5	GM													185	36	86	34
	S2	5 - 6.5	GM		1.0														
	S4	15 - 16.5	SM		1.4			37:41:22	19	18	1								
	D5	20 - 21.5	SM									15	45	13	45				
	S6	25 - 26.5	SM		2.0														
	D7	30 - 31.5	SM									301	44	307	44				
	S8	35 - 36.5	GP-GM		0.5			55:33:12											
	D9	40 - 41.5	GP-GM	126.7	2.0														
	S10	45 - 46.5	SM		2.7			40:42:18											
	S12	55 - 56.5	SM		3.7														
A0C4-GEO3	B1	1 - 5	SM		1.2			44:35:21											
	S4	15 - 16.5	SM		1.6			33:38:29											
	B5	10 - 11.5	SM			141.0	5.5									534	31	112	33
	D6	20 - 21.5	GM	113.4	1.2														
A0C4-GEO4	B1	1 - 5	SM					40:45:15											

SUMMARY OF LABORATORY TEST RESULTS

PROJECT NAME: PG&E TOPOCK

PROJECT NO: 382653.FP.03.01

DATE: 8/19/2009

EGL JOB NO: 09-119-001

CLIENT: CH2M HILL

SUMMARIZED BY: RJ

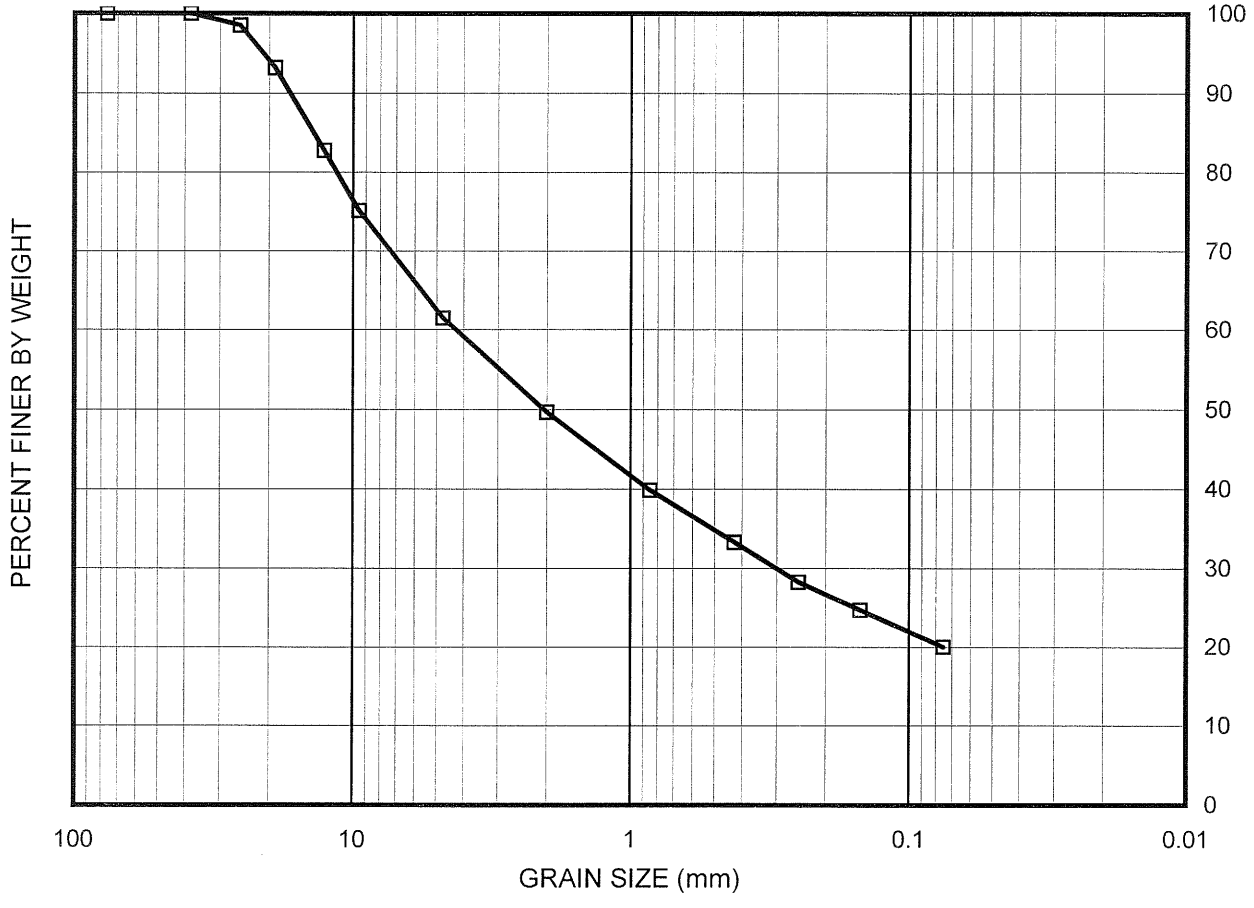
BORING NO	SAMPLE NO	DEPTH (ft)	MOISTURE CONTENT ASTM D2216 (%)	DRY DENSITY ASTM D2937 (pcf)	ATTERBERG LIMITS ASTM D4318 *(LL,PL,PI)
N/A	AOC4-Geo1-B1	1-5	1.8		17,16,1
N/A	AOC4-Geo1-S2	5-6.5	1.4		
N/A	AOC4-Geo1-S4	15-16.5	1.2		
N/A	AOC4-Geo1-S6	25-26.5	0.7		
N/A	AOC4-Geo1-D7	30-31.5	1.5	disturbed	
N/A	AOC4-Geo1-S9	35-36.5	1.9		
N/A	AOC4-Geo2-S2	5-6.5	1.0		
N/A	AOC4-Geo2-S4	15-16.5	1.4		19,18,1
N/A	AOC4-Geo2-S6	25-26.5	2.0		
N/A	AOC4-Geo2-S8	35-36.5	0.5		
N/A	AOC4-Geo2-D9	40-41.5	2.0	126.7	
N/A	AOC4-Geo2-S10	45-46.5	2.7		
N/A	AOC4-Geo2-S12	55-56.5	3.7		
N/A	AOC4-Geo3-B1	1-5	1.2		
N/A	AOC4-Geo3-S4	15-16.5	1.6		
N/A	AOC4-Geo3-D6	20-21.5	1.2	113.4	

*LL,PL,PI = LIQUID LIMIT, PLASTIC LIMIT, PLASTICITY INDEX

GRAVEL		SAND			SILT OR CLAY
COARSE	FINE	COARSE	MEDIUM	FINE	

U.S STANDARD SIEVE OPENING | U.S. STANDARD SIEVE NUMBER | HYDROMETER

3" 1-½" ¾" ⅜" #4 #10 #20 #40 #60 #100 #200



SYMBOL	BORING NO	SAMPLE NO	DEPTH (FT)	SAMPLE TYPE	SOIL TYPE	LIQUID LIMIT	PLASTICITY INDEX
□	N/A	AOC4-Geo1-B1	1-5	Bulk	SM	17	1

ENVIRONMENTAL GEOTECHNOLOGY LABORATORY

Project Name: PG&E Topock

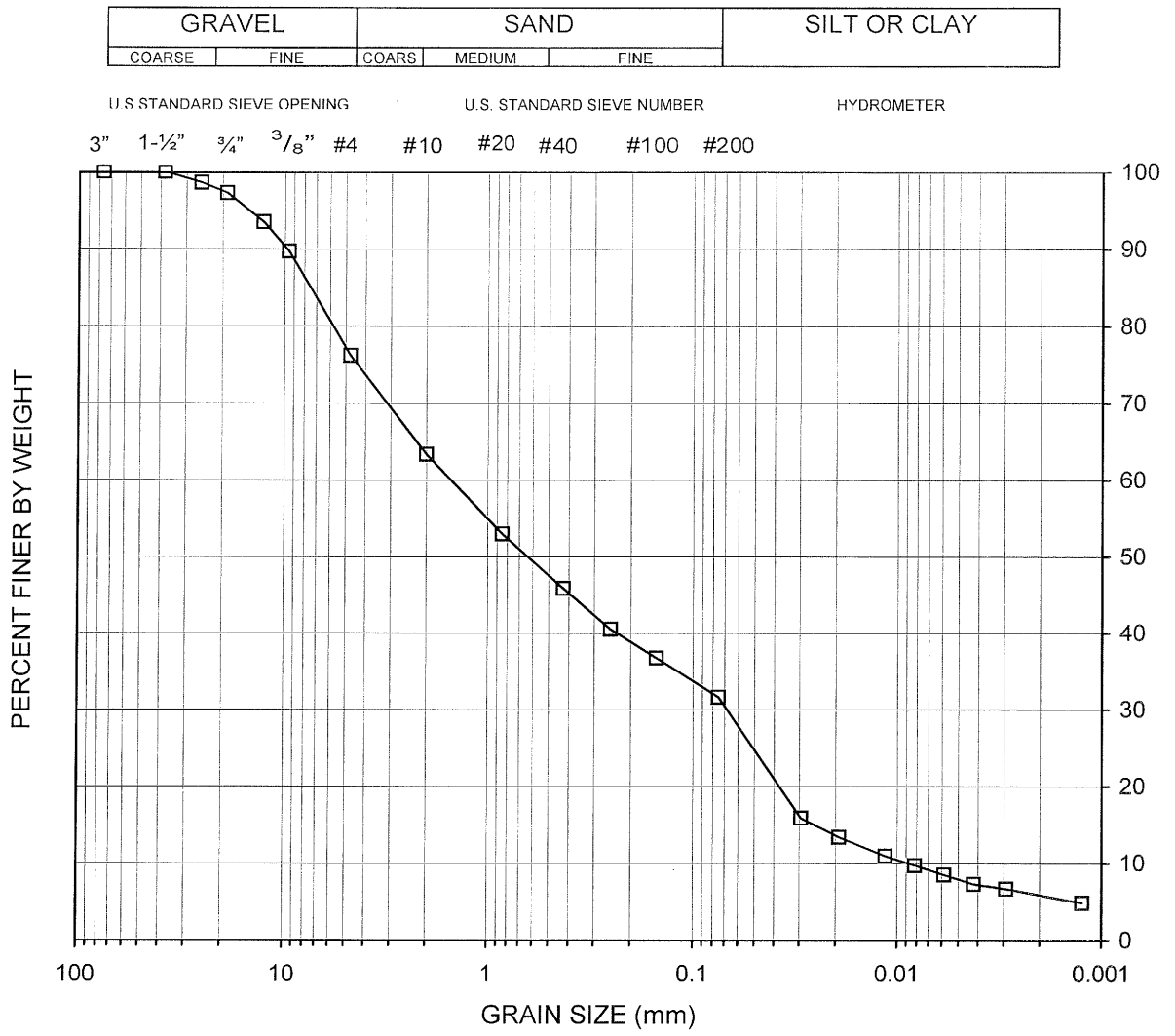
Client Job No.: 382653.FP.03.01

Client Name: CH2M Hill

EGL Project No: 09-119-001

GRAIN SIZE DISTRIBUTION CURVE

Aug-09 (ASTM D422) FIGURE



SYMBOL	BORING No.	SAMPLE No.	DEPTH (FT)	SAMPLE TYPE	SOIL TYPE	LIQUID LIMIT	PLASTICITY INDEX
□	N/A	AOC4-Geo1-S2	5-6.5	Bag	SM	N/A	N/A

ENVIRONMENTAL GEOTECHNOLOGY LABORATORY

Project Name: PG & E Topock

Client: CH2M Hill

Job No: 382653.FP.03.01

EGL Project No: 09-119-001

GRAINSIZE DISTRIBUTION CURVE

08/21/09 (ASTM D422) FIGURE



SYMBOL	BORING NO	SAMPLE NO	DEPTH (FT)	SAMPLE TYPE	SOIL TYPE	LIQUID LIMIT	PLASTIC INDEX
□	N/A	AOC4-Geo1-S6	25-26.5	Bag	GM	N/A	N/A

ENVIRONMENTAL GEOTECHNOLOGY LABORATORY

Project Name: PG&E Topock

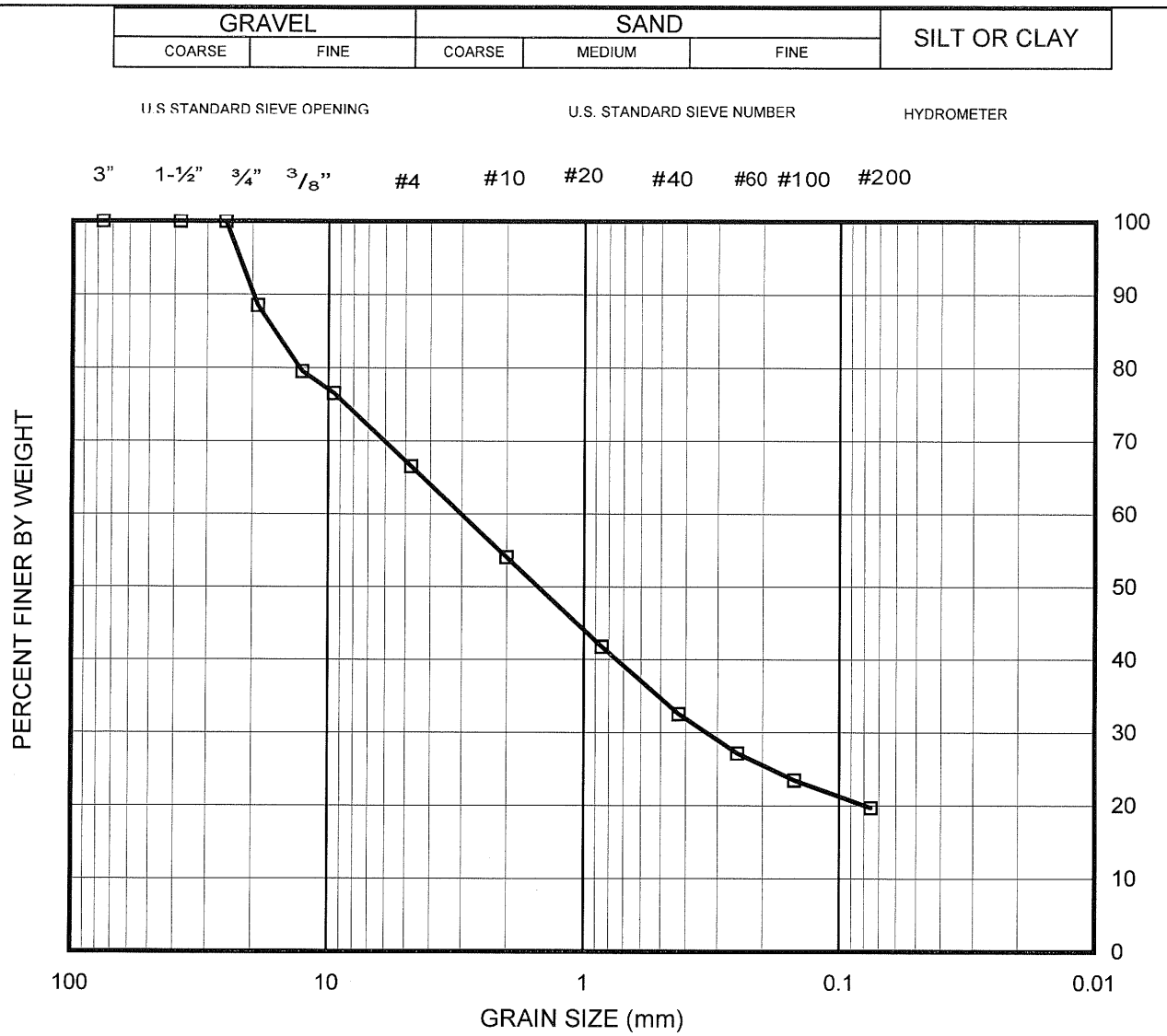
Client Job No.: 382653.FP.03.01

Client Name: CH2M Hill

EGL Project No: 09-119-001

GRAIN SIZE DISTRIBUTION CURVE

08/21/09 (ASTM D422) FIGURE



SYMBOL	BORING NO	SAMPLE NO	DEPTH (FT)	SAMPLE TYPE	SOIL TYPE	LIQUID LIMIT	PLASTIC INDEX
□	N/A	AOC4-Geo1-S9	35-36.5	Bag	SM	N/A	N/A

ENVIRONMENTAL GEOTECHNOLOGY LABORATORY

Project Name: PG&E Topock

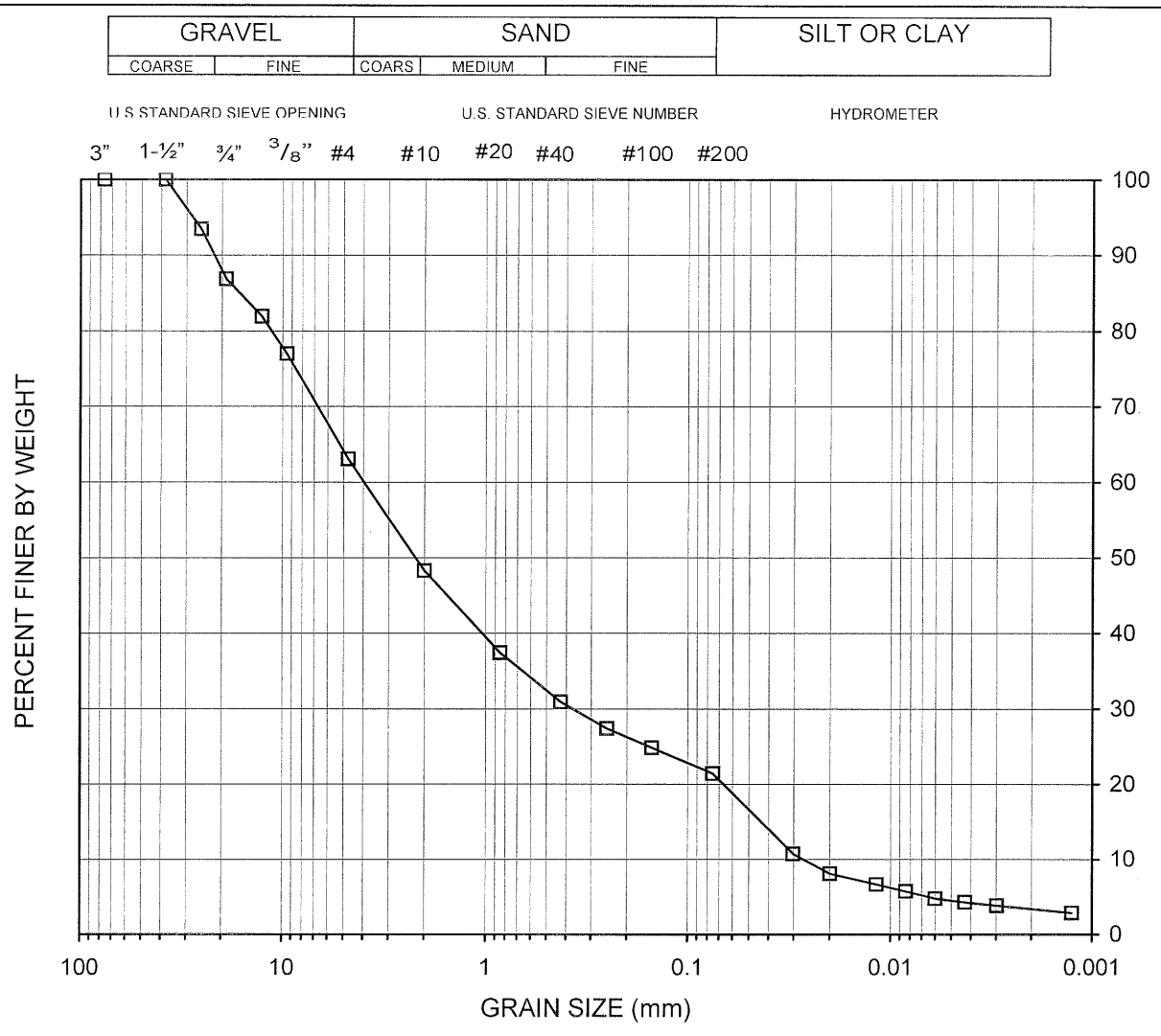
Client Job No.: 382653.FP.03.01

Client Name: CH2M Hill

EGL Project No: 09-119-001

GRAIN SIZE DISTRIBUTION CURVE

08/19/09 (ASTM D422) FIGURE



SYMBOL	BORING No.	SAMPLE No.	DEPTH (FT)	SAMPLE TYPE	SOIL TYPE	LIQUID LIMIT	PLASTICITY INDEX
□	N/A	AOC4-Geo2-S4	15-16.5	Bag	SM	19	1

ENVIRONMENTAL GEOTECHNOLOGY LABORATORY

Project Name: PG & E Topock

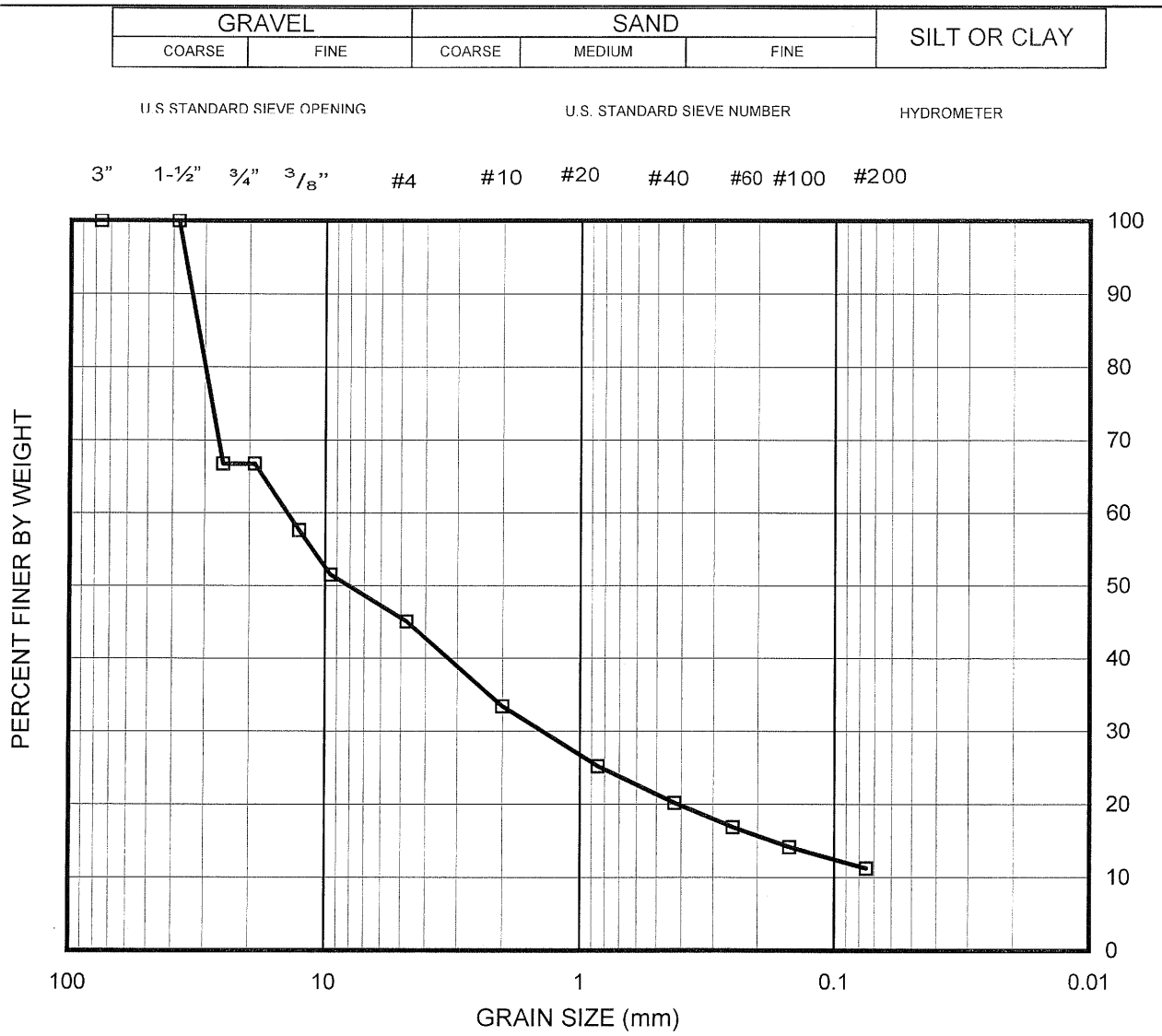
Client: CH2M Hill

Job No: 382653.FP.03.01

EGL Project No: 09-119-001

GRAINSIZE DISTRIBUTION CURVE

08/24/09 (ASTM D422) FIGURE



SYMBOL	BORING NO	SAMPLE NO	DEPTH (FT)	SAMPLE TYPE	SOIL TYPE	LIQUID LIMIT	PLASTIC INDEX
□	N/A	AOC4-Geo2-S8	35-36.5	Bag	GP-GM	N/A	N/A

ENVIRONMENTAL GEOTECHNOLOGY LABORATORY

Project Name: PG&E Topock

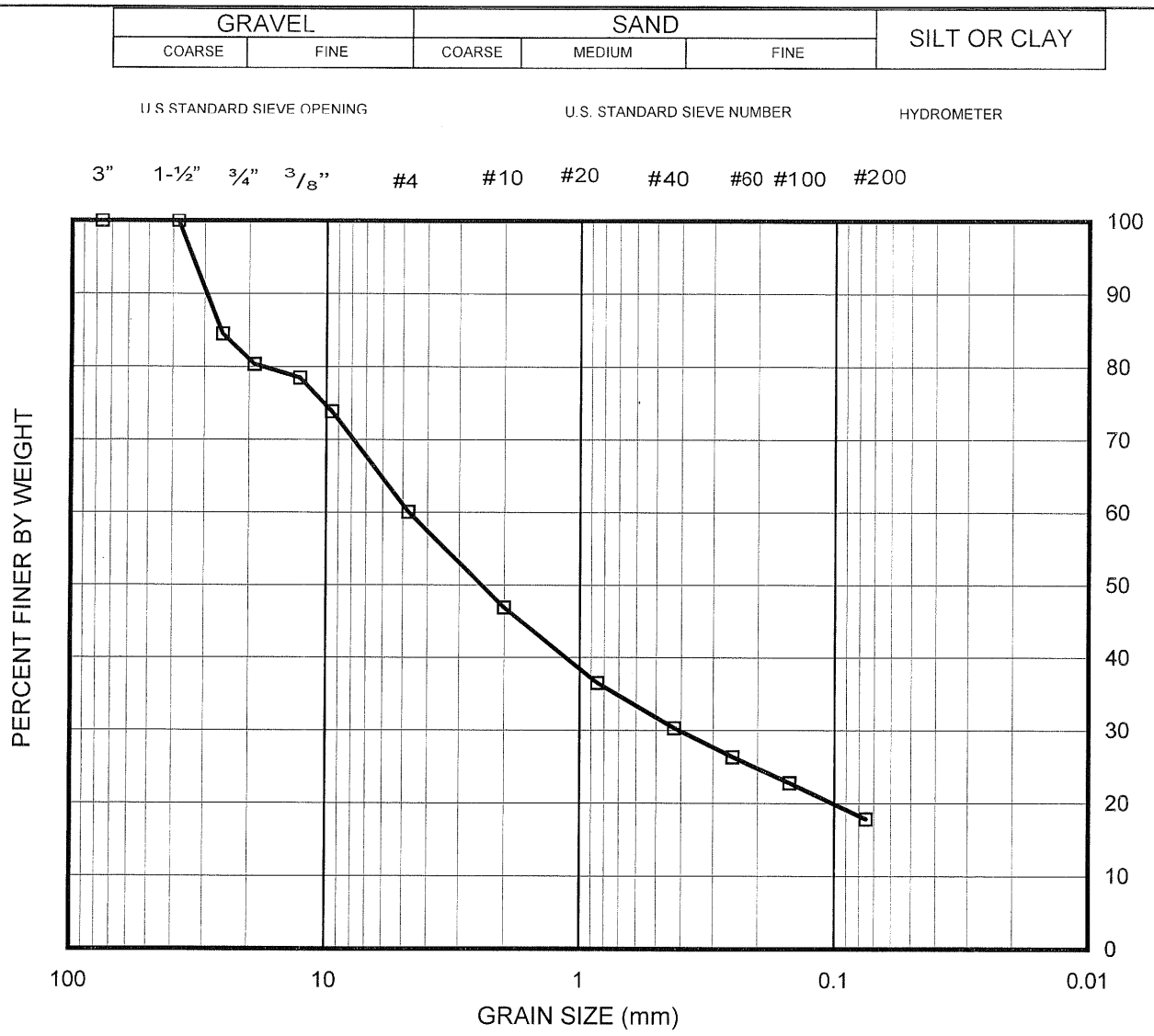
Client Job No.: 382653.FP.03.01

Client Name: CH2M Hill

EGL Project No: 09-119-001

GRAIN SIZE DISTRIBUTION CURVE

08/21/09 (ASTM D422) FIGURE



SYMBOL	BORING NO	SAMPLE NO	DEPTH (FT)	SAMPLE TYPE	SOIL TYPE	LIQUID LIMIT	PLASTIC INDEX
□	N/A	AOC4-Geo2-S10	45-46.5	Bag	SM	N/A	N/A

ENVIRONMENTAL GEOTECHNOLOGY LABORATORY

Project Name: PG&E Topock

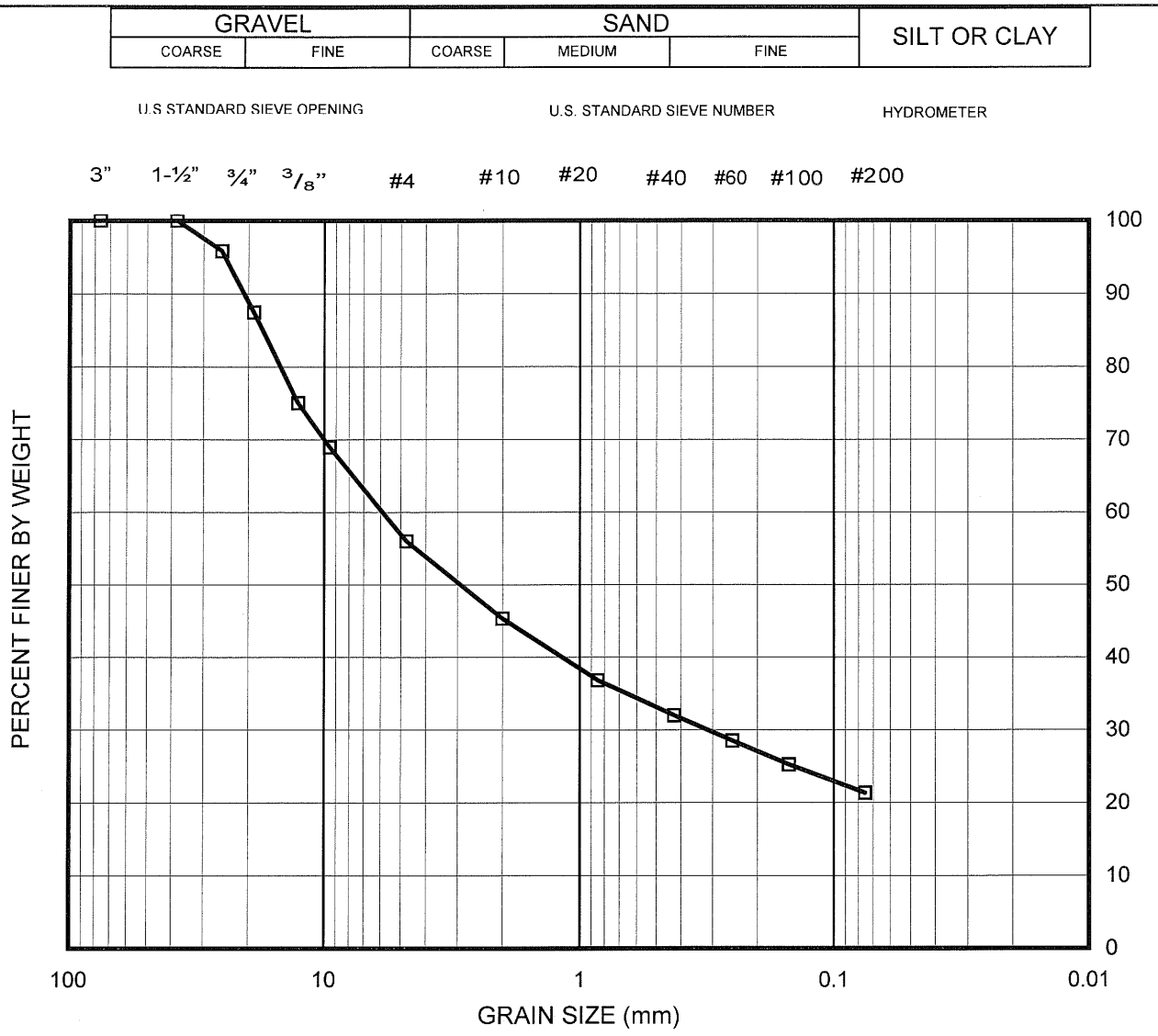
Client Job No.: 382653.FP.03.01

Client Name: CH2M Hill

EGL Project No: 09-119-001

GRAIN SIZE DISTRIBUTION CURVE

08/21/09 (ASTM D422) FIGURE



SYMBOL	BORING NO	SAMPLE NO	DEPTH (FT)	SAMPLE TYPE	SOIL TYPE	LIQUID LIMIT	PLASTIC INDEX
□	N/A	AOC4-Geo3-B1	1-5	Bulk	SM	N/A	N/A

ENVIRONMENTAL GEOTECHNOLOGY LABORATORY

Project Name: PG&E Topock

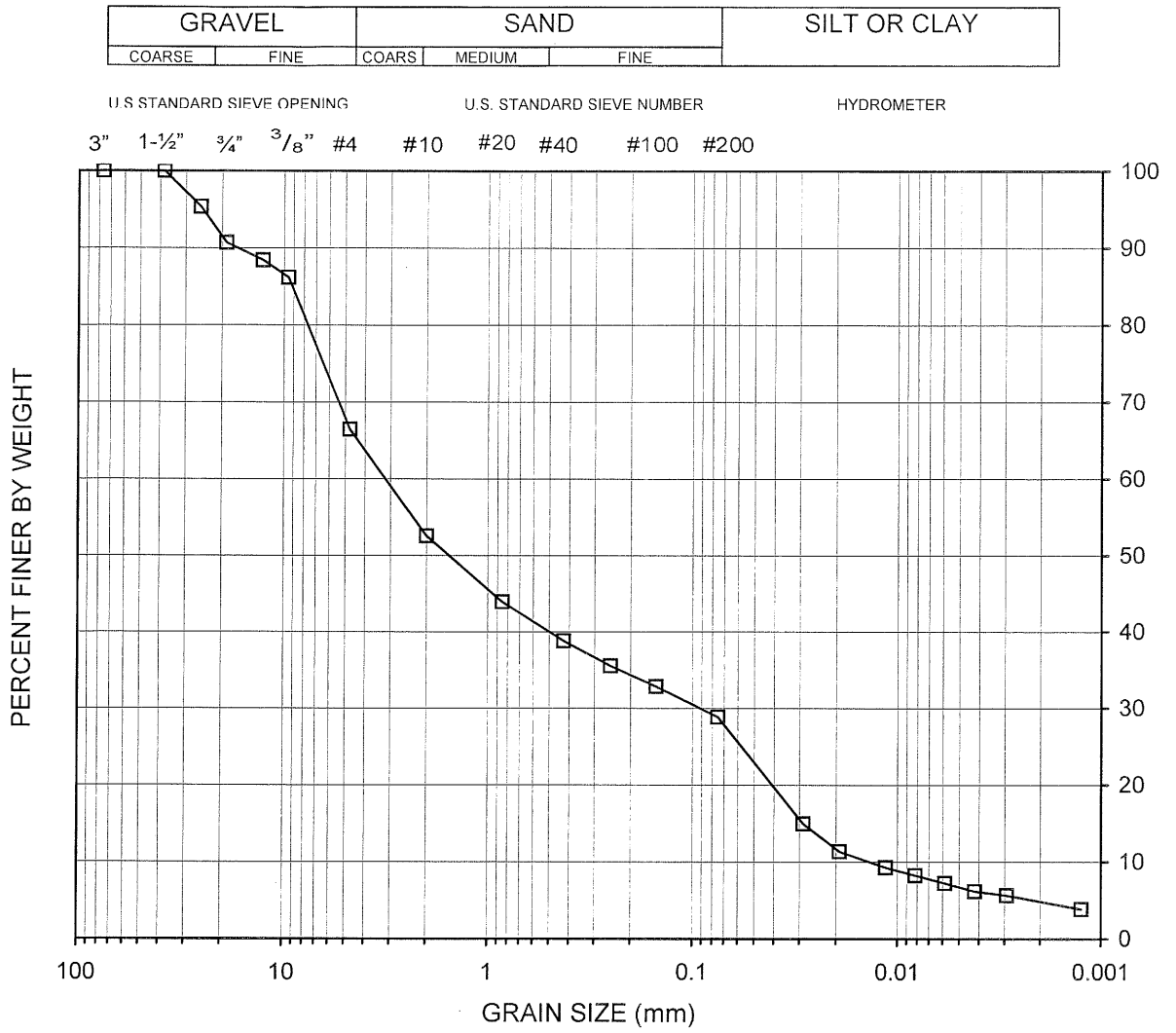
Client Job No.: 382653.FP.03.01

Client Name: CH2M Hill

EGL Project No: 09-119-001

GRAIN SIZE DISTRIBUTION CURVE

Aug-09 (ASTM D422) FIGURE



SYMBOL	BORING No.	SAMPLE No.	DEPTH (FT)	SAMPLE TYPE	SOIL TYPE	LIQUID LIMIT	PLASTICITY INDEX
□	N/A	AOC4-Geo3-S4	15-16.5	Bag	SM	N/A	N/A

ENVIRONMENTAL GEOTECHNOLOGY LABORATORY

Project Name: PG & E Topock

Client: CH2M Hill

Job No: 382653.FP.03.01

EGL Project No: 09-119-001

GRAINSIZE DISTRIBUTION CURVE

08/21/09

(ASTM D422)

FIGURE



SYMBOL	BORING NO	SAMPLE NO	DEPTH (FT)	SAMPLE TYPE	SOIL TYPE	LIQUID LIMIT	PLASTIC INDEX
□	N/A	AOC4-Geo4-B1	1-5	Bulk	SM	N/A	N/A

ENVIRONMENTAL GEOTECHNOLOGY LABORATORY

Project Name: PG&E Topock

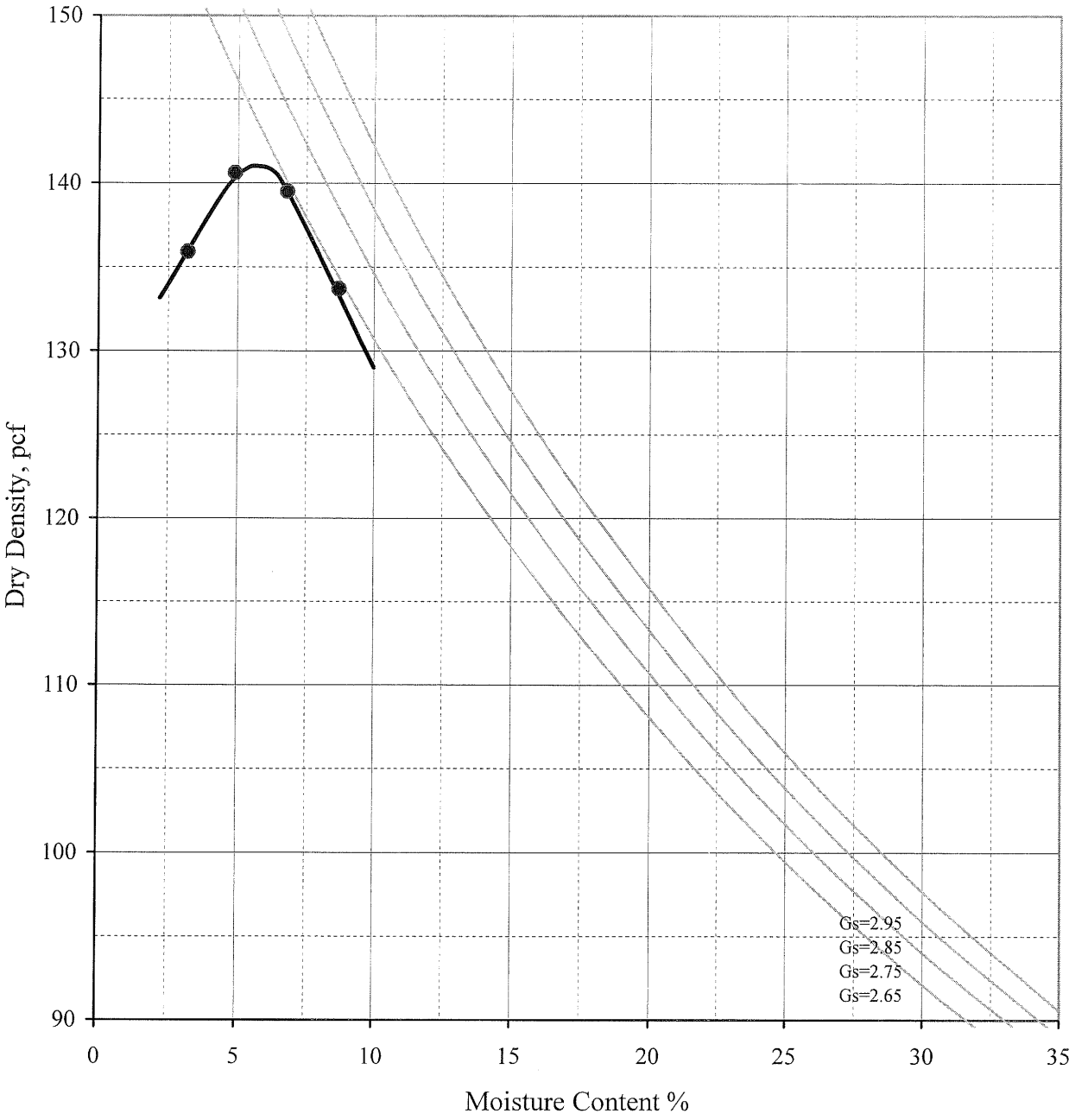
Client Job No.: 382653.FP.03.01

Client Name: CH2M Hill

EGL Project No: 09-119-001

GRAIN SIZE DISTRIBUTION CURVE

Aug-09 (ASTM D422) FIGURE



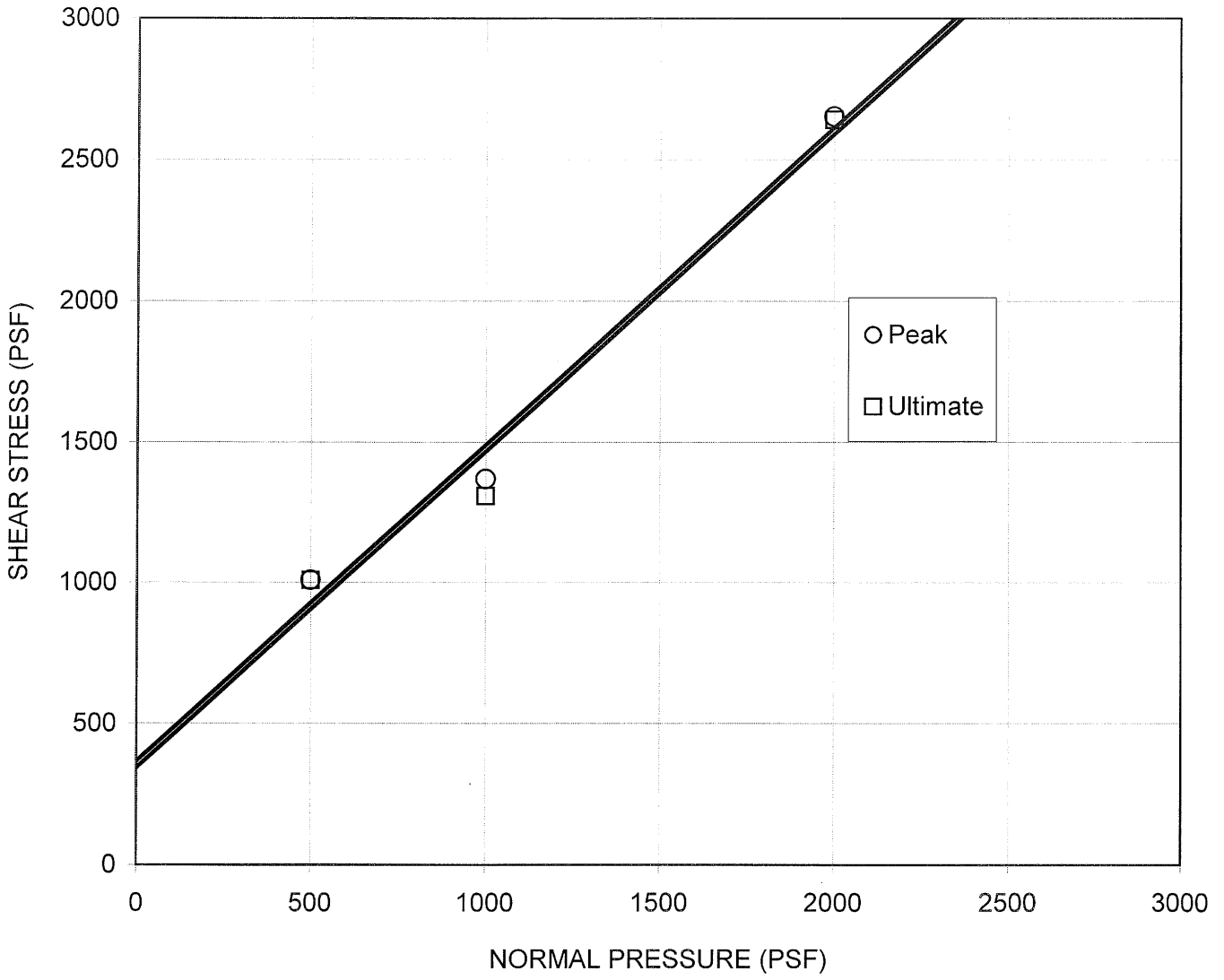
Maximum Dry Density = 141 pcf	Boring No: N/A
	Sample: ACO4-Geo4-B1
Optimum Moisture Content = 5.5 %	Depth : 1-5 feet
	Description : SC

Environmental Geotechnology Laboratory

Modified Proctor

(ASTM D1557)

Project Name:	PG & E Topock
	0
Client Name:	CH2M Hill
Job No:	382653.FP.03.01
EGL Project No.:	09-119-001
Date : Aug-09	Figure



Boring No.:	Sample No.	Depth (ft)	Sample Type	Soil Type	Symbol	Cohesion (PSF)	Friction Angle
N/A	AOC4-Geo1-D3	10-11.5	Ring	SM	○	366	48
					□	342	48

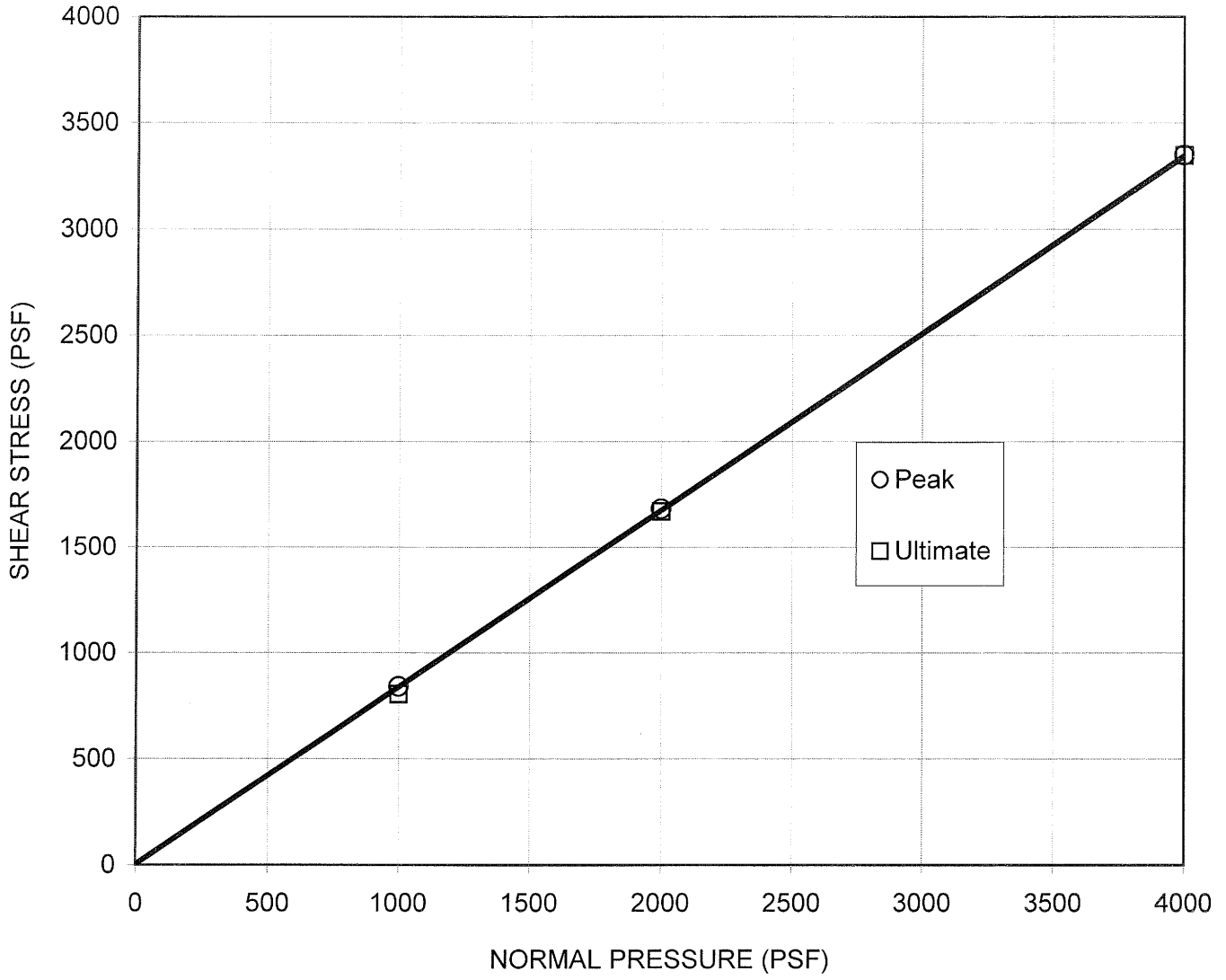
Normal Stress (psf)	Initial Moisture (%)	Final Moisture (%)
500	1.5	14.3
1000	1.5	13.4
2000	1.5	12.1

ENVIRONMENTAL GEOTECHNOLOGY LABORATORY

Project Address:
PG&E Topock
Client: CH2M Hill
Project No: 382653.FP.03.01
EGL Project No: 09-119-001

DIRECT SHEAR

08/09 (ASTM D3080) Figure



Boring No.:	Sample No.	Depth (ft)	Sample Type	Soil Type	Symbol	Cohesion (PSF)	Friction Angle
N/A	AOC4-Geo1-D5	20-21.5	Ring	SM	○	6	40
					□	0	40

Normal Stress (psf)	Initial Moisture (%)	Final Moisture (%)
1000	1.7	16.3
2000	1.7	15.7
4000	1.7	15.1

ENVIRONMENTAL GEOTECHNOLOGY LABORATORY

Project Address:
PG&E Topock

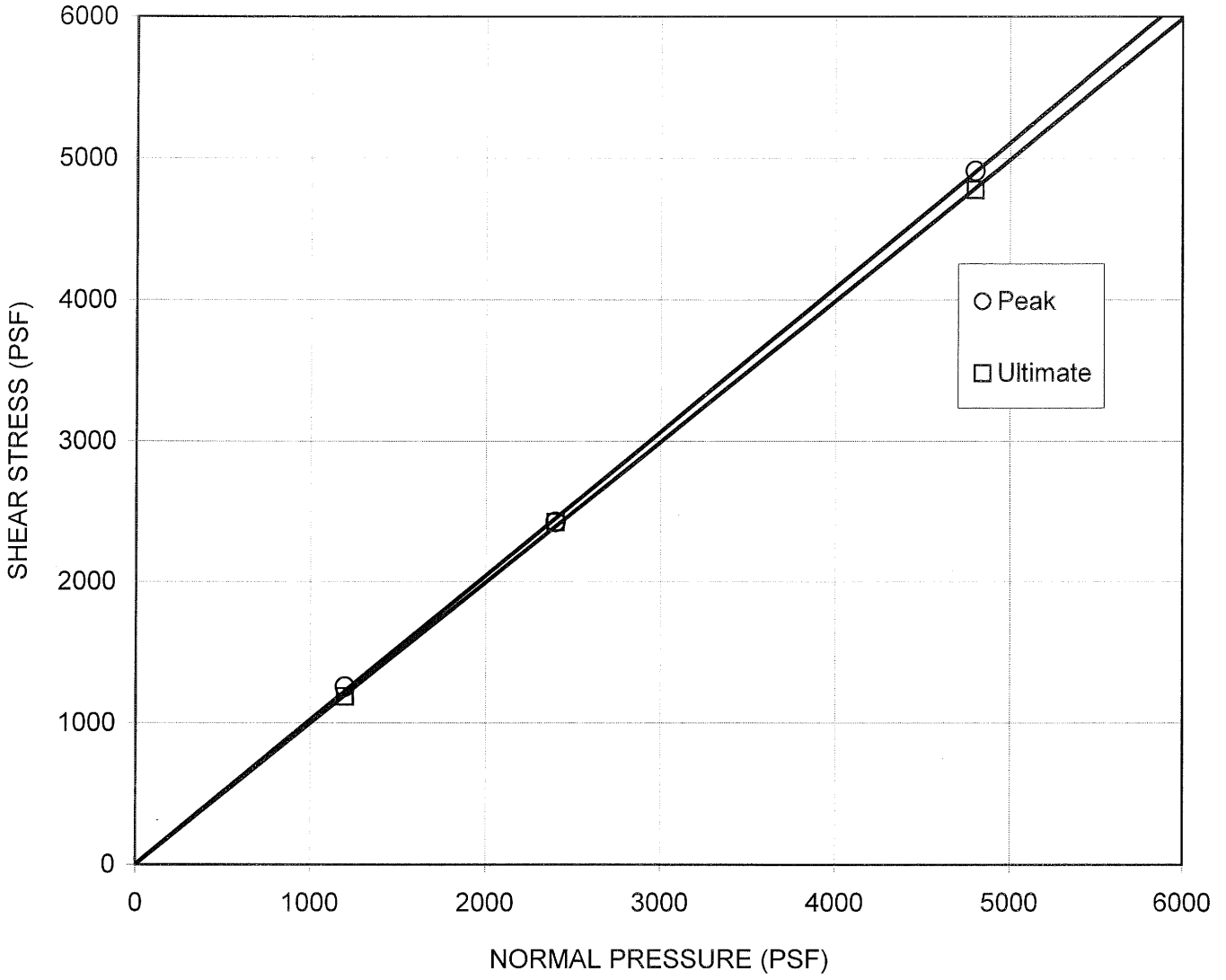
Client: CH2M Hill

Project No: 382653.FP.03.01

EGL Project No: 09-119-001

DIRECT SHEAR

08/09 (ASTM D3080) Figure



Boring No.:	Sample No.	Depth (ft)	Sample Type	Soil Type	Symbol	Cohesion (PSF)	Friction Angle
N/A	AOC4-Geo2-D5	20-21.5	Ring	SM	○	15	45
					□	13	45

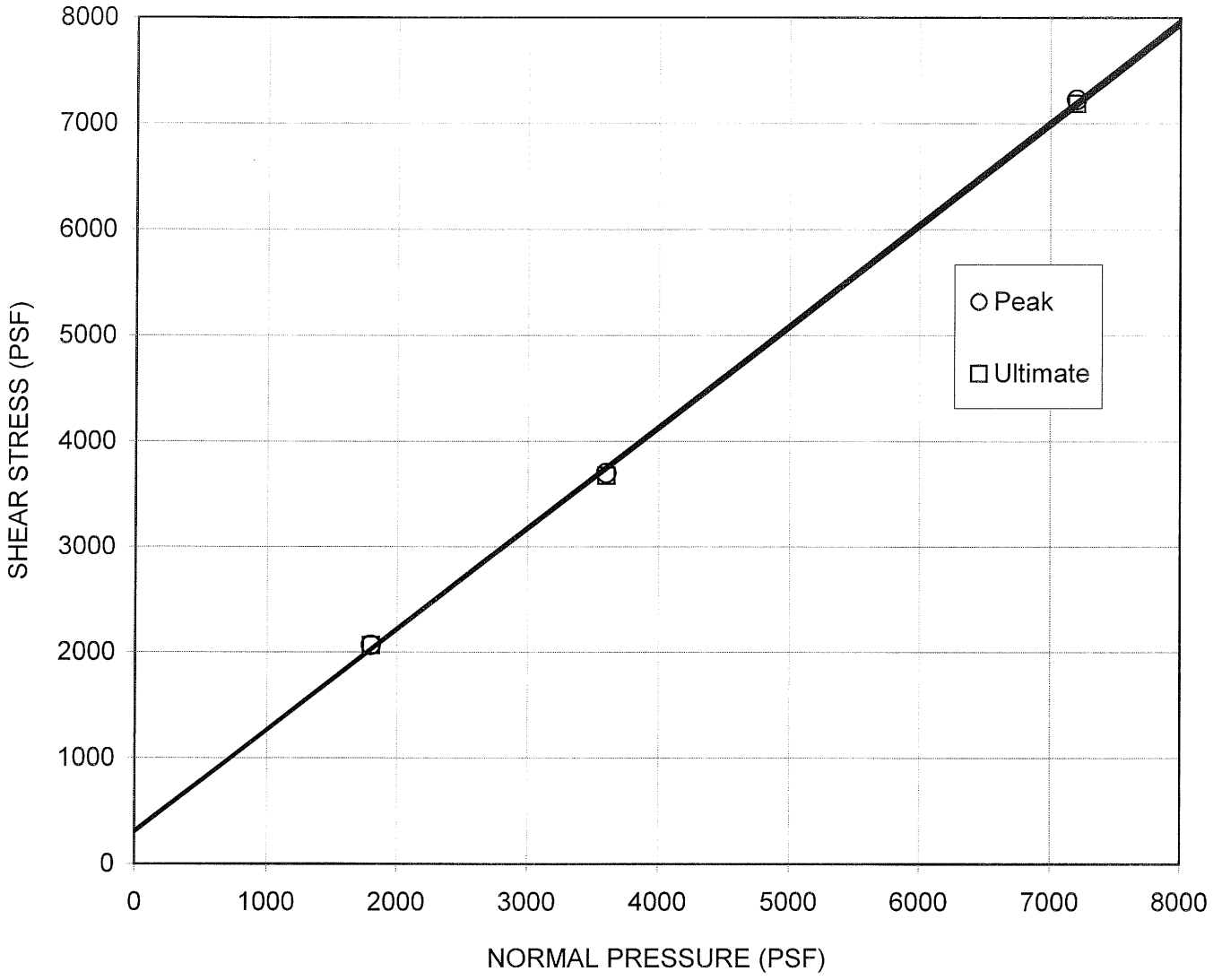
Normal Stress (psf)	Initial Moisture (%)	Final Moisture (%)
1200	1.4	14.1
2400	1.4	13.7
4800	1.4	13.2

ENVIRONMENTAL GEOTECHNOLOGY LABORATORY

Project Address:
PG&E Topock
Client: CH2M Hill
Project No: 382653.FP.03.01
EGL Project No: 09-119-001

DIRECT SHEAR

08/09 (ASTM D3080) Figure



Boring No.:	Sample No.	Depth (ft)	Sample Type	Soil Type	Symbol	Cohesion (PSF)	Friction Angle
N/A	AOC4-Geo2-D7	30-31.5	Ring	SM	○	301	44
					□	307	44

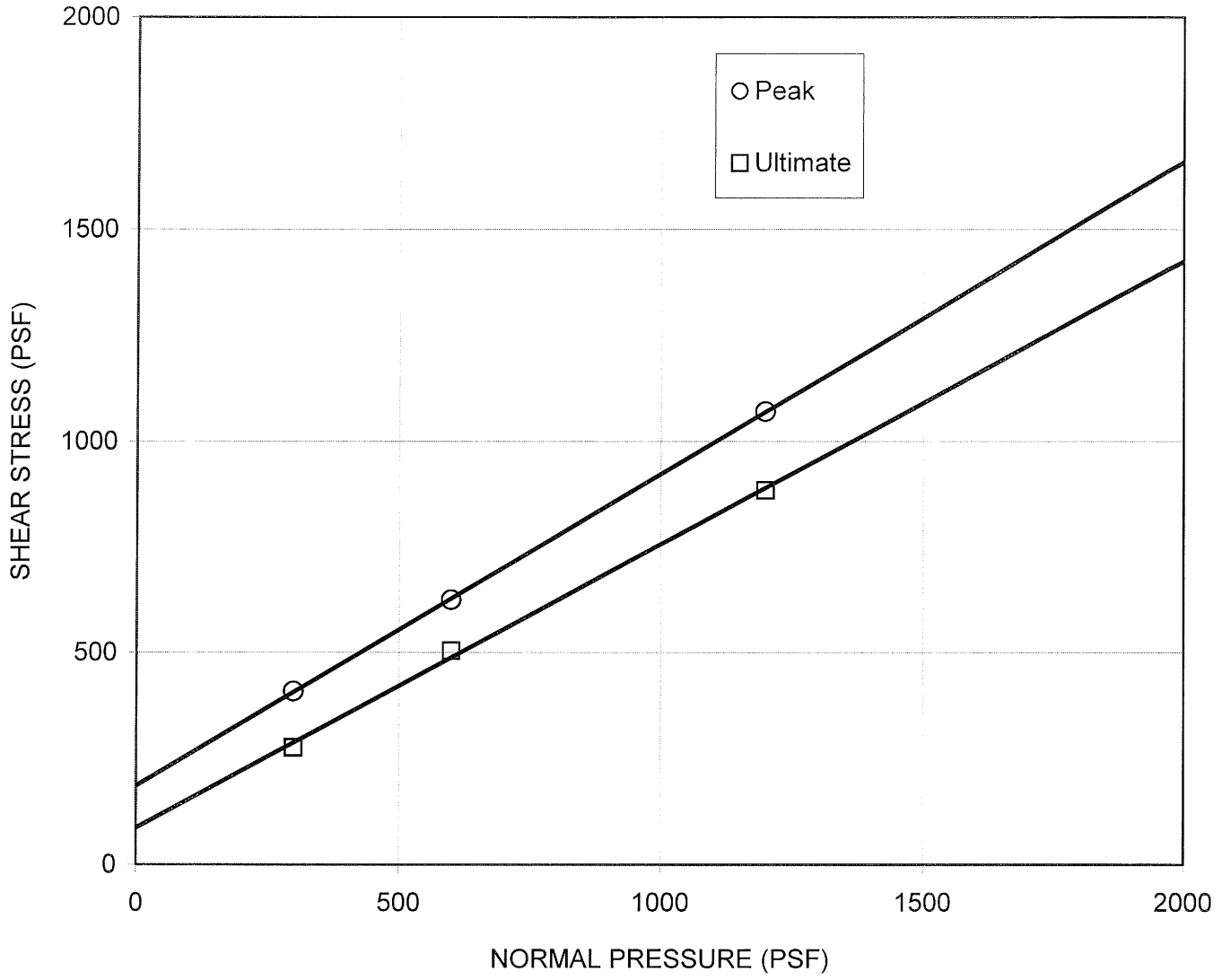
Normal Stress (psf)	Initial Moisture (%)	Final Moisture (%)
1800	0.9	12.8
3600	0.9	12.3
7200	0.9	11.0

ENVIRONMENTAL GEOTECHNOLOGY LABORATORY

Project Address:
PG&E Topock
Client: CH2M Hill
Project No: 382653.FP.03.01
EGL Project No: 09-119-001

DIRECT SHEAR

08/09 (ASTM D3080) Figure



Boring No.:	Sample No.	Depth (ft)	Sample Type	Soil Type	Symbol	Cohesion (PSF)	Friction Angle
N/A	AOC4-Geo2-B1	1-5	Bulk	SM	○	185	36
					□	86	34

Note: Sample was remolded to 90% maximum relative density and optimum moisture

Maximum Dry Density: 141 pcf Optimum Moisture: 5.5 %

Normal Stress (psf)	Initial Moisture (%)	Final Moisture (%)
300	5.5	13.1
600	5.5	12.5
1200	5.5	12.0

ENVIRONMENTAL GEOTECHNOLOGY LABORATORY

Project Address: PG&E Topock

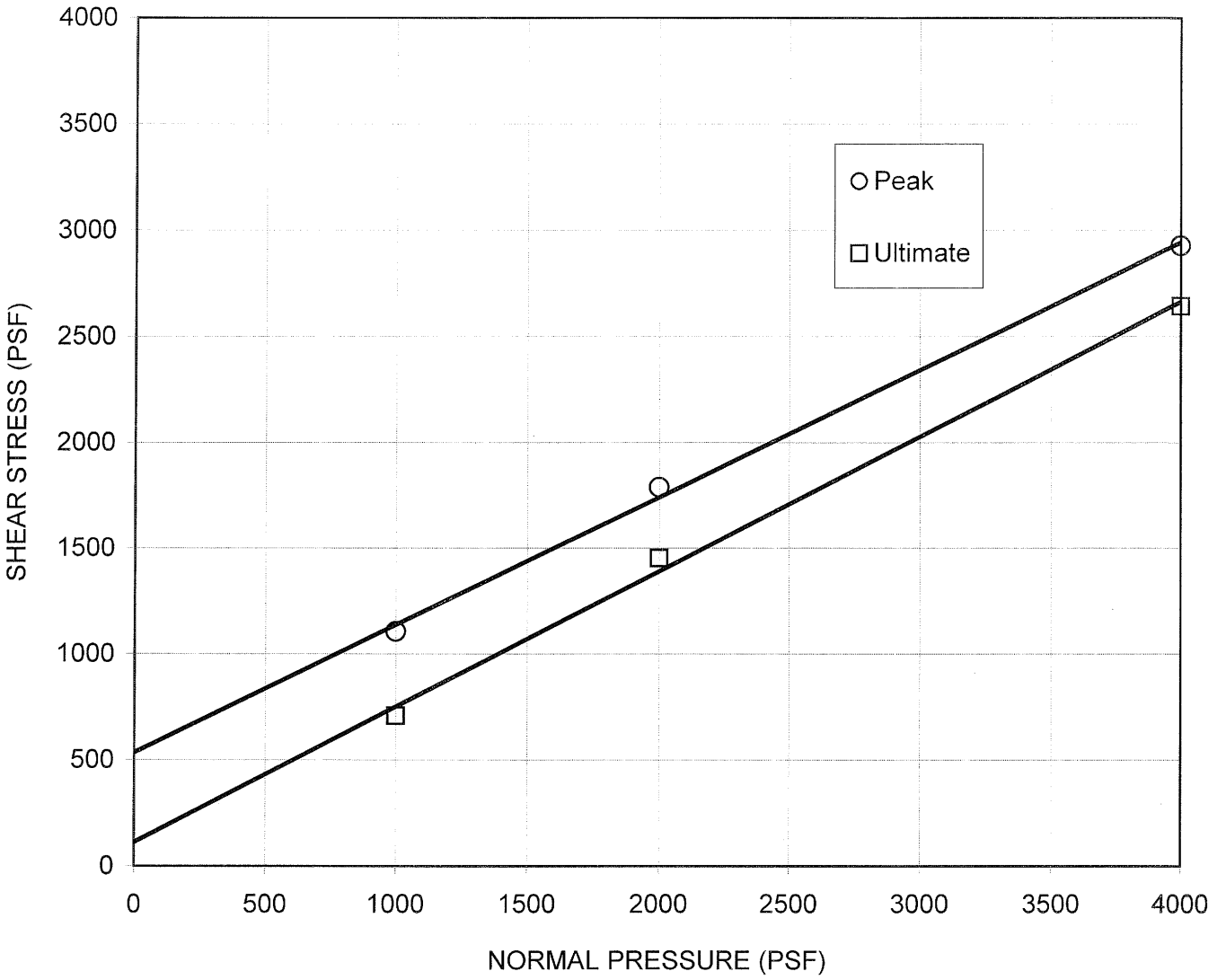
Client: CH2M Hill

Project No: 382653.FP.03.01

EGL Project No: 09-119-001

DIRECT SHEAR

08/09 (ASTM D3080) Figure



Boring No.:	Sample No.	Depth (ft)	Sample Type	Soil Type	Symbol	Cohesion (PSF)	Friction Angle
N/A	AOC4-Geo3-B5	16.5-20.0	Bulk	SM	○	534	31
					□	112	33

Note: Sample was remolded to 90% maximum relative density and optimum moisture

Maximum Dry Density: 141 pcf Optimum Moisture: 5.5 %

Normal Stress (psf)	Initial Moisture (%)	Final Moisture (%)
1000	5.5	12.9
2000	5.5	12.5
4000	5.5	12.3

ENVIRONMENTAL GEOTECHNOLOGY LABORATORY

Project Address: PG&E Topock

Client: CH2M Hill

Project No: 382653.FP.03.01

EGL Project No: 09-119-001

DIRECT SHEAR

08/09 (ASTM D3080) Figure

Attachment D:
Remediation Well Design and Field Approach
(*on CD-ROM only*)

1. Introduction

The three primary types of remediation wells that are part of the remedy design are as follows.

1) Extraction Wells
2) Freshwater/Upland Injection Wells
3) In-situ Reactive Zone (IRZ) Injection Wells

Although each type of remediation well has its specific function within the remedy design, there are design and construction objectives in common with each of the remediation wells. For example, each type of remediation well will be constructed within boreholes of a 12-inch diameter or larger. Also common to each of the three types of remediation wells are the following overall design goals: (1) optimize the hydraulic connection between the remediation well and the natural subsurface materials (i.e., the formation); (2) select the optimal interval(s) at which to screen the well (i.e., the well screen interval[s]); and (3) build the well to ease/minimize well maintenance.

This Design Bulletin presents an approach for achieving these goals through well design planning and field construction methods. Section 2 presents the general design plan, including three designs for the remediation wells: (1) single-screen wells; (2) multi-screen wells; and (3) bedrock wells. Section 3 is a discussion of field methods to be considered for design and construction of the remediation wells.

2. Remediation Well Design General Plan

Geology at the site consists of unconsolidated alluvial and fluvial sediments that overlie a conglomerate bedrock unit. The unconsolidated sediments are typically a poorly-sorted mixture of silt, sand, and gravel with varying amounts of clay, and these sediments vary in thickness significantly from north to south, with thicknesses of greater than 400 ft reported to the north near proposed well IRZ-1and less than 75 ft reported to the south near proposed well IRZ-39. The identification of distinct, laterally-continuous lithostratigraphic or hydrostratigraphic zones cannot be correlated from borehole to borehole. Therefore, the screened intervals proposed for the remediation wells as shown on Table 3.2.1-1 of the 60% design document are preliminary, and are based in part on the total vertical thickness of the unconsolidated sediments that are saturated.

Final determination of the screened intervals will be made based on information collected in the field during construction of the wells. Borehole data, discrete vertical interval sampling, and data from newly constructed wells may be used to inform each well design as the construction program proceeds. Information collected during the drilling of the boreholes can be used to identify permeable portions of the vertical section (i.e., these may represent target intervals for either extraction, injection, or delivery of the carbon source material), and in the case of the IRZ wells, to identify the zones with the highest concentrations of Cr(VI). The screened intervals will be based on these considerations.

The remediation wells will be constructed using 8-inch or larger nominal diameter well casing with one or more screens targeting a specific interval or intervals of the unconsolidated sediments (and also bedrock in a few of the extraction wells). The following are three general designs for the remediation wells that will likely be implemented.

1) **Single Screen Wells** – This type of construction would consist of a single screen well installed within

the unconsolidated sediments. The length of the screen would be based on formation thickness, the intended function of the well, and potentially other data developed in the field. This is the likely construction of the Freshwater/Upland Injection Wells, most of the Extraction Wells, and potentially some of the IRZ Injection wells. Depending on the geologic conditions encountered in the field, it is possible that one or more blank sections of casing could be inserted within the screen zone to avoid screening intervals where significant fines are encountered.

2) **Multi-Screen Wells** – This type of construction would consist of two or more screens installed within the unconsolidated sediments. The well screen intervals would be selected using field data to target specific zones based on permeability and concentrations of Cr(VI) in groundwater. This is the expected construction for many of the IRZ Wells, although as noted above, there is the potential that some of the IRZ wells could be installed using a longer single screen design.
3) **Bedrock Wells** – This type of construction would consist of drilling through the unconsolidated sediments and installing an outer/conductor casing to the top of the bedrock. After the conductor casing is installed the drilling methodology may change to accommodate drilling in the bedrock formation. Sonic, air rotary, and wire line drilling methods – or combinations of these methods may be employed to reach the target depth within the bedrock. The final well construction may be either an open hole completion within the bedrock or a more traditional well with a single screened interval installed within the bedrock. This will depend on the competency of the bedrock. If the bedrock is weathered and/or unstable, it would be desirable to install a traditional well with a single screen. The most appropriate construction will be deployed based on site conditions encountered in the East Ravine.

3. Field Methods

There are a number of potential tools that may be used for the collection and analysis of field data for final well design. Such tools described herein include: pilot borings, grain-size distribution analysis, vertical aquifer sampling, and downhole geophysical logging. These tools can be important in the selection and design of well screens and the associated filter pack material. Also discussed in this section are well drilling, construction, and development methods.

It is likely that the field program will evolve as data are collected and assessed for the purposes of remediation well design. Thus, it is important that the well design program, including the field methods described below, retain a measure of flexibility.

Pilot Borings

Drilling boreholes of the size and depth necessary to install the remediation wells generally requires the use of rotary drilling methods (see below for further discussion of drilling methods). It is difficult when using rotary drilling methods to gain accurate and depth-specific information on subsurface materials. For this reason, it may be desirable to drill a smaller diameter (4 to 6-inch diameter) pilot boring at selected locations using the sonic drilling method. Pilot borings would facilitate the collection of a continuous core of subsurface materials, allowing more accurate visual assessment of the geology and selection of subsurface sediment and groundwater samples for further analysis in support of well design.

Visual Description and Grain-Size Distribution Analysis

The subsurface materials will be described in the field and written descriptions will be included on the field boring log. If a pilot boring is drilled at a location, then the continuous core would be described. If a pilot boring is not drilled then the cuttings would be described. The descriptions will be used to identify potential screen interval(s).

Subsurface sediment samples may be collected at several intervals and submitted to a geotechnical laboratory (potentially onsite if needed for quick sample analysis turnaround) for grain-size distribution analysis. The lab would run each subsurface sediment sample through a series of sieves to determine grain-size distribution. The grain-size distribution data would be used to custom design the remediation well screen slot size and filter pack (Driscoll, 1987).

Vertical Aquifer Sampling

Vertical aquifer sampling (VAS) may be conducted at selected pilot borings to further define the subsurface distribution of Cr(VI) in groundwater. VAS depth interval(s) will be selected based on data developed during drilling of the pilot holes, available data from previous investigations, and general aquifer characteristics (i.e., saturated thickness, grain size distribution, etc.). The decision to conduct VAS at any individual pilot boring and the decision of which depth intervals to sample will likely evolve as the field program progresses. .

VAS would likely be conducted as the borehole is advanced using a Hydro-Punch, a temporary well, or another alternate sampling method. The VAS sampling methodology selected would typically depend on drilling conditions and saturated aquifer thickness. In general, the Hydro-Punch method is quicker but typically produces a more turbid sample as compared to a temporary well method. The Hydro-Punch method is essentially a “grab” sample that allows for collection of a groundwater sample at a discrete depth without purging using a specialized tool that is run inside the drill stem using drilling rods. The temporary well sampling method uses a temporary 2-inch diameter well with an inflatable packer above the well screen; and once the target depth is reached, the temporary well is installed inside the drill stem which is then pulled back 5ft to expose the screen to the formation. The packer is inflated to isolate the well screen from the overlying water column and then the well is purged/pumped to collect the sample.

In instances when drilling conditions are difficult, the Hydro-Punch method would likely be the preferred method. In instances when drilling conditions are not difficult, the temporary well method may be preferred due to its ability to produce a less turbid sample and its greater sample integrity.

Downhole Geophysical Logging

Another type of data that may be collected from the pilot borings is downhole geophysical logs. There are many types of geophysical logging instruments that could potentially be used to develop additional subsurface data at the site to assist with determining appropriate remediation well screened intervals. Some types of downhole geophysical logging devices require direct access to the formation while others can be used inside a casing. Because the borehole may collapse when the drill stem is pulled back within the unconsolidated sediments, downhole geophysical logging methods may be limited to those that can be used inside a casing. One such geophysical logging method that could be used inside a drilling casing would be gamma-ray logging (Keys, 1988). If boreholes are stable, then open-hole borehole geophysical tools can be considered, including spontaneous potential, electrical resistivity, and sonic methods along with gamma-ray.

Screen and Filterpack Design

There are two key well components that can be designed using site-specific lithologic data: well screen slot size and filter pack. The screen slot size for a particular well design may be selected on a site-specific basis using lithologic data collected from a pilot boring as described above (samples selected from a continuous core for grain-size distribution analysis). Otherwise, if there is found to be little variability in the subsurface sediments, a more qualitative averaging approach can be used to select the screen slot size instead.

Typical accepted screen slot size design recommendations for non-homogeneous formations allows for a range of 40-50% of the formation materials to pass through the screen based on the grain size distribution (Driscoll, 1987 and Misstear et al., 2006). The percent passing recommendation for screen slot size selection may influence screen interval selection depending on the degree of heterogeneity in the subsurface materials.

Recommendations for well screen slot size design are typically a balance between maximizing open screen area which improves well performance and reduces the frequency of well maintenence, well development requirements which increase as percent passing increases, and the amount of fine-grained heterogeneities that could pose longer term turbidity issues in the well, a potential concern for the remediation wells. In some instances it may be desirable to recommend a different slot size for one portion of a screened interval compared to another or to even recommend that a blank section be installed.

In addition, the filter pack material that surrounds the screen may also be custom designed for each screen section in the well based on the formation grain-size and screen slot size recommendation. Typically, the recommended filter pack will consist of a well sorted, well rounded, sand of a grain size that allows <10% passing through the screen.

Well Drilling/Construction Methods

Unconsolidated Deposits

There are only a few drilling technologies available that will drill boreholes in the unconsolidated sediments of the size and depth needed to install the remediation wells. Drilling methods such as sonic and hollow stem augers are limited in regards to borehole diameter, and the cable tool method is generally considered too slow. Therefore, rotary methods are the likely recommendation for drilling the remediation wells in the unconsolidated sediments due to their speed and ability to drill large diameter (i.e., >12-inch diameter) boreholes to the likely target depths at the site. In general, it will be preferable to avoid the use of drilling mud to optimize the hydraulic connection between the well and the formation and to reduce the required well development time. For these reasons, dual tube rotary or reverse circulation rotary drilling methods which typically use water as drilling fluid would be preferred over the mud rotary drilling method. When pilot borings are needed the likely drilling method would be sonic.

Bedrock

The East Ravine area is the only location at the site where bedrock drilling is anticipated. Geology in this area consists of <200ft of unconsolidated sediments directly on top of bedrock. As discussed above, the bedrock wells would consist of installing a conductor casing to the top of the bedrock (or perhaps a few feet into the bedrock if the bedrock is weathered) using sonic drilling, followed by changing drilling methods to air rotary,

wire line, or another appropriate method to drill the bedrock portion of the borehole.

Well Development Methods

Well development is a primary step in optimizing well performance after well construction and before well operation. A variety of development methods may be used to properly develop the remediation wells, including over pumping, jetting, air lifting, surging, and backwashing. The specific development methods will be determined based on the drilling method, well construction characteristics such as the number and length of well screens, and the grain-size distribution and sorting of the formation.

In general, the goals of well development are to repair damage to the formation incurred during drilling, and to optimize the hydraulic connection of the well to the formation. Typically it is recommended that turbidity and potentially other field parameters such as conductivity and pH are measured in the extracted fluids during well development to assess progress.

REFERENCES

Driscoll 1987. *Groundwater and Wells Second Edition.* Pub. Johnson Division, St. Paul, Minnesota 1089p.

Keys 1988. *Borehole Geophysics Applied To Ground-Water Investigations*. United States Geological Survey Open File Report 87-539, Denver, Colorado 305p.

Misstear, Banks, and Clark 2006. *Water Wells and Boreholes.* Pub. John Wiley & Sons, LTD, West Sussex, England 498p.

Attachment E:
Firewater System Analyses
(*on CD-ROM only*)

Topock Remediation Design

Hydraulic Analysis of Fire Water System

The existing fire water system at Topock Compressor Station needs to be expanded to accommodate new facilities associated with the groundwater remediation system. The existing fire water system is supplied from the freshwater tanks and consists of a pump station discharging to a six inch diameter distribution loop with branches to fourteen hydrants serving buildings and structures at the compressor station. This system needs to be expanded to provide water in case of fire at either the carbon amendment building at the TW bench or the MW-20 bench. A hydraulic network analysis was conducted to determine 1) the size of the expanded piping segments to serve TW and MW-20 bench, 2) whether existing storage capacity is sufficient and 3) if the existing fire pump station is adequate or needs to be modified.

A hydraulic network model of the expanded fire water system proposed for Topock remediation improvements was constructed using EPANET. EPANET is a software program that models water distribution piping systems. EPANET tracks the flow of water at each pipe, the pressure at each node, pumping heads and levels of water in tanks and reservoirs. Chemical species can be tracked, although that was not needed for the fire water system at Topock.

Pipe junctions, reservoirs and tanks are represented as nodes. A listing of nodes is contained on the following pages. Pipes, pumps and valves are represented as links. A listing of links is contained on the pages following the node listing. A schematic map showing the location of all nodes and links is shown on the sheet following the links listing.

The existing fire water system was compiled from as-built drawings when available. In the areas where as-built information was not available, piping routes were hypothesized based on logical assumptions. If more as-built information becomes available, then the analysis can be refined.

The piping routes and corridors for expanded piping segments have been approved by the client, Pacific Gas & Electric; however, they are subject to change pending stakeholder and regulatory review. The following summary describes the development of the hydraulic model:

Ground elevations for pipe junctions and tanks were taken from the 60% plan and profile sheets, which were based on the Toponex aerial survey. Pipe lengths have been taken off from plant as-built drawings and plan and profile drawings for the 60% submittal. Pump curve and test data was provided by PG & E

Projected fire flow demands are based on information provided from PG & E's fire protection consultant and data provided by the carbon amendment building designers. For the both the TW bench and MW-20 bench, the worst case fire flow scenario occurs at the carbon amendment buildings with its combustible roof and flammable liquid mixing. The projected fire flow demands are 0.30 gpm per sq ft plus a 500 gpm hose allowance. For the 480 sq ft building at the TW bench, this amounts to 644 gpm (at node 103). At the MW-20 bench this computes to 863 gpm (at node 102).

There are two existing fresh water tanks located above TCS at a base elevation of 672 feet (above sea level). Each tank is 30 feet high and contains 210,000 gallons. A minimum tank level of 2 feet and maximum tank level of 28 feet was assumed for this analysis.

There are two fire water pumps. One is an electric driven pump rated for approximately 900 gpm. The other is a diesel engine backup rated for approximately 1050 gpm.

Hazen-Williams C value of 120 was assumed for all existing pipes. New HDPE pipes were assumed to have a C value of 150.

The hydraulic network model of existing system was calibrated against the most recent pump test data results (September 2012) at hydrant 78. A comparison is shown in the table below.

Hydrant at Node 78	Measured	Modeled
Static pressure (closed)	160	156
Dynamic pressure (flowing)	98	96

Pipe sizing is an iterative process. After the initial simulation, pipe diameters for various segments of pipes are increased or decreased for subsequent simulations until an optimum size is selected for each segment. Typically, the criterion used for determining optimum size is unit head loss. In general, unit head losses of between 1 to 10 feet per 1,000 foot of pipe length yield the optimal combination of pipe capital cost and pumping energy costs. In this instance, the TW bench and MW-20 are sufficiently lower than the existing fire water system so that head losses in excess of 10 feet per 1,000 feet of pipe length are tolerable. The governing factor then becomes providing a minimum of 20 psi dynamic pressure at the hydrant. Hydraulic analysis simulations of 6 inch diameter (5.421 internal diameter for SDR 11 HDPE) for the expanded fire water piping yield sufficient dynamic pressures as shown in the table below:

Location	Pump	Tank Level	Residual Pressure
TW Bench	Electric	High	145
TW Bench	Electric	Low	133
TW Bench	Diesel	High	145
TW Bench	Diesel	Low	133
MW-20 Bench	Electric	High	44
MW-20 Bench	Electric	Low	33
MW-20 Bench	Diesel	High	44
MW-20 Bench	Diesel	Low	33

The criteria for fire flow volume is based on Insurance Services Office standard of one hour duration for each 1,000 gpm of fire flow plus one hour for each increment of 1,000 gpm fire flow. For the worst case scenario of 863 gpm, this indicates a one hour duration and a required fire flow volume of 51,780 gallons. The combined capacity of the 30 foot high freshwater tanks when full is 420,000 gallons, which is more than adequate. If the tanks are less than full, then storage is adequate assuming the following minimum tanks are maintained prior to the onset of a fire:

No. of Tanks in service	Supply wells	Required Minimum tank level
2	On	5.7
2	Off	7.2
1	On	9.4
1	Off	12.3

The required minimum tank level calculation assumes that the bottom two feet of the tank is dead storage and not available for consumption. It is assumed that the supply wells (from Arizona) will fully supply the groundwater remediation system and compressor system water demands during a fire flow emergency. If for some reason the supply wells are off (power outage, etc), then the tank must supply the fire flow (863 gpm) plus the combined remediation and compressor station demand (1200 gpm).

The supply well pumps will be set to maintain tanks levels significantly higher than the highest required minimum tank level (12.3).

The horsepower required to pump fire flows is less than the rated horsepower for the electric motor and diesel engine pumps. The electric driven pump results are summarized as follows:

Location	Q (gpm)	TDH (ft)	Pump Eff	Motor Eff	Hp	Rated Hp
TW bench	644	255.4	0.83	0.90	55.6	69.0
MW-20 bench	863	211.2	0.80	0.90	63.9	69.0

Q and TDH are taken from the hydraulic network simulations. Pump Eff is from the pump curves supplied by PG & E. Motor Eff is assumed at 90%. The rated hp includes a 1.15 service factor.

The diesel engine driven pump results are summarized as follows:

Location	Q (gpm)	TDH (ft)	Pump Eff	Engine Eff	Hp	Rated HP
TW bench	644	256.6	0.72	0.92	63.0	75.0
MW-20 bench	863	212.8	0.76	0.92	66.3	75.0

Q and TDH are taken from the hydraulic network simulations. Pump Eff and Engine Eff are from the pump curves supplied by PG & E. Engine Eff is back calculated from the engine hp curve.

The following conclusions may be drawn from the hydraulic analysis:

- Six inch diameter piping is sufficient for the expanded portion of the fire water system
- Existing storage is adequate for the fire flow scenarios anticipated
- Existing pumps are capable of supplying the worst case fire flows

If building sizes increase, then this analysis may need to be revisited.

TCS Firewater Node Junction and Tank Data

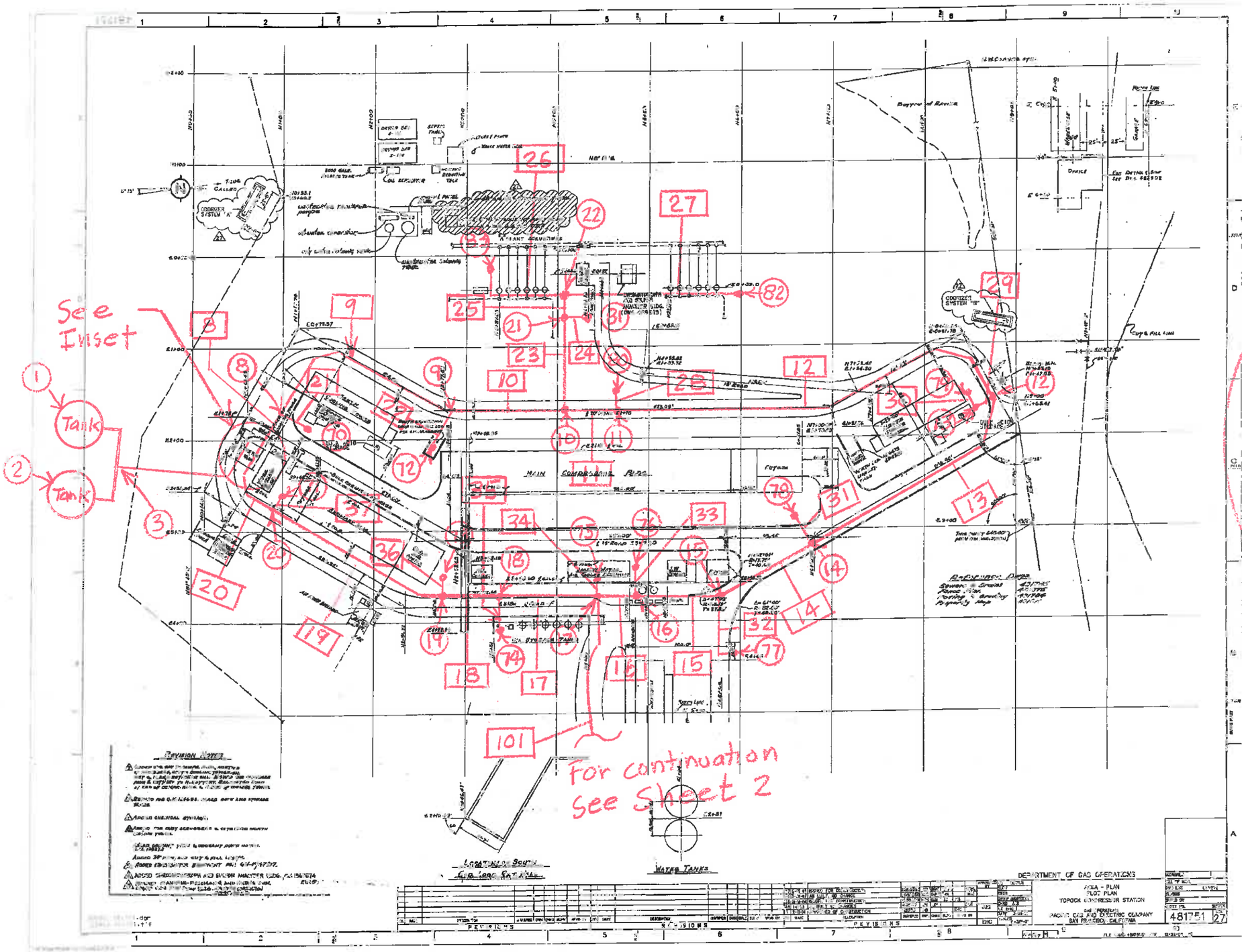
Node	Type	Ground Elev	Demand
1	Tank	672	
2	Tank	672	
3	Junction	672	
4	Junction	627	
4A	Junction	627	
4B	Junction	627	
5	Junction	627	
5A	Junction	627	
5B	Junction	627	
6	Junction	627	
7	Junction	627	
8	Junction	621	
9	Junction	621	
10	Junction	617	
11	Junction	617	
12	Junction	623	
13	Junction	623	
14	Junction	621	
15	Junction	620	
16	Junction	617	
17	Junction	617	
18	Junction	617	
19	Junction	619	
20	Junction	621	
21	Junction	590	
22	Junction	590	
70	Hydrant	626	
71	Hydrant	626	
72	Hydrant	622	
73	Hydrant	626	
74	Hydrant	622	
75	Hydrant	622	
76	Hydrant	625	
77	Hydrant	622	
78	Hydrant	625	920
79	Hydrant	627	
80	Hydrant	622	
81	Hydrant	596	
82	Hydrant	590	
83	Hydrant	595	
101	Junction	532	
102	Junction	500	863
103	Junction	550	644

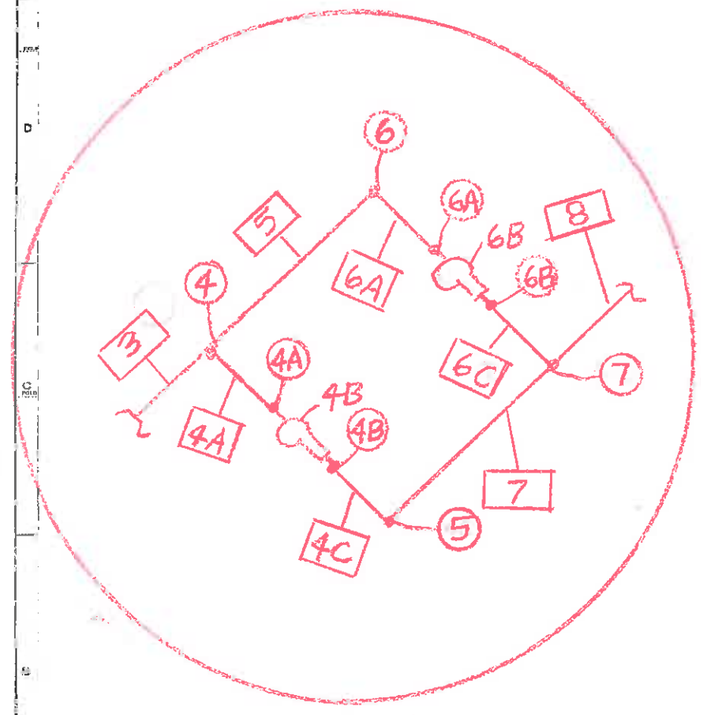
TCS Fire Water System Pipe and Pump Data

Link	Type	Upstr Node	Downstr Node	Dia (in)	Material	C value	Straight Length	Fitting Length	Equivalent Length	$V^2/2g$
1	Pipe	1	3	8	Stl	120	21	49	70	0.5
2	Pipe	2	3	8	Stl	120	21	49	70	0.5
3	Pipe	3	4	8	Stl	120	263	64	327	
4A	Pipe	4	4A	6	Stl	120	6	58	64	
4B	Pump	4A	4B							
4C	Pipe	4B	5	6	Stl	120	6	76	82	
5	Pipe	4	6	6	Stl	120	6	15	21	
6A	Pipe	6	6A	6	Stl	120	6	58	64	
6B	Pump	6A	6B							
6C	Pipe	6B	7	6	Stl	120	6	76	82	
7	Pipe	5	7	6	Stl	120	6	15	21	
8	Pipe	7	8	6	Stl	120	52	45	97	
9	Pipe	8	9	6	Stl	120	238	27	265	
10	Pipe	9	10	6	Stl	120	123	11	134	
11	Pipe	10	11	6	Stl	120	57	11	68	
12	Pipe	11	12	6	Stl	120	453	35	488	
13	Pipe	12	14	6	Stl	120	287	27	314	
14	Pipe	14	15	6	Stl	120	113	22	135	
15	Pipe	15	16	6	Stl	120	98	11	109	
16	Pipe	16	17	6	Stl	120	41	11	52	
17	Pipe	17	18	6	Stl	120	107	11	118	
18	Pipe	18	19	6	Stl	120	58	11	69	
19	Pipe	19	20	6	Stl	120	213	19	232	
20	Pipe	20	5	6	Stl	120	79	50	129	
21	Pipe	8	70	4	Stl	120	30	34	64	
22	Pipe	9	72	4	Stl	120	39	34	73	
23	Pipe	10	21	4	Stl	120	117	13	130	
24	Pipe	21	81	3	Stl	120	17	31	48	
25	Pipe	21	22	4	Stl	120	13	23	36	
26	Pipe	22	83	4	Stl	120	109	30	139	
27	Pipe	22	82	4	Stl	120	198	30	228	
28	Pipe	11	80	4	Stl	120	26	30	56	
29	Pipe	12	13	6	Stl	120	21	28	49	
30	Pipe	13	79	3	Stl	120	11	14	25	
31	Pipe	14	78	3	Stl	120	31	14	45	
32	Pipe	15	77	4	Stl	120	82	30	112	
33	Pipe	16	76	4	Stl	120	36	30	66	
34	Pipe	17	75	4	Stl	120	9	30	39	
35	Pipe	18	74	4	Stl	120	34	30	64	
36	Pipe	19	73	3	Stl	120	8	14	22	
37	Pipe	20	71	4	Stl	120	16	30	46	
101	Pipe	17	101	7.057	HDPE	150	911	55	966	
102	Pipe	101	102	5.421	HDPE	150	2661	283	2944	
103	Pipe	101	103	5.421	HDPE	150	290	45	335	

TCS Fire Pump Curve Data

Pump Curve Data				
Diesel Pump			Electric Pump	
Flow (gpm)	Head (ft)		Flow (gpm)	Head (ft)
0	144		0	290
200	140		200	286
400	130		400	280
600	117		600	265
800	100		800	229
1000	77		1000	170
1200	47		1200	100
Test Data				
Diesel Pump			Electric Pump	
Flow (gpm)	Head (ft)		Flow (gpm)	Head (ft)
0	334.56		0	281.50
272	318.41		450	276.88
800	230.73		784	239.96
1125	138.44		968	173.05





Inset

Legend

- Pipe Junction or Tank Node
- Pipe Number
- Pump

FIRE WATER SYSTEM
HYDRAULIC MODEL
SCHEMATIC 1 OF 2

NATIONAL TRAIL HWY

IRZ-1
RB-1
IRZ-5
IRZ-9
IRZ-11
RB-2
IRZ-13
RB-3
IRZ-15
IRZ-16
IRZ-17
RB-4
IRZ-19
IRZ-20
IRZ-21
IRZ-23
RB-5
IRZ-25
IRZ-27
IRZ-29
IRZ-31
IRZ-33
IRZ-35
IRZ-37
IRZ-39

IRL-1
IRL-2
IRL-3
IRL-4
FW-1
FW-2

BAT CAVE WASH

COLORADO RIVER

MOHAVE COUNTY HWY 10

TOPOCK 3
TOPOCK 2

BNSF RAIL ROAD

102
103
104
101

See Sheet 1

TCS-1
TCS-2
PG&E COMPRESSOR STATION

TWB-1
TWB-2

ER-1
ER-2
ER-3
ER-4

ARCH BRIDGE

COLORADO RIVER

Legend
Pipe Junction
Pipe Number

LEGEND

- IRL-1 NEW WELL
- EXISTING WELL
- FUTURE PROVISIONAL WELL

NOTE:

REFER TO DRAWING C-00-03 FOR SCHEDULE OF COORDINATE LOCATIONS.

FIRE WATER SYSTEM HYDRAULIC MODEL SCHEMATIC 2 OF 2

N

WELL LOCATION MAP

1" = 250'

0 250 500

SCALE: 1"=250'

DRAFT
NOT FOR CONSTRUCTION

E2 Consulting Engineers, Inc.
1900 Powell Street, Ste. 250
Emeryville, CA 94608
(510) 652-1164

CH2MHILL.

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	9/12/12	INTERMEDIATE (60%) DESIGN SUBMITTAL					

REVISIONS

APPROVED BY: SD, SUPV, DSGN PT, DWN PC, CHKD PT, OK, DATE, SCALES

TOPOCK GROUNDWATER REMEDIATION PROJECT

WELL LOCATION MAP

GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
SUPSDS
SUPSD BY
SHEET NO. of SHEETS
C-00-02
REV

PLOT DATE: $PLOTDATE PLOT TIME: $PLOTTIME
FILENAME: E2-C-XXX-0002

644 gpm fire flow at TW bench, electric pump on, high water tank levels

Network Table - Nodes

Node ID	Demand GPM	Head ft	Pressure psi
Junc 3	0.00	699.79	12.04
Junc 4	0.00	696.72	30.21
Junc 4A	0.00	694.28	29.15
Junc 4B	0.00	949.72	139.83
Junc 5	0.00	946.59	138.48
Junc 6A	0.00	696.72	30.21
Junc 6B	0.00	946.48	138.43
Junc 6	0.00	696.72	30.21
Junc 7	0.00	946.48	138.43
Junc 8	0.00	945.94	140.80
Junc 9	0.00	944.47	140.16
Junc 10	0.00	943.73	141.57
Junc 11	0.00	943.36	141.41
Junc 12	0.00	940.65	137.64
Junc 13	0.00	940.65	137.64
Junc 14	0.00	938.92	137.75
Junc 15	0.00	938.17	137.86
Junc 16	0.00	937.57	138.90
Junc 17	0.00	937.28	138.78
Junc 18	0.00	939.28	139.65
Junc 19	0.00	940.46	139.29
Junc 20	0.00	944.40	140.13
Junc 21	0.00	943.73	153.27
Junc 22	0.00	943.73	153.27
Junc 70	0.00	945.94	138.63

644 gpm fire flow at TW bench, electric pump on, high water tank levels

Node ID	Demand GPM	Head ft	Pressure psi
Junc 71	0.00	944.40	137.96
Junc 72	0.00	944.47	139.73
Junc 73	0.00	940.46	136.25
Junc 74	0.00	939.28	137.48
Junc 75	0.00	937.28	136.61
Junc 76	0.00	937.57	135.43
Junc 77	0.00	938.17	137.00
Junc 78	0.00	938.92	136.02
Junc 79	0.00	940.65	135.91
Junc 80	0.00	943.36	139.24
Junc 81	0.00	943.73	150.67
Junc 82	0.00	943.73	153.27
Junc 83	0.00	943.73	151.11
Junc 101	0.00	897.39	158.32
Junc 102	0.00	897.39	172.19
Junc 103	644.00	883.56	144.53
Tank 1	-322.01	700.00	12.13
Tank 2	-322.01	700.00	12.13

644 gpm fire flow at TW bench, electric pump on, high water tank levels

Network Table - Links

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 1	322.01	2.06	3.07	Open
Pipe 2	322.01	2.06	3.07	Open
Pipe 3	644.01	4.11	9.38	Open
Pipe 4A	644.01	7.31	38.08	Open
Pipe 4C	644.01	7.31	38.08	Open
Pipe 5	0.00	0.00	0.00	Open
Pipe 6A	0.00	0.00	0.00	Open
Pipe 6C	0.00	0.00	0.00	Open
Pipe 7	227.34	2.58	5.53	Open
Pipe 8	227.34	2.58	5.54	Open
Pipe 9	227.34	2.58	5.54	Open
Pipe 10	227.34	2.58	5.54	Open
Pipe 11	227.34	2.58	5.54	Open
Pipe 12	227.34	2.58	5.54	Open
Pipe 13	227.33	2.58	5.54	Open
Pipe 14	227.33	2.58	5.54	Open
Pipe 15	227.33	2.58	5.54	Open
Pipe 16	227.33	2.58	5.54	Open
Pipe 17	-416.67	4.73	17.00	Open
Pipe 18	-416.67	4.73	17.00	Open
Pipe 19	-416.67	4.73	17.00	Open
Pipe 20	-416.67	4.73	17.00	Open
Pipe 21	0.00	0.00	0.00	Open
Pipe 22	0.00	0.00	0.00	Open
Pipe 23	0.00	0.00	0.00	Open

644 gpm fire flow at TW bench, electric pump on, high water tank levels

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 24	0.00	0.00	0.00	Open
Pipe 25	0.00	0.00	0.00	Open
Pipe 26	0.00	0.00	0.00	Open
Pipe 27	0.00	0.00	0.00	Open
Pipe 28	0.00	0.00	0.00	Open
Pipe 29	0.00	0.00	0.00	Open
Pipe 30	0.00	0.00	0.00	Open
Pipe 31	0.00	0.00	0.00	Open
Pipe 32	0.00	0.00	0.00	Open
Pipe 33	0.00	0.00	0.00	Open
Pipe 34	0.00	0.00	0.00	Open
Pipe 35	0.00	0.00	0.00	Open
Pipe 36	0.00	0.00	0.00	Open
Pipe 37	0.00	0.00	0.00	Open
Pipe 101	644.00	8.95	41.29	Open
Pipe 102	0.00	0.00	0.00	Open
Pipe 103	644.00	8.95	41.29	Open
Pump 4B	644.01	0.00	-255.43	Open
Pump 6B	0.00	0.00	0.00	Closed

644 gpm fire flow at TW bench, electric pump on, low water tank levels

Network Table - Nodes

Node ID	Demand GPM	Head ft	Pressure psi
Junc 3	0.00	673.79	0.77
Junc 4	0.00	670.72	18.94
Junc 4A	0.00	668.28	17.89
Junc 4B	0.00	923.72	128.57
Junc 5	0.00	920.59	127.21
Junc 6A	0.00	670.72	18.94
Junc 6B	0.00	920.48	127.16
Junc 6	0.00	670.72	18.94
Junc 7	0.00	920.48	127.16
Junc 8	0.00	919.94	129.53
Junc 9	0.00	918.47	128.90
Junc 10	0.00	917.73	130.31
Junc 11	0.00	917.35	130.14
Junc 12	0.00	914.65	126.37
Junc 13	0.00	914.65	126.37
Junc 14	0.00	912.92	126.49
Junc 15	0.00	912.17	126.60
Junc 16	0.00	911.56	127.63
Junc 17	0.00	911.28	127.51
Junc 18	0.00	913.28	128.38
Junc 19	0.00	914.46	128.02
Junc 20	0.00	918.40	128.86
Junc 21	0.00	917.73	142.01
Junc 22	0.00	917.73	142.01
Junc 70	0.00	919.94	127.36

644 gpm fire flow at TW bench, electric pump on, low water tank levels

Node ID	Demand GPM	Head ft	Pressure psi
Junc 71	0.00	918.40	126.70
Junc 72	0.00	918.47	128.46
Junc 73	0.00	914.46	124.99
Junc 74	0.00	913.28	126.21
Junc 75	0.00	911.28	125.34
Junc 76	0.00	911.56	124.17
Junc 77	0.00	912.17	125.73
Junc 78	0.00	912.92	124.75
Junc 79	0.00	914.65	124.64
Junc 80	0.00	917.35	127.98
Junc 81	0.00	917.73	139.41
Junc 82	0.00	917.73	142.01
Junc 83	0.00	917.73	139.84
Junc 101	0.00	871.39	147.06
Junc 102	0.00	871.39	160.92
Junc 103	644.00	857.56	133.26
Tank 1	-322.01	674.00	0.87
Tank 2	-322.01	674.00	0.87

644 gpm fire flow at TW bench, electric pump on, low water tank levels

Network Table - Links

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 1	322.01	2.06	3.07	Open
Pipe 2	322.01	2.06	3.07	Open
Pipe 3	644.01	4.11	9.38	Open
Pipe 4A	644.01	7.31	38.08	Open
Pipe 4C	644.01	7.31	38.08	Open
Pipe 5	0.00	0.00	0.00	Open
Pipe 6A	0.00	0.00	0.00	Open
Pipe 6C	0.00	0.00	0.00	Open
Pipe 7	227.34	2.58	5.54	Open
Pipe 8	227.34	2.58	5.54	Open
Pipe 9	227.34	2.58	5.54	Open
Pipe 10	227.34	2.58	5.54	Open
Pipe 11	227.34	2.58	5.54	Open
Pipe 12	227.34	2.58	5.54	Open
Pipe 13	227.33	2.58	5.54	Open
Pipe 14	227.33	2.58	5.54	Open
Pipe 15	227.33	2.58	5.54	Open
Pipe 16	227.33	2.58	5.54	Open
Pipe 17	-416.67	4.73	17.00	Open
Pipe 18	-416.67	4.73	17.00	Open
Pipe 19	-416.67	4.73	17.00	Open
Pipe 20	-416.67	4.73	17.00	Open
Pipe 21	0.00	0.00	0.00	Open
Pipe 22	0.00	0.00	0.00	Open
Pipe 23	0.00	0.00	0.00	Open

644 gpm fire flow at TW bench, electric pump on, low water tank levels

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 24	0.00	0.00	0.00	Open
Pipe 25	0.00	0.00	0.00	Open
Pipe 26	0.00	0.00	0.00	Open
Pipe 27	0.00	0.00	0.00	Open
Pipe 28	0.00	0.00	0.00	Open
Pipe 29	0.00	0.00	0.00	Open
Pipe 30	0.00	0.00	0.00	Open
Pipe 31	0.00	0.00	0.00	Open
Pipe 32	0.00	0.00	0.00	Open
Pipe 33	0.00	0.00	0.00	Open
Pipe 34	0.00	0.00	0.00	Open
Pipe 35	0.00	0.00	0.00	Open
Pipe 36	0.00	0.00	0.00	Open
Pipe 37	0.00	0.00	0.00	Open
Pipe 101	644.00	8.95	41.29	Open
Pipe 102	0.00	0.00	0.00	Open
Pipe 103	644.00	8.95	41.29	Open
Pump 4B	644.01	0.00	-255.43	Open
Pump 6B	0.00	0.00	0.00	Closed

644 gpm fire flow at TW bench, diesel pump on, high water tank levels

Network Table - Nodes

Node ID	Demand GPM	Head ft	Pressure psi
Junc 3	0.00	699.79	12.04
Junc 4	0.00	696.72	30.21
Junc 4A	0.00	696.72	30.21
Junc 4B	0.00	946.64	138.50
Junc 5	0.00	946.64	138.50
Junc 6A	0.00	693.48	28.81
Junc 6B	0.00	950.12	140.01
Junc 6	0.00	695.92	29.86
Junc 7	0.00	947.00	138.65
Junc 8	0.00	946.44	141.01
Junc 9	0.00	944.93	140.36
Junc 10	0.00	944.16	141.76
Junc 11	0.00	943.77	141.59
Junc 12	0.00	940.98	137.78
Junc 13	0.00	940.98	137.78
Junc 14	0.00	939.19	137.87
Junc 15	0.00	938.41	137.97
Junc 16	0.00	937.79	139.00
Junc 17	0.00	937.49	138.87
Junc 18	0.00	939.46	139.72
Junc 19	0.00	940.62	139.36
Junc 20	0.00	944.49	140.17
Junc 21	0.00	944.16	153.46
Junc 22	0.00	944.16	153.46
Junc 70	0.00	946.44	138.85

644 gpm fire flow at TW bench, diesel pump on, high water tank levels

Node ID	Demand GPM	Head ft	Pressure psi
Junc 71	0.00	944.49	138.00
Junc 72	0.00	944.93	139.92
Junc 73	0.00	940.62	136.32
Junc 74	0.00	939.46	137.56
Junc 75	0.00	937.49	136.70
Junc 76	0.00	937.79	135.53
Junc 77	0.00	938.41	137.10
Junc 78	0.00	939.19	136.14
Junc 79	0.00	940.98	136.05
Junc 80	0.00	943.77	139.42
Junc 81	0.00	944.16	150.86
Junc 82	0.00	944.16	153.46
Junc 83	0.00	944.16	151.29
Junc 101	0.00	897.61	158.42
Junc 102	0.00	897.61	172.28
Junc 103	644.00	883.77	144.62
Tank 1	-322.00	700.00	12.13
Tank 2	-322.00	700.00	12.13

644 gpm fire flow at TW bench, diesel pump on, high water tank levels

Network Table - Links

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 1	322.00	2.06	3.07	Open
Pipe 2	322.00	2.06	3.07	Open
Pipe 3	644.00	4.11	9.38	Open
Pipe 4A	0.00	0.00	0.00	Open
Pipe 4C	0.00	0.00	0.00	Open
Pipe 5	644.00	7.31	38.08	Open
Pipe 6A	644.00	7.31	38.08	Open
Pipe 6C	644.00	7.31	38.08	Open
Pipe 7	-412.67	4.68	16.70	Open
Pipe 8	231.33	2.62	5.72	Open
Pipe 9	231.33	2.62	5.72	Open
Pipe 10	231.33	2.62	5.72	Open
Pipe 11	231.33	2.62	5.72	Open
Pipe 12	231.33	2.62	5.72	Open
Pipe 13	231.33	2.62	5.72	Open
Pipe 14	231.33	2.62	5.72	Open
Pipe 15	231.33	2.62	5.72	Open
Pipe 16	231.33	2.62	5.72	Open
Pipe 17	-412.67	4.68	16.70	Open
Pipe 18	-412.67	4.68	16.70	Open
Pipe 19	-412.67	4.68	16.70	Open
Pipe 20	-412.67	4.68	16.70	Open
Pipe 21	0.00	0.00	0.00	Open
Pipe 22	0.00	0.00	0.00	Open
Pipe 23	0.00	0.00	0.00	Open

644 gpm fire flow at TW bench, diesel pump on, high water tank levels

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 24	0.00	0.00	0.00	Open
Pipe 25	0.00	0.00	0.00	Open
Pipe 26	0.00	0.00	0.00	Open
Pipe 27	0.00	0.00	0.00	Open
Pipe 28	0.00	0.00	0.00	Open
Pipe 29	0.00	0.00	0.00	Open
Pipe 30	0.00	0.00	0.00	Open
Pipe 31	0.00	0.00	0.00	Open
Pipe 32	0.00	0.00	0.00	Open
Pipe 33	0.00	0.00	0.00	Open
Pipe 34	0.00	0.00	0.00	Open
Pipe 35	0.00	0.00	0.00	Open
Pipe 36	0.00	0.00	0.00	Open
Pipe 37	0.00	0.00	0.00	Open
Pipe 101	644.00	8.95	41.29	Open
Pipe 102	0.00	0.00	0.00	Open
Pipe 103	644.00	8.95	41.29	Open
Pump 4B	0.00	0.00	0.00	Closed
Pump 6B	644.00	0.00	-256.64	Open

644 gpm fire flow at TW bench, diesel pump on, low water tank levels

Network Table - Nodes

Node ID	Demand GPM	Head ft	Pressure psi
Junc 3	0.00	673.79	0.77
Junc 4	0.00	670.72	18.94
Junc 4A	0.00	670.72	18.94
Junc 4B	0.00	920.64	127.24
Junc 5	0.00	920.64	127.24
Junc 6A	0.00	667.48	17.54
Junc 6B	0.00	924.12	128.74
Junc 6	0.00	669.92	18.60
Junc 7	0.00	921.00	127.39
Junc 8	0.00	920.44	129.75
Junc 9	0.00	918.93	129.09
Junc 10	0.00	918.16	130.49
Junc 11	0.00	917.77	130.32
Junc 12	0.00	914.98	126.52
Junc 13	0.00	914.98	126.52
Junc 14	0.00	913.19	126.60
Junc 15	0.00	912.41	126.70
Junc 16	0.00	911.79	127.73
Junc 17	0.00	911.49	127.60
Junc 18	0.00	913.46	128.46
Junc 19	0.00	914.62	128.09
Junc 20	0.00	918.49	128.90
Junc 21	0.00	918.16	142.19
Junc 22	0.00	918.16	142.19
Junc 70	0.00	920.44	127.58

644 gpm fire flow at TW bench, diesel pump on, low water tank levels

Node ID	Demand GPM	Head ft	Pressure psi
Junc 71	0.00	918.49	126.74
Junc 72	0.00	918.93	128.66
Junc 73	0.00	914.62	125.06
Junc 74	0.00	913.46	126.29
Junc 75	0.00	911.49	125.44
Junc 76	0.00	911.79	124.27
Junc 77	0.00	912.41	125.84
Junc 78	0.00	913.19	124.87
Junc 79	0.00	914.98	124.78
Junc 80	0.00	917.77	128.16
Junc 81	0.00	918.16	139.59
Junc 82	0.00	918.16	142.19
Junc 83	0.00	918.16	140.03
Junc 101	0.00	871.61	147.15
Junc 102	0.00	871.61	161.02
Junc 103	644.00	857.77	133.36
Tank 1	-322.00	674.00	0.87
Tank 2	-322.00	674.00	0.87

644 gpm fire flow at TW bench, diesel pump on, low water tank levels

Network Table - Links

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 1	322.00	2.06	3.07	Open
Pipe 2	322.00	2.06	3.07	Open
Pipe 3	644.00	4.11	9.38	Open
Pipe 4A	0.00	0.00	0.00	Open
Pipe 4C	0.00	0.00	0.00	Open
Pipe 5	644.00	7.31	38.08	Open
Pipe 6A	644.00	7.31	38.08	Open
Pipe 6C	644.00	7.31	38.08	Open
Pipe 7	-412.67	4.68	16.70	Open
Pipe 8	231.33	2.62	5.72	Open
Pipe 9	231.33	2.62	5.72	Open
Pipe 10	231.33	2.62	5.72	Open
Pipe 11	231.33	2.62	5.72	Open
Pipe 12	231.33	2.62	5.72	Open
Pipe 13	231.33	2.62	5.72	Open
Pipe 14	231.33	2.62	5.72	Open
Pipe 15	231.33	2.62	5.72	Open
Pipe 16	231.33	2.62	5.72	Open
Pipe 17	-412.67	4.68	16.70	Open
Pipe 18	-412.67	4.68	16.70	Open
Pipe 19	-412.67	4.68	16.70	Open
Pipe 20	-412.67	4.68	16.70	Open
Pipe 21	0.00	0.00	0.00	Open
Pipe 22	0.00	0.00	0.00	Open
Pipe 23	0.00	0.00	0.00	Open

644 gpm fire flow at TW bench, diesel pump on, low water tank levels

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 24	0.00	0.00	0.00	Open
Pipe 25	0.00	0.00	0.00	Open
Pipe 26	0.00	0.00	0.00	Open
Pipe 27	0.00	0.00	0.00	Open
Pipe 28	0.00	0.00	0.00	Open
Pipe 29	0.00	0.00	0.00	Open
Pipe 30	0.00	0.00	0.00	Open
Pipe 31	0.00	0.00	0.00	Open
Pipe 32	0.00	0.00	0.00	Open
Pipe 33	0.00	0.00	0.00	Open
Pipe 34	0.00	0.00	0.00	Open
Pipe 35	0.00	0.00	0.00	Open
Pipe 36	0.00	0.00	0.00	Open
Pipe 37	0.00	0.00	0.00	Open
Pipe 101	644.00	8.95	41.29	Open
Pipe 102	0.00	0.00	0.00	Open
Pipe 103	644.00	8.95	41.29	Open
Pump 4B	0.00	0.00	0.00	Closed
Pump 6B	644.00	0.00	-256.64	Open

863 gpm fire flow at MW-20 bench, electric pump on, high water tank levels

Network Table - Nodes

Node ID	Demand GPM	Head ft	Pressure psi
Junc 3	0.00	699.63	11.97
Junc 4	0.00	694.36	29.19
Junc 4A	0.00	690.16	27.37
Junc 4B	0.00	901.39	118.89
Junc 5	0.00	896.02	116.57
Junc 6A	0.00	694.36	29.19
Junc 6B	0.00	895.82	116.48
Junc 6	0.00	694.36	29.19
Junc 7	0.00	895.82	116.48
Junc 8	0.00	894.90	118.68
Junc 9	0.00	892.38	117.59
Junc 10	0.00	891.10	118.77
Junc 11	0.00	890.45	118.49
Junc 12	0.00	885.81	113.88
Junc 13	0.00	885.81	113.88
Junc 14	0.00	882.82	113.45
Junc 15	0.00	881.54	113.32
Junc 16	0.00	880.50	114.17
Junc 17	0.00	880.00	113.96
Junc 18	0.00	883.45	115.45
Junc 19	0.00	885.47	115.46
Junc 20	0.00	892.25	117.53
Junc 21	0.00	891.10	130.47
Junc 22	0.00	891.10	130.47
Junc 70	0.00	894.90	116.51

863 gpm fire flow at MW-20 bench, electric pump on, high water tank levels

Node ID	Demand GPM	Head ft	Pressure psi
Junc 71	0.00	892.25	115.37
Junc 72	0.00	892.38	117.15
Junc 73	0.00	885.47	112.43
Junc 74	0.00	883.45	113.29
Junc 75	0.00	880.00	111.79
Junc 76	0.00	880.50	110.71
Junc 77	0.00	881.54	112.46
Junc 78	0.00	882.82	111.71
Junc 79	0.00	885.81	112.14
Junc 80	0.00	890.45	116.32
Junc 81	0.00	891.10	127.87
Junc 82	0.00	891.10	130.47
Junc 83	0.00	891.10	128.30
Junc 101	0.00	811.41	121.07
Junc 102	863.00	602.37	44.36
Junc 103	0.00	811.41	113.27
Tank 1	-431.51	700.00	12.13
Tank 2	-431.51	700.00	12.13

863 gpm fire flow at MW-20 bench, electric pump on, high water tank levels

Network Table - Links

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 1	431.51	2.75	5.31	Open
Pipe 2	431.51	2.75	5.31	Open
Pipe 3	863.01	5.51	16.13	Open
Pipe 4A	863.01	9.79	65.48	Open
Pipe 4C	863.01	9.79	65.48	Open
Pipe 5	0.00	0.00	0.00	Open
Pipe 6A	0.00	0.00	0.00	Open
Pipe 6C	0.00	0.00	0.00	Open
Pipe 7	304.65	3.46	9.52	Open
Pipe 8	304.65	3.46	9.52	Open
Pipe 9	304.65	3.46	9.52	Open
Pipe 10	304.65	3.46	9.52	Open
Pipe 11	304.64	3.46	9.52	Open
Pipe 12	304.64	3.46	9.52	Open
Pipe 13	304.64	3.46	9.52	Open
Pipe 14	304.64	3.46	9.52	Open
Pipe 15	304.64	3.46	9.52	Open
Pipe 16	304.64	3.46	9.52	Open
Pipe 17	-558.36	6.34	29.23	Open
Pipe 18	-558.36	6.34	29.23	Open
Pipe 19	-558.36	6.34	29.23	Open
Pipe 20	-558.36	6.34	29.23	Open
Pipe 21	0.00	0.00	0.00	Open
Pipe 22	0.00	0.00	0.00	Open
Pipe 23	0.00	0.00	0.00	Open

863 gpm fire flow at MW-20 bench, electric pump on, high water tank levels

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 24	0.00	0.00	0.00	Open
Pipe 25	0.00	0.00	0.00	Open
Pipe 26	0.00	0.00	0.00	Open
Pipe 27	0.00	0.00	0.00	Open
Pipe 28	0.00	0.00	0.00	Open
Pipe 29	0.00	0.00	0.00	Open
Pipe 30	0.00	0.00	0.00	Open
Pipe 31	0.00	0.00	0.00	Open
Pipe 32	0.00	0.00	0.00	Open
Pipe 33	0.00	0.00	0.00	Open
Pipe 34	0.00	0.00	0.00	Open
Pipe 35	0.00	0.00	0.00	Open
Pipe 36	0.00	0.00	0.00	Open
Pipe 37	0.00	0.00	0.00	Open
Pipe 101	863.00	12.00	71.01	Open
Pipe 102	863.00	12.00	71.01	Open
Pipe 103	0.00	0.00	0.00	Open
Pump 4B	863.01	0.00	-211.23	Open
Pump 6B	0.00	0.00	0.00	Closed

863 gpm fire flow at MW-20 bench, electric pump on, low water tank levels

Network Table - Nodes

Node ID	Demand GPM	Head ft	Pressure psi
Junc 3	0.00	673.63	0.71
Junc 4	0.00	668.36	17.92
Junc 4A	0.00	664.16	16.10
Junc 4B	0.00	875.39	107.63
Junc 5	0.00	870.02	105.30
Junc 6A	0.00	668.36	17.92
Junc 6B	0.00	869.82	105.22
Junc 6	0.00	668.36	17.92
Junc 7	0.00	869.82	105.22
Junc 8	0.00	868.90	107.42
Junc 9	0.00	866.38	106.32
Junc 10	0.00	865.10	107.50
Junc 11	0.00	864.45	107.22
Junc 12	0.00	859.81	102.61
Junc 13	0.00	859.81	102.61
Junc 14	0.00	856.82	102.18
Junc 15	0.00	855.54	102.06
Junc 16	0.00	854.50	102.91
Junc 17	0.00	854.00	102.69
Junc 18	0.00	857.45	104.19
Junc 19	0.00	859.47	104.20
Junc 20	0.00	866.25	106.27
Junc 21	0.00	865.10	119.20
Junc 22	0.00	865.10	119.20
Junc 70	0.00	868.90	105.25

863 gpm fire flow at MW-20 bench, electric pump on, low water tank levels

Node ID	Demand GPM	Head ft	Pressure psi
Junc 71	0.00	866.25	104.10
Junc 72	0.00	866.38	105.89
Junc 73	0.00	859.47	101.16
Junc 74	0.00	857.45	102.02
Junc 75	0.00	854.00	100.53
Junc 76	0.00	854.50	99.44
Junc 77	0.00	855.54	101.19
Junc 78	0.00	856.82	100.45
Junc 79	0.00	859.81	100.88
Junc 80	0.00	864.45	105.06
Junc 81	0.00	865.10	116.60
Junc 82	0.00	865.10	119.20
Junc 83	0.00	865.10	117.04
Junc 101	0.00	785.41	109.80
Junc 102	863.00	576.37	33.09
Junc 103	0.00	785.41	102.00
Tank 1	-431.51	674.00	0.87
Tank 2	-431.51	674.00	0.87

863 gpm fire flow at MW-20 bench, electric pump on, low water tank levels

Network Table - Links

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 1	431.51	2.75	5.31	Open
Pipe 2	431.51	2.75	5.31	Open
Pipe 3	863.01	5.51	16.13	Open
Pipe 4A	863.01	9.79	65.48	Open
Pipe 4C	863.01	9.79	65.48	Open
Pipe 5	0.00	0.00	0.00	Open
Pipe 6A	0.00	0.00	0.00	Open
Pipe 6C	0.00	0.00	0.00	Open
Pipe 7	304.65	3.46	9.52	Open
Pipe 8	304.65	3.46	9.52	Open
Pipe 9	304.65	3.46	9.52	Open
Pipe 10	304.65	3.46	9.52	Open
Pipe 11	304.64	3.46	9.52	Open
Pipe 12	304.64	3.46	9.52	Open
Pipe 13	304.64	3.46	9.52	Open
Pipe 14	304.64	3.46	9.52	Open
Pipe 15	304.64	3.46	9.52	Open
Pipe 16	304.64	3.46	9.52	Open
Pipe 17	-558.36	6.34	29.23	Open
Pipe 18	-558.36	6.34	29.23	Open
Pipe 19	-558.36	6.34	29.23	Open
Pipe 20	-558.36	6.34	29.23	Open
Pipe 21	0.00	0.00	0.00	Open
Pipe 22	0.00	0.00	0.00	Open
Pipe 23	0.00	0.00	0.00	Open

863 gpm fire flow at MW-20 bench, electric pump on, low water tank levels

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 24	0.00	0.00	0.00	Open
Pipe 25	0.00	0.00	0.00	Open
Pipe 26	0.00	0.00	0.00	Open
Pipe 27	0.00	0.00	0.00	Open
Pipe 28	0.00	0.00	0.00	Open
Pipe 29	0.00	0.00	0.00	Open
Pipe 30	0.00	0.00	0.00	Open
Pipe 31	0.00	0.00	0.00	Open
Pipe 32	0.00	0.00	0.00	Open
Pipe 33	0.00	0.00	0.00	Open
Pipe 34	0.00	0.00	0.00	Open
Pipe 35	0.00	0.00	0.00	Open
Pipe 36	0.00	0.00	0.00	Open
Pipe 37	0.00	0.00	0.00	Open
Pipe 101	863.00	12.00	71.01	Open
Pipe 102	863.00	12.00	71.01	Open
Pipe 103	0.00	0.00	0.00	Open
Pump 4B	863.01	0.00	-211.23	Open
Pump 6B	0.00	0.00	0.00	Closed

863 gpm fire flow at MW-20 bench, diesel pump on, high water tank levels

Network Table - Nodes

Node ID	Demand GPM	Head ft	Pressure psi
Junc 3	0.00	699.63	11.97
Junc 4	0.00	694.36	29.19
Junc 4A	0.00	694.36	29.19
Junc 4B	0.00	895.65	116.41
Junc 5	0.00	895.65	116.41
Junc 6A	0.00	688.79	26.77
Junc 6B	0.00	901.63	119.00
Junc 6	0.00	692.98	28.59
Junc 7	0.00	896.26	116.67
Junc 8	0.00	895.30	118.86
Junc 9	0.00	892.70	117.73
Junc 10	0.00	891.38	118.89
Junc 11	0.00	890.71	118.60
Junc 12	0.00	885.91	113.92
Junc 13	0.00	885.91	113.92
Junc 14	0.00	882.83	113.45
Junc 15	0.00	881.50	113.31
Junc 16	0.00	880.43	114.14
Junc 17	0.00	879.92	113.92
Junc 18	0.00	883.31	115.39
Junc 19	0.00	885.29	115.38
Junc 20	0.00	891.95	117.40
Junc 21	0.00	891.38	130.59
Junc 22	0.00	891.38	130.59
Junc 70	0.00	895.30	116.69

863 gpm fire flow at MW-20 bench, diesel pump on, high water tank levels

Node ID	Demand GPM	Head ft	Pressure psi
Junc 71	0.00	891.95	115.24
Junc 72	0.00	892.70	117.29
Junc 73	0.00	885.29	112.35
Junc 74	0.00	883.31	113.22
Junc 75	0.00	879.92	111.76
Junc 76	0.00	880.43	110.68
Junc 77	0.00	881.50	112.44
Junc 78	0.00	882.83	111.72
Junc 79	0.00	885.91	112.19
Junc 80	0.00	890.71	116.43
Junc 81	0.00	891.38	127.99
Junc 82	0.00	891.38	130.59
Junc 83	0.00	891.38	128.42
Junc 101	0.00	811.33	121.03
Junc 102	863.00	602.29	44.32
Junc 103	0.00	811.33	113.23
Tank 1	-431.51	700.00	12.13
Tank 2	-431.51	700.00	12.13

863 gpm fire flow at MW-20 bench, diesel pump on, high water tank levels

Network Table - Links

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 1	431.51	2.75	5.31	Open
Pipe 2	431.51	2.75	5.31	Open
Pipe 3	863.01	5.51	16.13	Open
Pipe 4A	0.00	0.00	0.00	Open
Pipe 4C	0.00	0.00	0.00	Open
Pipe 5	863.01	9.79	65.48	Open
Pipe 6A	863.01	9.79	65.48	Open
Pipe 6C	863.01	9.79	65.48	Open
Pipe 7	-553.00	6.28	28.72	Open
Pipe 8	310.01	3.52	9.83	Open
Pipe 9	310.01	3.52	9.83	Open
Pipe 10	310.01	3.52	9.83	Open
Pipe 11	310.00	3.52	9.83	Open
Pipe 12	310.00	3.52	9.83	Open
Pipe 13	310.00	3.52	9.83	Open
Pipe 14	310.00	3.52	9.83	Open
Pipe 15	310.00	3.52	9.83	Open
Pipe 16	310.00	3.52	9.83	Open
Pipe 17	-553.00	6.27	28.72	Open
Pipe 18	-553.00	6.27	28.72	Open
Pipe 19	-553.00	6.28	28.72	Open
Pipe 20	-553.00	6.28	28.72	Open
Pipe 21	0.00	0.00	0.00	Open
Pipe 22	0.00	0.00	0.00	Open
Pipe 23	0.00	0.00	0.00	Open

863 gpm fire flow at MW-20 bench, diesel pump on, high water tank levels

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 24	0.00	0.00	0.00	Open
Pipe 25	0.00	0.00	0.00	Open
Pipe 26	0.00	0.00	0.00	Open
Pipe 27	0.00	0.00	0.00	Open
Pipe 28	0.00	0.00	0.00	Open
Pipe 29	0.00	0.00	0.00	Open
Pipe 30	0.00	0.00	0.00	Open
Pipe 31	0.00	0.00	0.00	Open
Pipe 32	0.00	0.00	0.00	Open
Pipe 33	0.00	0.00	0.00	Open
Pipe 34	0.00	0.00	0.00	Open
Pipe 35	0.00	0.00	0.00	Open
Pipe 36	0.00	0.00	0.00	Open
Pipe 37	0.00	0.00	0.00	Open
Pipe 101	863.00	12.00	71.01	Open
Pipe 102	863.00	12.00	71.01	Open
Pipe 103	0.00	0.00	0.00	Open
Pump 4B	0.00	0.00	0.00	Closed
Pump 6B	863.01	0.00	-212.84	Open

863 gpm fire flow at MW-20 bench, diesel pump on, low water tank levels

Network Table - Nodes

Node ID	Demand GPM	Head ft	Pressure psi
Junc 3	0.00	673.63	0.71
Junc 4	0.00	668.36	17.92
Junc 4A	0.00	668.36	17.92
Junc 4B	0.00	869.65	105.14
Junc 5	0.00	869.65	105.14
Junc 6A	0.00	662.79	15.51
Junc 6B	0.00	875.63	107.73
Junc 6	0.00	666.98	17.32
Junc 7	0.00	870.26	105.40
Junc 8	0.00	869.30	107.59
Junc 9	0.00	866.70	106.46
Junc 10	0.00	865.38	107.62
Junc 11	0.00	864.71	107.33
Junc 12	0.00	859.91	102.65
Junc 13	0.00	859.91	102.65
Junc 14	0.00	856.83	102.18
Junc 15	0.00	855.50	102.04
Junc 16	0.00	854.43	102.88
Junc 17	0.00	853.92	102.66
Junc 18	0.00	857.31	104.12
Junc 19	0.00	859.29	104.12
Junc 20	0.00	865.95	106.14
Junc 21	0.00	865.38	119.32
Junc 22	0.00	865.38	119.32
Junc 70	0.00	869.30	105.42

863 gpm fire flow at MW-20 bench, diesel pump on, low water tank levels

Node ID	Demand GPM	Head ft	Pressure psi
Junc 71	0.00	865.95	103.97
Junc 72	0.00	866.70	106.03
Junc 73	0.00	859.29	101.08
Junc 74	0.00	857.31	101.96
Junc 75	0.00	853.92	100.49
Junc 76	0.00	854.43	99.41
Junc 77	0.00	855.50	101.18
Junc 78	0.00	856.83	100.45
Junc 79	0.00	859.91	100.92
Junc 80	0.00	864.71	105.17
Junc 81	0.00	865.38	116.72
Junc 82	0.00	865.38	119.32
Junc 83	0.00	865.38	117.16
Junc 101	0.00	785.33	109.77
Junc 102	863.00	576.29	33.06
Junc 103	0.00	785.33	101.97
Tank 1	-431.51	674.00	0.87
Tank 2	-431.51	674.00	0.87

863 gpm fire flow at MW-20 bench, diesel pump on, low water tank levels

Network Table - Links

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 1	431.51	2.75	5.31	Open
Pipe 2	431.51	2.75	5.31	Open
Pipe 3	863.01	5.51	16.13	Open
Pipe 4A	0.00	0.00	0.00	Open
Pipe 4C	0.00	0.00	0.00	Open
Pipe 5	863.01	9.79	65.48	Open
Pipe 6A	863.01	9.79	65.48	Open
Pipe 6C	863.01	9.79	65.48	Open
Pipe 7	-553.00	6.28	28.72	Open
Pipe 8	310.01	3.52	9.83	Open
Pipe 9	310.01	3.52	9.83	Open
Pipe 10	310.01	3.52	9.83	Open
Pipe 11	310.00	3.52	9.83	Open
Pipe 12	310.00	3.52	9.83	Open
Pipe 13	310.00	3.52	9.83	Open
Pipe 14	310.00	3.52	9.83	Open
Pipe 15	310.00	3.52	9.83	Open
Pipe 16	310.00	3.52	9.83	Open
Pipe 17	-553.00	6.27	28.72	Open
Pipe 18	-553.00	6.27	28.72	Open
Pipe 19	-553.00	6.28	28.72	Open
Pipe 20	-553.00	6.28	28.72	Open
Pipe 21	0.00	0.00	0.00	Open
Pipe 22	0.00	0.00	0.00	Open
Pipe 23	0.00	0.00	0.00	Open

863 gpm fire flow at MW-20 bench, diesel pump on, low water tank levels

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Status
Pipe 24	0.00	0.00	0.00	Open
Pipe 25	0.00	0.00	0.00	Open
Pipe 26	0.00	0.00	0.00	Open
Pipe 27	0.00	0.00	0.00	Open
Pipe 28	0.00	0.00	0.00	Open
Pipe 29	0.00	0.00	0.00	Open
Pipe 30	0.00	0.00	0.00	Open
Pipe 31	0.00	0.00	0.00	Open
Pipe 32	0.00	0.00	0.00	Open
Pipe 33	0.00	0.00	0.00	Open
Pipe 34	0.00	0.00	0.00	Open
Pipe 35	0.00	0.00	0.00	Open
Pipe 36	0.00	0.00	0.00	Open
Pipe 37	0.00	0.00	0.00	Open
Pipe 101	863.00	12.00	71.01	Open
Pipe 102	863.00	12.00	71.01	Open
Pipe 103	0.00	0.00	0.00	Open
Pump 4B	0.00	0.00	0.00	Closed
Pump 6B	863.01	0.00	-212.84	Open

CP 1.1

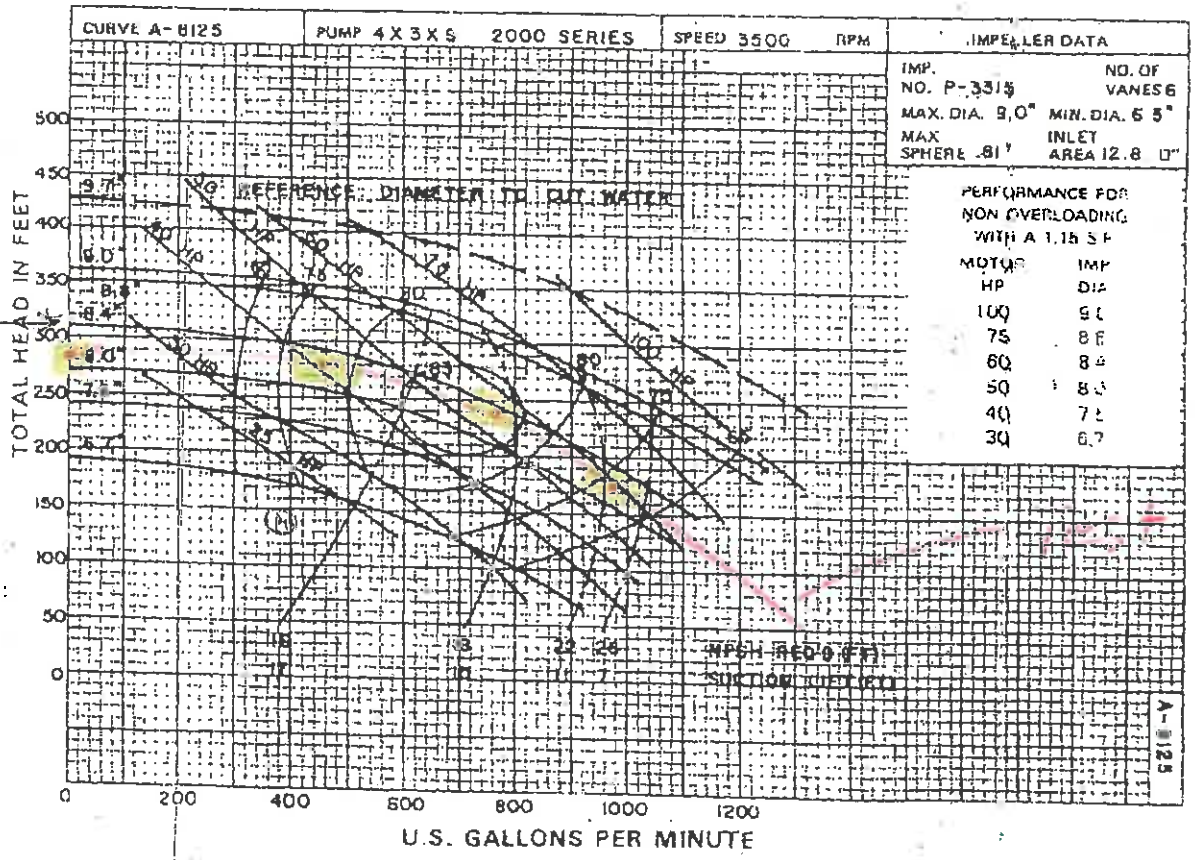
Page 42

END SUCTION PUMPS

2000 Series — Single-Stage Close-Coupled or Frame Mounted with Mechanical Seals or Packing

Performance Curves — Key 66 — 3500 Rpm

TOPOCK ELECTRIC FIRE PUMP





curve

ITT A-C Pump

A unit of ITT Corporation

DTP-F3

5608-0231

IMPELLER DWG.	IMPELLER DIA.	SPECIFIC GRAVITY	VISCOSITY
52-233-459-116	10.500 in.	1.000	32.0 SSU

Topock Diesel Fire Pump

CURVE NO. B94915-03-01-1E1

SIZE 6x4x10F-M TYPE 8100

500 G.P.M. 125 P.S.I. 3000 R.P.M.

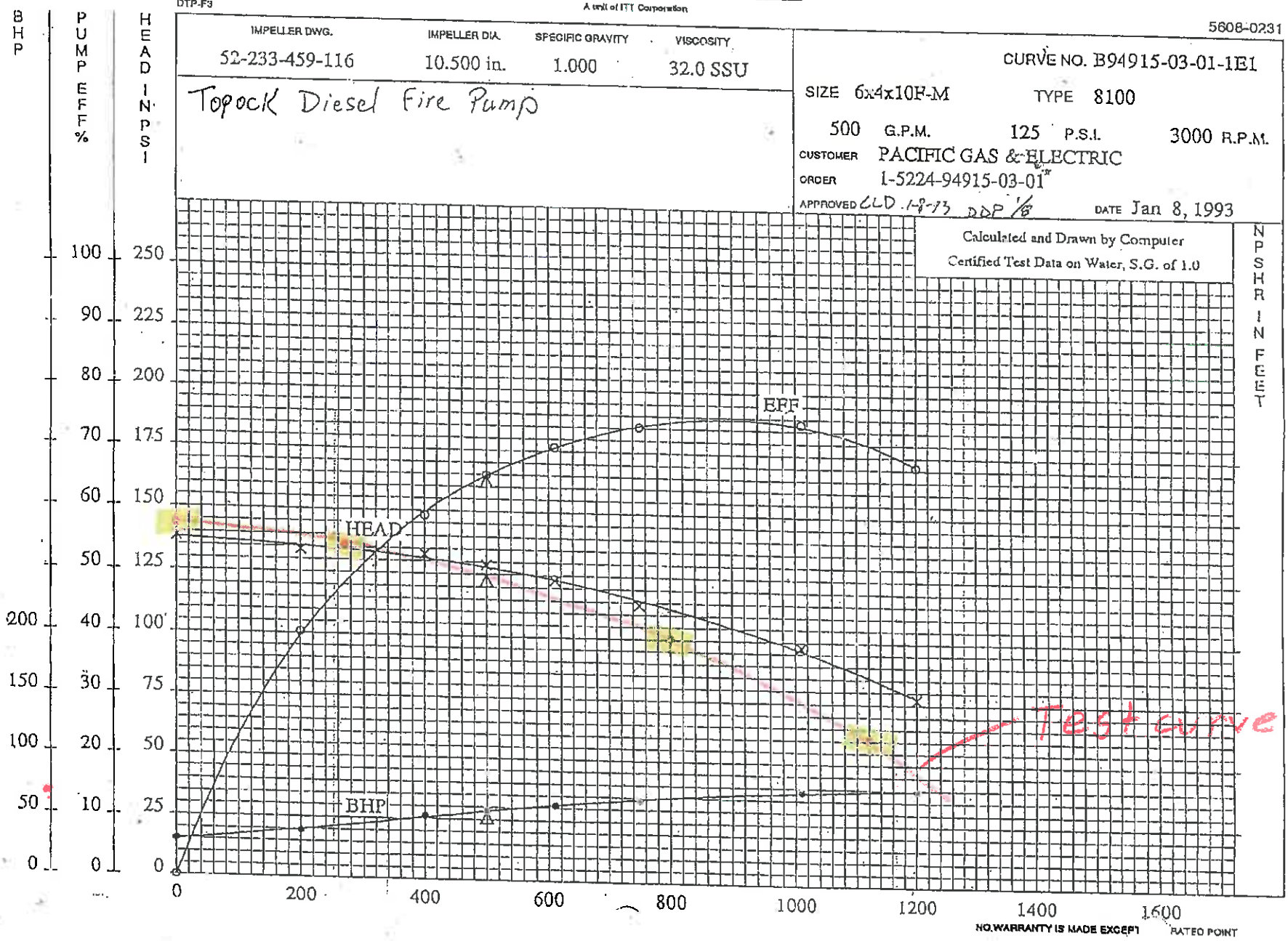
CUSTOMER PACIFIC GAS & ELECTRIC

ORDER 1-5224-94915-03-01

APPROVED CLD 1-8-93 DAP 1/8 DATE Jan 8, 1993

Calculated and Drawn by Computer

Certified Test Data on Water, S.G. of 1.0



Appendix D
Plans (Engineering Drawings)

D1: Equipment Lists

D2: Drawings

This appendix is presented under separate cover in a standalone volume, as well as on the CD-ROM version of the BOD Report.

Appendix E
Draft Specifications
(*on CD-ROM only*)

TABLE OF CONTENTS

Pages

PART 1—PROCUREMENT REQUIREMENTS

PART 2—CONTRACTING REQUIREMENTS

PART 3—TECHNICAL SPECIFICATIONS

DIVISION 1—GENERAL REQUIREMENTS

01 11 00 Summary of Work 1- 2

DIVISION 2—EXISTING CONDITIONS

DIVISION 3—CONCRETE

03 10 00 Concrete Forming and Accessories 1- 9
03 21 00 Reinforcing Steel 1- 8
03 30 00 Cast-in-Place Concrete 1- 51
Supplementary Information
Concrete Mix Design Class 5000F3S1P2C1 ..... 1- 3
Concrete Mix Design, Class CF00F1S1P0C1 ..... 1- 3
Concrete Mix Design, Class 4500F3S1P1C2 ..... 1- 3
Concrete Mix Design, Class 4000F0S1P0C0 ..... 1- 2
Concrete Mix Design, Class TC00F0S1P1C1 ..... 1- 2
Concrete Mix Design, Class GT00F1S1P0C1 ..... 1- 2
03 35 00 Concrete Finishing 1- 8
03 39 00 Concrete Curing 1- 6
03 40 00 Precast Concrete 1- 12
03 62 00 Nonshrink Grouting 1- 7
Supplement: 24 Hour Evaluation of Nonshrink Grout Test Form 1- 1
Grout Testing Procedures 2- 4

DIVISION 4 (NOT USED)

DIVISION 5—METALS

05 05 23 Welding 1- 5
Supplement: Welding and Nondestructive Testing Table 1- 2

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Pages

05 12 00 Structural Steel Framing 1- 15
05 21 19 Open Web Steel Joist Framing 1- 4
05 31 00 Steel Decking 1- 8
05 41 00 Structural Metal Stud Framing 1- 9
05 50 00 Metal Fabrications 1- 35
05 52 00 Metal Railings 1- 14
Supplement: Supplemental Paragraphs 1- 2
05 53 00 Metal Gratings 1- 7

DIVISION 6 (NOT USED)

DIVISION 7—THERMAL AND MOISTURE PROTECTION

07 14 00 Fluid-Applied Waterproofing 1- 7
07 21 00 Thermal Insulation 1- 4
07 26 00 Vapor Retarders 1- 7
07 92 00 Joint Sealants 1- 10

DIVISION 8—OPENINGS

08 11 00 Metal Doors and Frames 1- 5
08 33 23 Overhead Coiling Doors 1- 6
08 71 00 Door Hardware 1- 19
08 90 00 Louvers [and Vents] 1- 4
Supplement: Louver [and Vents] Schedule 1- 1
Louver [and Vents] Schedule Example 1- 1

DIVISION 9—FINISHES

09 29 00 Gypsum Board 1- 14
09 90 00 Painting and Coating 1- 38
Supplement: Paint System Data Sheet (PSDS) 1- 1
Paint Product Data Sheet (PDS) 1- 1
09 90 05 Architectural Painting 1- 9
09 96 35 Chemical-Resistant Coatings 1- 5
Supplement: Corrosion Control Assistance Form 1- 1
09 97 13 Steel Tank Coatings 1- 20
Supplement: Paint System Data Sheet 1- 2
Paint Product Data Sheet 1- 1
09 97 26 Cementitious Coatings 1- 6

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Pages

DIVISION 10—SPECIALTIES

10 14 00 Signage 1- 5
10 44 00 Fire Protection Specialties 1- 4

DIVISION 11—EQUIPMENT

11 53 00 Laboratory Equipment 1- 6

DIVISION 13—SPECIAL CONSTRUCTION

13 34 19 Metal Building Systems 1- 16

DIVISION 14 THROUGH 20 (NOT USED)

DIVISION 21—FIRE SUPPRESSION

21 24 00 Dry-Chemical Fire-Extinguishing Systems 1- 15

DIVISION 22—PLUMBING

22 10 01 Plumbing Piping and Accessories 1- 23
22 10 01.01 Plumbing Piping Schedule 1- 2
22 10 01.02 Polyvinyl Chloride Drain Waste and Vent (PVC-DWV) Pipe and Fittings (Data Sheet) 1- 1
22 10 01.04 Acid-Resistant Cast Iron Pipe and Fittings 1- 1
22 13 01.06 Acid-Resistant Polypropylene Waste and Vent Pipe and Fittings 1- 1
22 10 01.08 Double Contained Pipe and Fittings Datasheet 1- 3
22 30 00 Plumbing Equipment 1- 9
Supplement Data Sheets:
Instantaneous Water Heater 1- 1
Simplex, Submersible Sump Pump 1- 1
Duplex, Submersible Sump Pump 1- 2
Duplex, Column Type, Sump Pump (Acid Resistant) 1- 2
Backflow Preventers 1- 2
22 40 00 Plumbing Fixtures 1- 15

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Pages

DIVISION 23—HEATING, VENTILATING, AND AIR-CONDITIONING

23 05 93	Testing, Adjusting, and Balancing for HVAC	1- 6
23 34 00	HVAC Fans	1- 52
23 81 00.01	Ductless Split System DX Indoor Units Data Sheet	1- 2

DIVISION 24 THROUGH 25 (NOT USED)

DIVISION 26—ELECTRICAL

26 05 02	Basic Electrical Requirements	1- 7
26 05 04	Basic Electrical Materials and Methods	1- 15
26 05 05	Conductors	1- 27
26 05 26	Grounding and Bonding for Electrical Systems	1- 6
26 05 33	Raceway and Boxes	1- 11
26 12 02	Oil-Filled Pad Mounted Transformers	1- 9
26 13 16.01	Metal-Enclosed Switchgear	1- 24
26 13 16.02	Pad-Mounted Switchgear	1- 18
26 14 13	Switchboards	1- 15
26 18 39	Medium-Voltage Motor Control	1- 15
26 22 00	Low-Voltage Transformers	1- 10
26 24 16	Panelboards	1- 9
26 24 19	Motor Control Center	1- 6
26 27 26	Wiring Devices	1- 7
26 29 23	Low-Voltage Adjustable Frequency Drive System	1- 16
Supplement:	Simplified Plant One-Line Diagram	1- 1
26 43 00	Transient Voltage Suppression	1- 5
26 50 00	Lighting	1- 18
Supplement:	Luminaire Schedule	1- 2
26 56 00	Exterior Lighting	1- 8

DIVISION 27 THROUGH 30 (NOT USED)

DIVISION 31—EARTHWORK

31 10 00	Site Clearing	1- 6
31 23 13	Subgrade Preparation	1- 3
31 23 16	Excavation	1- 5
31 23 23	Fill and Backfill	1- 11
31 41 00	Shoring	1- 2

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Pages

DIVISION 32—EXTERIOR IMPROVEMENTS

32 11 23	Aggregate Base Courses	1- 7
32 12 16	Asphalt Paving	1- 12
32 17 23	Pavement Markings	1- 6
32 31 13	Chain Link Fences and Gates	1- 18

DIVISION 33—UTILITIES

33 05 01	Conveyance Piping – General	1- 10
33 05 01.10	High-Density Polyethylene (HDPE) Pressure Pipe and Fittings	1- 9
33 05 13	Manholes	1- 15
33 05 23.16	Utility Pipe Jacking	1- 7
33 12 16.29	Air and Vacuum Release Valve Assemblies	1- 9
33 16 13.13	Welded Steel Tank	1- 5
33 16 13.14	Frac Tanks	1- 6
Supplement:	Equipment Data Sheets	1- 8
33 21 13.01	Water Well Mobilization Demobilization	1- 3
33 21 13.03	Water Well Drilling	1- 9
33 41 01.01	Storm Drain Sanitary Sewer and Drainage Piping	1- 5
Supplement:	33 41 01.01 Corrugated Metal Data Sheet	1- 1
33 46 00	Subsurface Drainage	1- 10

DIVISION 34 THROUGH 39 (NOT USED)

DIVISION 40—PROCESS INTEGRATION

40 50 00	Power Plant Piping Materials	1- 2
Supplement:	Power Plant Pipe Index	1- 2
	Power Piping Specification Designator	1- 1
	Power Pipe Material Specifications	1- 40
40 50 10	Underground Piping	1- 10
Supplement:	Piping Pretest Checklist	1- 1
	Piping Test and Post-Test Checklist	2- 2
	Power Piping Standard PP-1, Dielectric Flanged Joint	3- 3
40 50 20	Aboveground Piping	1- 12
Supplement:	Piping Pretest Checklist	1- 2
	Status of Instruments during Pressure Test	2- 2
	Piping Test and Post Test Checklist	3- 3
	Power Piping Standard PP-1 – Dielectric Flanged Joint	4- 5

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Pages

40 55 00 Power Plant Valves 1- 12
Supplement: Valve Index 1- 3
Valve Data Sheet 1- 14
Specialty List 1- 1
40 57 20 Power Plant Piping Engineered Supports 1- 8
Supplement: Engineered Support Index 1-
Support Detail Sheets .....
40 90 00 Instrumentation and Control for Process Systems 1- 34
Supplement: Supplemental Paragraphs 1- 2
Example Instrument List 1- 1
Example Loop Specifications 1- 2
Example Instrument Calibration Sheet 1- 2
I&C Valve Adjustment Sheet 1- 2
Performance Acceptance Sheet 1- 2
PLC Equipment List
PLC Input/Output List
Control Panel Schedule
Preparation for Testing and Functional Test Forms:
Loop Status Report:
Adjustment Sheet
Performance Test Sheet
40 90 01 I&C Component Index 1- 19
40 95 60 Telemetry System 1- 11
Supplements: RTU List.
RTU Input/Output Summary.
40 95 80 Fiber Optic Communication System 1- 27

DIVISION 41—MATERIAL PROCESSING AND HANDLING EQUIPMENT

41 22 13.13 Overhead Cranes 1- 11
Supplement: Crane Data Sheet 1- 1
Crane Dimension Sheet 1- 1

DIVISION 42 (NOT USED)

DIVISION 43—PROCESS GAS AND LIQUID HANDLING, PURIFICATION, AND STORAGE EQUIPMENT

43 40 02 High Density PolyethyleneTank 1- 6
Supplement: HDPE Tank Schedule 1- 3

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Pages

Equipment Data Sheet 1- 1

DIVISION 44—POLLUTION CONTROL EQUIPMENT

44 42 56.04 Submersible Well Pumps 1- 3
Supplement: Submersible Well Pump Data Sheet 1- 3
44 42 56.04 Submersible Sump Pumps 1- 3
Supplement: Submersible Sump Pump Data Sheets: 1- 4
44 42 56.10 Horizontal End Suction Centrifugal Pumps 1- 4
Supplement: Horizontal End suction Centrifugal Pump and Motor Datasheet 1- 10
44 42 56.15 Air Operated Diaphragm Pumps 1- 3
Supplement: Air Operated Diaphragm Pump Data Sheet 1- 2
44 43 13.16 Cartridge Filters 1- 4
Supplement: Equipment Data Sheet 5- 6
44 44 13.01 Chemical Metering Pumps 1- 5
Supplement: Chemical Metering Data Sheet 1- 6

DIVISION 45 THRUGH 49 (NOT USED)

PART 4—DRAWINGS (BOUND SEPARATELY)

END OF SECTION

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SECTION 01 11 00
SUMMARY OF WORK

PART 1 GENERAL

1.01 WORK COVERED BY CONTRACT DOCUMENTS

A. The completed Work will provide OWNER with the Final Groundwater Remedy described including:

B. The Work is divided into the following schedules:

1. Installation of 51 new remedy wells including drilling, casing, concrete well and meter vaults, piping, pumps, valves, instrumentation and controls, and pipe appurtenances. Well installation includes post construction well development.
2. 2 carbon amendment facilities including ethanol storage tanks, 5 building-housing equipment (pumps, piping, instrumentation and controls, valves, pipe appurtenances, and PLCs), and additional security fencing.
3. Construction of a Remedy Produced Water Conditioning Plant, including but not limited to; metal building, concrete foundation, retaining wall, decontamination pad, filtration equipment, laboratory, motor control center, chemical storage area, electrical and control systems and ancillary support systems.
4. Construction of 1 (Produced Water) Influent Tank Farm, including but not limited to frac tanks, secondary containment, pumps, sumps, and piping.
5. Construction of 1 Conditioned Water Storage Tank Farm, including but not limited to frac tanks, secondary containment, pumps, sumps, and piping.
6. Construction of a Conditioned Water Storage Tank, including but not limited to the tank, foundation, piping, and appurtenances.
7. Construction of interconnecting piping, valves, and controls for freshwater, extracted groundwater, remedy produced water and conditioned water distribution.
8. Construction of medium voltage power distribution wiring, electrical transformers, remote terminals (HMI), and communications lines to all wells and facilities.
9. Upgrade of existing well HNWR-1 located in Arizona to include new equipment pads, controls, piping, valves, appurtenances, electrical panels, submersible pump, site improvements, and fencing. Also,

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includes installing new freshwater pipe from the well to the Compressor Station crossing the Colorado River on an existing pipe bridge (Arch Bridge) and demolition of existing 6-inch water supply pipeline.

C. Alternates: Only those alternates that were selected by the OWNER, as evidenced in the Agreement, are made a part of this Contract.

1.02 WORK NOT COVERED BY CONTRACT DOCUMENTS

A. 3,000-gallon double-wall ethanol storage tank provided by OWNER.

B. 3 500-barrel frac tanks provided by OWNER

1.03 PROVISIONS FOR FUTURE WORK

A. Provisions for future construction are as shown.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION (NOT USED)

END OF SECTION

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SECTION 03 10 00
CONCRETE FORMING AND ACCESSORIES

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Concrete Institute (ACI):
   a. 117/117R, Standard Tolerances for Concrete Construction and Materials.
   b. 301, Specifications for Structural Concrete in Buildings.
   c. 318/318R, Building Code Requirements for Structural Concrete and Commentary.
   d. 347, Guide to Formwork for Concrete.
   e. SP-4, Formwork for Concrete
2. APA – The Engineered Wood Association (APA/EWA):
3. PS 1, Construction and Industrial Plywood.
4. Western Wood Products Association (WWPA): G5, Western Lumber Grading Rules.

1.02 DESIGN REQUIREMENTS

A. Design, engineer, and construct formwork in accordance with ACI 301, ACI 347 and ACI 318/318R to provide concrete finishes specified in Section 03 30 00, Cast-in-Place Concrete.

A. CONTRACTOR responsible for form design, form removal procedures and sequences, shoring and re-shoring, and shore removals according to ACI 301 Section 2.

B. Make joints in forms watertight.

C. Limit panel deflection to 1/360th of each component span to achieve tolerances specified.

1.03 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. Layout of panel joints, form liners, and tie hole pattern.

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b. Form Ties-Tapered Through-Bolts: Proposed method of sealing form tie hole; coordinate with details shown.
c. Manufacturer's data for form release agent.
d. Manufacturer's literature for form materials, form accessories, and prefabricated forms, including type, size, quantity and strength of all form materials.
e. Plan for jointing of facing panels.
f. Details affecting the appearance.
g. Assumed design values. And loading conditions.

2. Samples: One each as follows:
   a. Form ties.
   b. Form liners.

1.04 INFORMATIONAL SUBMITTALS:

A. Statement of qualification for formwork designer.

1. Manufacturer's Certificate of Proper Installation in accordance with Section 01 43 33, Manufacturers' Field Services.
2. Design computations for the formwork.
3. On-Site contractor quality Control Plan.
4. On-Site Contractor Quality Control Reports.

1.05 QUALIFICATIONS

A. Formwork Designer: Formwork, falsework, and shoring design shall be by an engineer licensed in the state of California.

1.06 CONTRACTOR QUALITY CONTROL

A. Perform work in accordance with ACI 301, ACI 318, and ACI 347. Tolerance shall be as necessary to provide completed concrete structure within the tolerance specified in ACI 117.

B. Supply all labor, tools, equipment and materials to set forms so that the resultant concrete conforms to required shapes, lines, and dimensions of the design, as well as the necessary code requirements.

1. It is the Contractor's responsibility to design and build adequate forms and to leave them in in-place until the forms can be safely removed.
2. Bear responsibility for damage and injury caused by removing forms carelessly or before the concrete has gained sufficient strength.

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C. Inspect erected formwork, shoring, and bracing to ensure that work is in accordance with formwork design and that supports, fastenings, wedges, ties, and items are secure.

D. Monitor forms during concrete placement and correct deficiencies.

PART 2 - PRODUCTS

2.01 FORM MATERIALS

A. Wall Forms and Underside of Slabs and Beams:

1. Materials: Plywood, hard plastic finished plywood, overlaid waterproof particle board, or steel in "new and undamaged" condition, of sufficient strength and surface smoothness to produce specified finish. Use plywood forms when using form liners. Plywood may be of lower finish grade when use in conjunction with form liners.

B. Form Liners:

1. Glass Fiber Reinforced Plastic Forms: Matched, tight fitting stiffened to support weight of concrete without deflection detrimental to structural tolerances and appearances of finished concrete surface.
2. Lumber: Fir species No. 2 grade or better, with grade stamp clearly visible.
3. Steel: Minimum 16 gauge sheet, well matched, tight fitting, stiffened to support weight of concrete without deflection detrimental to structural tolerances and appearance of finished surfaces.

C. Sandblasted Surface Forms: Medium density overlay plywood for flat concrete surfaces to be sandblasted.

D. Painted Surface Forms: High-density overlay plywood for flat concrete surfaces to be painted.

E. All Other Forms: Materials as specified for wall forms.

F. Form Release Agent:

1. Material: Release agent shall be colorless, not bond with, stain, or adversely affect concrete surfaces, and shall not impair subsequent treatments of concrete surfaces when applied to forms or form liners. A ready-to-use water based material formulated to reduce or eliminate surface imperfections, containing no mineral oil or organic solvents.

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Environmentally safe, meeting local, state, and federal regulations and can be used in potable water facilities.

2. Manufacturers and Products:
   a. BASF, Shakopee, MN; MBT, Rheofinish 211.
   b. Cresset Chemical Company; Crete-Lease 20-VOC.
3. Form Ties:
   a. Material: Removable snap-off type, galvanized metal, 3/4-inch break back dimension, fixed length, cone type.
   b. Spreader Inserts:
      1) Conical or spherical type.
      2) Design to maintain positive contact with forming material.
      3) Furnish units that will leave no metal closer than 1.5 inches to concrete surface when forms, inserts, and tie ends are removed.
   c. Wire ties not permitted
   d. Flat bar ties for panel forms; furnish plastic or rubber inserts with minimum 1.5-inch depth and sufficient dimensions to permit patching of tie hole.
   e. Water Stop Ties: For water-holding structures, basements, pipe galleries, and accessible spaces below finish grade, furnish the following:
4. Neoprene water stop 3/16 inch thick and 15/16 inch diameter whose center hole is one half diameter of tie, or molded plastic water stop of comparable size.
5. Through-Bolt: Tapered minimum 1-inch diameter at smallest end.
6. Nails, Spikes, Lag Bolts, Anchorages: Sized as required, of sufficient strength and character to maintain formwork in place while placing concrete.
7. Joint filler: A dense, closed-cell foam rubber.

B. Corners: Chamfered strip type; 3/4 inch by 3/4 inch size; maximum possible lengths.

C. Preformed Plastic Adhesive Waterstop Fuel Resistant (PPAWS FR): extruded rope form (consisting of N.B.R. compound with poly propylene resins and other solvent resistant elastomers) between two protective silicone treated papers, 7/8 inch x 1 inch cross section, 1 inch lap splice, furnish and use with primer; Henry Company, SF312-Synko-Flex FR, or as approved.

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PART 3 - EXECUTION

3.01 FORM SURFACE PREPARATION

A. Thoroughly clean form surfaces that will be in contact with concrete or that have been in contact with previously cast concrete, dirt, and other surface contaminants as erection proceeds and prior to coating surface.

B. Exposed Wood Forms in Contact with Concrete: Apply form release agent as recommended by the manufacturer.

1. Apply prior to placement of reinforcing steel, anchoring devices and embedded items.
2. After form release agent is applied to forms, place concrete within 14 calendar days. If concrete is not placed within 14 calendar days, remove the forms and reapply the form release agent.
3. Do not apply form release agent where concrete surfaces are scheduled to receive special finishes which may be affected by the agent, such as crystal forming waterproofing. Soak contact surfaces of untreated forms with clean water. Keep surfaces wwet prior to placing concrete.

C. Steel Forms: Apply form release agent to steel forms as soon as they are cleaned to prevent discoloration of concrete from rust.

D. Form Liners: Provide liners with full sheets and place seams at horizontal and vertical grooves. Prepare as recommended by manufacturer.

1. Use anchorage systems recommended by manufacturer to anchor liner to formwork.
2. Do not use form release agent on formwork.

E. Earth Forms:

1. Hand trim sides and bottom of earth forms. Remove loose soil prior to placing concrete.
2. Do not use rock cuts for forms except where specifically indicated or permitted. When rock form is indicated or permitted, the rock face shall be sound and no rock shall extend inside the concrete lines indicated.

3.02 ERECTION

A. General: Unless specified otherwise, follow applicable recommendations of ACI 347 and ACI 301.

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1. Provide bracing to ensure stability of formwork. Shore or strengthen formwork subject to overstressing by construction loads.
2. Arrange assemble formwork to permit dismantling and stripping. Do not damage concrete during stripping.
3. Align joints and make watertight to prevent leakage of mortar. Keep form joints to a minimum.
4. Verify lines, levels and centers before proceeding with formwork. Ensure that dimensions agree with Drawings.
5. Obtain approval before framing openings in structural members which are not indicated on Drawings.
6. Retighten forms and bracing after concrete placement, if required.

B. Beveled Edges (Chamfer):

1. Form 3/4-inch bevels at concrete edges, unless otherwise shown.
2. Where beveled edges on existing adjacent structures are other than 3/4 inch, obtain ENGINEER's approval of size prior to placement of beveled edge.

C. Wall Forms:

1. Do not reuse forms with damaged surfaces.
2. Locate form ties and joints in an uninterrupted uniform pattern.
3. Inspect form surfaces prior to installation to assure conformance with specified tolerances.

D. Forms Supporting Form Liners:

1. Construct forms to structurally withstand deflection, movement, leakage, high hydraulic pressures resulting from rapid filling and heavy-high frequency vibration.
2. Lay out form joints and ties in uniform pattern, unless otherwise shown.

E. Forms for Curbs, Sidewalks, and Driveways:

1. Provide standard steel or wood forms.
2. Set forms to true lines and grades, and securely stake in position.

F. Form Tolerances: Provide forms in accordance with ACI 117/117R, ACI 347, and ACI 318/318R and the following tolerances for finishes specified:

1. Wall Tolerances:
   a. Straight Vertical or Horizontal Wall Surface: Flat planes within tolerance specified.
   b. Wall Type W-A:

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1) Plumb within 1/4 inch in 10 feet or within 1 inch from top to bottom for walls over 40 feet high.
2) Depressions in Wall Surface: Maximum 5/16 inch when 10-foot straightedge is placed on high points in all directions.

c. Wall Type W-B:
1) Plumb within 1/8 inch in 10 feet or within 1/2 inch from top to bottom for walls over 40 feet high.
2) Depressions in Wall Surface: Maximum 1/8 inch when 10-foot straightedge is placed on high points in all directions.

d. Thickness: Maximum 1/4 inch minus or 1/2 inch plus from dimension shown.

e. Form Offset: Between adjacent pieces of formwork, facing material shall not exceed 1/8 inch].

2. Beam Tolerances:

a. Exposed Straight Horizontal and Vertical Surfaces: Flat planes within tolerances specified.

b. Lateral Alignment:
1) Centerlines must be within plus or minus 1/2 inch from dimensions shown.
2) At intersections, centerlines shall intersect within plus or minus 1/2 inch of dimensions shown.

c. Beam Type B-A:
1) Physical Dimensions: Maximum 1/4 inch minus or 1/2 inch plus from dimension shown.
2) Elevations: Within plus or minus 1/2 inch, except where tops of beams become part of finished slab. In this case refer to slab tolerances.

G. Application - Form Release Agent:

1. Clean reused forms of concrete residue. Repair and patch as required to return forms to acceptable surface condition.

2. Apply form release agent on formwork prior to placement of reinforcing steel, anchoring devices, and embedded items.

3. Do not apply form release agent where concrete surfaces will receive special finishes which are affected by agent. Soak inside surfaces of untreated forms with clean water. Keep surfaces coated prior to placement of concrete.

H. Inserts, Embedded Parts and Openings:

1. Provide formed openings where required for items to e embedded in or pass through the concrete work.

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2. Locate and set in place items which will be cast directly into concrete.
3. Coordinate work of other sections in forming and placing openings, sleeves, bolts, anchors and other inserts.
4. Install accessories in accordance with the manufacturer's instructions, straight, level and plumb. Secure all embedded items before placing concrete. Ensure that items are not disturbed during concrete placement. Fill voids with readily removable material to prevent entry of concrete.
5. Provide block outs wherever necessary, even when not shown on the Drawings.
6. Install waterstops, where required, continuous without displacing reinforcement. Heat seal joints watertight per waterstop manufacturer's instructions.
7. Provide temporary ports or openings in formwork where required to facilitate cleaning and inspection. Locate openings at bottom of forms to allow flushing water to drain.
8. Close temporary openings with tight fitting panels, flush with inside face of forms and neatly fitted so joints will not be apparent in exposed concrete surfaces.

I. Form Cleaning

1. Clean forms as erection proceeds to remove foreign matter within forms.
2. Clean formed cavities of debris prior to placing concrete.
3. Flush with water or use compressed air to to remove remaining foreign matter. Ensure that water and debris drain to exterior of the formwork through the clean-out ports.
4. During cold weather, remove ice and snow from within forms. Do not use de-icing salts. Do not use water to clean out forms, unless formwork and concrete construction proceed within a heat enclosure. Use compressed air or other means to remove foreign matter.

3.03 FORM REMOVAL

A. General:

1. Notify the ENGINEER prior to removal of forms.
2. Remove forms in a manner that will not damage concrete.
3. Do not wedge pry bars, hammers or tools against finish concrete surfaces scheduled for exposure to view.

B. Nonsupporting forms (sides of beams, walls, columns, and similar parts of Work) may be removed after cumulatively curing at not less than 50 degrees F for 24 hours from time of concrete placement if:

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1. Concrete is sufficiently hard so as not to sustain damage by form removal operations.
2. Curing and protection operations are maintained.

C. Elevated Structural Slabs or Beams: In accordance with ACI 318/318R, Chapter 6, and at such time as concrete has reached compressive strength equal to 80 percent of specified 28-day compressive strength as determined by test cylinders. In no case shall the formwork be removed less than the following number of days after concrete placement. Where forms may be removed without disturbing shores, use half the values given, but in no event less than three days after concrete placement. Distance between supports indicated below refer to permanent structural supports only.

1. Joist, beam and girder soffits:
   a. Clear span less than 10 feet: 7 days
   b. Clear span 10 to 20 feet: 14 days
   c. Clear span greater than 20 feet: 21 days
2. Floor slabs:
   a. Clear span less than 10 feet: 4 days
   b. Clear span 10 to 20 feet: 7 days
   c. Clear span greater than 20 feet: 10 days

D. Construction Loads: Limit construction loads at all times to those which can be carried safely by the developed strength of the structure at the time of loading, and by formwork and shoring in-place at the time of loading.

E. Store removed forms in a manner that the surfaces to be in contact with fresh concrete will not be damaged. Discard and remove from the job site damaged forms.

END OF SECTION

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SECTION 03 21 00
REINFORCING STEEL

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Concrete Institute (ACI):
   a. 301, Standard Specifications for Structural Concrete for Buildings.
   b. 315, Details and detailing of Concrete Reinforcement.
   c. 318, Building Code Requirements for Structural Concrete and Commentary.
   d. SP-66, Detailing Manual.
2. American Welding Society (AWS): D1.4/D1.4M, Structural Welding Code - Reinforcing Steel.
3. ASTM International (ASTM):
   a. A82/A82M, Standard Specification for Steel Wire, Plain, for Concrete Reinforcement.
   b. A185/A185M, Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete.
   c. A497/A497M, Standard Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete.
   d. A615/A615M, Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement.
   e. A706/A706M, Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement.
   f. A767/767M, Standard Specification for Zinc-Coated (Galvanized) Steel bars for Concrete Reinforcement
   g. A775/A775M, Standard Specification for Epoxy-Coated Steel Reinforcing Bars.
4. Concrete Reinforcing Steel Institute (CRSI):
   a. 63, Recommended Practice for Placing Reinforcing Bars.
   b. 65, Recommended Practice for Placing bar Supports, specifications, and Nomenclature.
   c. Manual of Standard Practice.
5. International Code Council (ICC): Evaluation Services Report.
6. Wire Reinforcement Institute (WRI): WWR-500, Manual of Standard Practice, Structural Welded Wire Reinforcement.

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1.02 SUBMITTALS

A. Action Submittals:

1. Shop Drawings prepared in accordance with CRSI Manual of Standard Practice and ACI SP-66, and ACI 315:
   a. Bending lists.
   b. Placement drawings.
      1) Indicate bar sizes, spaces, locations and quantities of reforcing steel, bending and cutting schedules, and supporting and spacing devices.
      2) Show location of splices. Obtain ENGINEER's approval of proposed reinforcing splices not indicated on the Drawings.

B. Informational Submittals:

1. Certified Lab (Mill) test reports for reinforcing steel showing stress-strain curves and ultimate strengths.
2. Mechanical Threaded Connections:
   a. Current ICC Evaluation Services Report or equivalent code agency report listing findings to include acceptance, special inspection requirements, and restrictions.
   b. Verification device threads have been tested and meet requirements for thread quality, in accordance with manufacturer's published methods.
   c. Manufacturer's instructions.
3. Epoxy-Coated Reinforcing Bars: Written certification in accordance with Paragraph 14.1 of ASTM A775/A775M.
4. Test results of field testing.
5. Contractor CQC Plan.
6. Contractor CQC Reports.

1.1 ADJUSTMENT PRICE - MEASUREMENT AND PAYMENT

A. The Contract Price shall include the cost of providing 5,000 pounds of reinforcing steel to be used as directed by ENGINEER and not to be fabricated or delivered to the Project until ordered by ENGINEER. At completion of the Project, OWNER shall be given a credit for the unused amount and such credit shall be at the adjustment price included in the Contract, or as agreed upon

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1.03 QUALITY ASSURANCE

A. Perform concrete reinforced work in accordance with CRSI manual of standard Practice and Document 63 and 65.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Unload, store, and handle bars in accordance with CRSI publication "Placing Reinforcing Bars."

1. Store reinforcement of different sizes and shapes in separate piles or racks raised above ground to avoid rusting.
2. Protect from contaminants such as grease, oil and dirt.
3. Provide identification on reinforcement after bundles are broken and tags removed.

B. Epoxy-coated Reinforcing Bars:

1. Protect contact areas of epoxy-coated bars from handling equipment.
2. Lift bundles of bars at multiple pickup points to minimize bar-to-bar abrasion from sags in bundles.
3. Do not drop or drag bars or bundles of bars.
4. Store bars on protective cribbing.
5. Color fading of coating is not cause for rejection of epoxy-coated reinforcing bars.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Reinforcing Bars:

1. Includes stirrups, ties, and spirals.
2. ASTM A615/A615M, Grade 60.
3. ASTM A767/767M, Grade 60, for galvanized bars.
4. ASTM A775/A775M, for epoxy-coated bars.

B. Mechanical Splices and Connections:

1. Metal Sleeve Splice:
   a. Furnish with cast filler metal, capable of developing, in tension or compression, 125 percent of minimum tensile strength of bar.

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b. Manufacturer and Product: Erico Products, Inc., Cleveland, OH; Cadweld T-Series.

2. Mechanical Threaded Connections:
   a. Furnish positive-locking, straight or taper-threaded bars and couplers developing in tension or compression 125 percent of yield strength of bar. Flanged coupler with nail holes for form attachment and internal coupler thread protection. System shall posses a current and valid International Code Council Evaluation Service Report.
   b. Manufacturers and Products:
      1) Erico Products, Inc., Cleveland, OH; Lenton Reinforcing Steel Couplers.
      2) Richmond Screw Anchor Co., Inc., Fort Worth, TX; Richmond DB-SAE Dowel Bar Splicers.

C. Welded Wire Fabric:

1. ASTM A185 or ASTM A497 and ACI 318, using ASTM A82 wire of 75 ksi minimum tensile strength.
2. Furnish flat sheets only, rolled sheets not permitted.

2.02 ACCESSORIES

A. Tie Wire:

1. Black, soft-annealed 16-gauge wire.
2. Nylon-, epoxy-, or plastic-coated wire.

B. Bar Supports and Spacers:

1. Use precast concrete bar supports and side form spacers, unless noted otherwise. Do not use other types of supports or spacers.
2. Bar supports shall have sufficient strength and stiffness to carry loads without failure, displacement, or significant deformation. Space bar supports so minimum concrete cover is maintained for reinforcing between supports.
3. Use only precast concrete bar supports where concrete surfaces are exposed to weather, earth, water, chloride intrusion, or corrosive chemicals. Bar supports shall be nonconductive and have geometry and bond characteristics that deter movement of moisture from the surface to the reinforcement.
4. Precast concrete supports shall have same minimum strength (minimum 4,000 pounds per square inch at 28 days) and shall be made from same materials as that of the concrete in which they are to be embedded. Precast concrete supports shall be cast and properly cured for at least 7 days before

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use and shall have a wire or other device cast into each block for the purpose of attaching them securely to reinforcing steel.

5. In Beams, Columns, Walls, and Slabs Exposed to View after Form Removal: Use small precast concrete blocks made of same color as concrete in which they are embedded.
6. Design and fabricate special bar supports for top reinforcing bars in slabs where standard bar supports do not possess necessary geometry, strength, or stiffness.
7. Use supports made of dielectric material for epoxy-coated reinforcing bars supported from formwork.
8. If epoxy-coated reinforcing is used, furnish epoxy-coated reinforcing bars for spreader bars.
9. Precast Concrete Supports: Total bond precast high performance concrete bar supports as supplied by Con Sys Inc., Pinawa, MB, Canada.

2.03 FABRICATION

A. Follow CRSI Manual of Standard Practice, ACI SP-66, and ACI 315.

B. Bend bars cold.

C. Welding reinforcing bars is not permitted.

PARTPART 3 - EXECUTION

3.01 PREPARATION

A. Notify ENGINEER when reinforcing is ready for inspection and allow sufficient time for inspection prior to placing concrete.

B. Repair epoxy coating damaged due to handling, shipment, and placing. Repair with patching material in accordance with ASTM A775/A775M and manufacturer’s recommendations.

C. Clean reinforcing bars of loose mill scale, oil, earth, and other contaminants. Remove rust by vigorous rubbing with burlap cloth or wire brushing.

D. Coat wire projecting from precast concrete bar supports with dielectric material, epoxy, or plastic.

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3.02 INSTALLATION

A. Bundle or space bars, instead of field bending where construction access through reinforcing is necessary. Field Bending is not allowed unless approved by the ENGINEER. Do not bend reinforcement after embedment in hardened concrete

1. Accommodate formed openings.

B. Spacing and Positioning: Conform to ACI 318. Place, support and secure reinforcement against displacement. Do not deviate from the required position.

C. Location Tolerances: In accordance with CRSI publication, "Placing Reinforcing Bars".

D. Splicing:

1. Lap splices to be in accordance with Lap Splice Dimension Table on Drawings.
   1. Follow ACI 318.
   2. Use lap splices, unless otherwise shown or permitted in writing by Engineer. Securely wire together lap splicesENGINEER.
   3. Welded Splices: Welding reinforcing bars is not permitted.
   4. Stagger splices in adjacent bars where indicated.
   5. Reinforcing splices have been located on the Drawings. Additional splices shall be reviewed and approved by the ENGINEER.

E. Mechanical Splices and Connections:

1. Use only in areas specifically approved in writing by ENGINEER.
2. Install threaded rods as recommended by manufacturer with threads totally engaged into coupling sleeve and in accordance with ICC Evaluation Services Report or equivalent code agency report.
3. For metal sleeve splice, follow manufacturer's installation recommendations.
4. Maintain minimum edge distance and concrete cover.

F. Tying Reinforcing Bars:

1. Tie every other intersection on mats made up of Nos. 3, 4, 5, and 6 bars to hold them firmly at required spacing.
2. Bend tie wire away from concrete surface to provide clearance of 1 inch from surface of concrete to tie wire.
3. Epoxy-coated Reinforcing Bars:
   a. Use epoxy-coated or nonmetallic clips.

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b. Repair coating damage at clipped or welded intersections.

G. Reinforcement Around Openings: On each side and above and below pipe or opening, place an equivalent area of steel bars to replace steel bars cut for opening. Extend steel reinforcing a standard lap length beyond opening at each end.

H. Straightening and Rebending: Field bending of reinforcing steel bars is not permitted.

I. Unless permitted by ENGINEER, do not cut reinforcing bars in field. When epoxy-coated reinforcing bars are cut in field, coat ends of bars with same material specified for repair of epoxy coating damage.

J. Place and secure embedded metalwork and conduit.

K. Place reinforcement with clear distance of 1-inch, minimum, between reinforcement and anchor bolts, form ties, or other embedded metalwork unless otherwise shown on the Drawings.

L. See Drawings for Structural Notes, and for Reinforcement cover Requirements.

M. Tolerances:

1. Maintain concrete cover over reinforcement within 1/2 inch of specified cover where the specified cover is greater than 2-1/2 inches.
2. Maintain concrete cover over reinforcement within 1/4 inch of the specified cover where the specified cover is 2-1/2 inches or less.
3. Maintain spacing of reinforcing bars within 1 inch of the required spacing.

3.03 WELDED WIRE FABRIC INSTALLATION

A. Use only where specifically shown.

B. Extend fabric to within 2 inches of edges of slab, and lap splices at least 1-1/2 courses of fabric or minimum 8 inches.

C. Tie laps and splices securely at ends and at least every 24 inches with tie wire.

D. Place welded wire fabric on concrete blocks and rigidly support equal to that provided for reinforced bars. Do not use broken concrete, brick, or stone.

E. Follow ACI 318 and WRI WWR-500.

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F. Do not use fabric that has been rolled. Install flat sheets only.

3.04 TESTS AND INSPECTION

A. Notify the ENGINEER when reinforcing steel is in place and provide sufficient time in the schedule for the ENGINEER to inspect the reinforcing steel prior to placement of concrete. Concrete placed without inspection and approval by the ENGINEER may be subject to rejection and removal at no additional cost to the OWNER.

B. An independent testing agency [will be retained by OWNER] [shall be retained by CONTRACTOR and approved by ENGINEER] to visually inspect and test reinforcing steel welds in accordance with AWS D1.4/D1.4M as specified in Section 05 05 23, Welding.

C. An independent testing agency [will be retained by OWNER] [shall be retained by CONTRACTOR and approved by ENGINEER] to inspect each mechanical splice and verify each component is installed in accordance with manufacturer's instructions and ICC Evaluation Services Report or equivalent code agency report.

D. Special inspection will be provided by OWNER as indicated on Drawings.

E. The ENGINEER's (and Special Inspector's) inspection of steel reinforcing prior to concrete placement will not relieve the CONTRACTOR from responsibility to conform to the Drawings and Specifications.

3.05 SCHEDULE

A. ASTM A615/A615M, Grade 60 reinforcing bars:

1. TCS Loop Injection and Extraction Well and Well Casing Vaults.
2. IRZ Injection and Extraction Well and Well Casing Vaults.
3. Inner Recirculation Loop Injection and Extraction Well and Well Casing Vaults.
4. MW-20 Bench Storage Tank Foundation.
5. MW-20 Bench Building Foundation.
6. MW-20 Bench Unloading Pad.
7. TW Bench Storage Tank Foundation.
8. TW Bench Building Foundation.

END OF SECTION

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SECTION 03 30 00
CAST-IN-PLACE CONCRETE

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards that may be referenced in this section:

1. American Concrete Institute (ACI):
   a. 117, Specification for Tolerances for Concrete Construction and Materials.
   b. 301, Specifications for Structural Concrete.
   c. 305.1, Specification for Hot Weather Concreting.
   d. 306.1, Standard Specification for Cold Weather Concreting.
   e. 117, Tolerances for Concrete Construction and Materials.
   f. 318, Building Code Requirements for Structural Concrete.
   g. 350.1, Specification for Tightness Testing of Environmental Engineering Concrete Containment Structures.
   h. CP-1, Technical Workbook for ACI Certification of Concrete Field Testing Technician – Grade 1.

B. ASTM International (ASTM):

1. C31/C31M, Standard Practice for Making and Curing Concrete Test Specimens in the Field.
2. C33/C33M, Standard Specification for Concrete Aggregates.
3. C39/C39M, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.
4. C94/C94M, Standard Specification for Ready-Mixed Concrete.
5. C109/C109M, Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens).
6. C143/C143M, Standard Test Method for Slump of Hydraulic-Cement Concrete.
7. C150/C150M, Standard Specification for Portland Cement.
8. C157/C157M, Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete.
9. C227, Standard Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method).
10. C231/C231M, Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method.

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11. C260/C260M, Standard Specification for Air-Entraining Admixtures for Concrete.
12. C309, Specifications for Liquid Membrane –Forming Compounds for Curing Concrete.
13. C441, Standard Test method for Effectiveness of Pozzolans or Ground Blast-Furnace Slag in Preventing Excessive Expansion of Concrete Due to the Alkali-Silica Reaction.
14. C494/C494M, Standard Specification for Chemical Admixtures for Concrete.
15. C595/C595M, Standard Specification for Blended Hydraulic Cements.
16. C618, Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete.
17. C881/C881M, Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete.
18. C979/C979M, Standard Specification for Pigments for Integrally Colored Concrete.
19. C989, Standard Specification for Slag Cement for Use in Concrete and Mortars.
20. C1012/C1012M, Standard Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution.
21. C1017/C1017M, Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete.
22. C1074, Standard Practice for Estimating Concrete Strength by the Maturity Method.
23. C1077, Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation.
24. C1218/C1218M, Standard Test Method for Water-Soluble Chloride in Mortar and Concrete.
25. C1240, Standard Specification for Silica Fume Used in Cementitious Mixtures.
26. C1260, Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method).
27. C1293, Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction.
28. C1567, Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method).
29. C1582/C1582M, Standard Specification for Admixtures to Inhibit Chloride-Induced Corrosion of Reinforcing Steel in Concrete.

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30. C1602/C1602M, Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete.
31. D1752, Standard Specification for Preformed Sponge Rubber and cork Expansion Joint Fillers for Concrete Paving and Structural Construction.
32. E329, Standard Specification for Agencies Engaged in Construction Inspection, Special Inspection, or Testing Materials Used in Construction.
33. E1155, Standard Test Method for Determining F_F Floor Flatness and F_L Floor Levelness Numbers.

C. National Ready Mixed Concrete Association (NRMCA).

D. American Association of State Highway and Transportation Officials (AASHTO): M182, Burlap Cloth Made From Jute or Kenaf

E. NSF International: NSF 61, Drinking water Supply Components – Health Effects.

F. International Concrete Repair Institute (ICRI): 03732, Selecting and Specifying Concrete Surface Preparation for Coatings, Sealers, and Polymer Overlays.

G. U. S. Bureau of Reclamation (USBR):

1. Guide to Concrete Repair – 1997
2. M-47, Standard Specification for Repair of Concrete, August 1996.

1.02 DEFINITIONS

A. [Architectural Concrete: Concrete indicated as such in Contract Documents. Requires specified care in selection of concrete materials, forming, placing, and finishing in order to obtain desired architectural appearance.]

B. Basin Train: Series of interconnected basins that operate as a unit with same water level.

C. Cold Weather: When ambient temperature is below 40 degrees F or is approaching 40 degrees F and falling.

D. CONTRACTOR’s Licensed Design Engineer: Individual representing CONTRACTOR who is licensed to practice engineering as defined by statutory requirements of professional licensing laws in state or jurisdiction in which Project is to be constructed.

E. Defective Area: Surface defects that include honeycomb, rock pockets, indentations, and surface voids greater than 3/16-inch deep, surface voids greater

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than 3/4 inch in diameter, cracks in liquid containment structures and below grade habitable spaces that are 0.005-inch wide and wider, and cracks in other structures that are 0.010-inch wide and wider, spalls, chips, embedded debris, sand streaks, mortar leakage from form joints, deviations in formed surface that exceed specified tolerances and include but are not limited to fins, form pop-outs, and other projections. At exposed concrete, defective areas also include texture irregularities, stains, and other color variations that cannot be removed by cleaning.

F. Exposed Concrete: Concrete surface that can be seen inside or outside of structure regardless of whether concrete is above water, dry at all times, or can be seen when structure is drained.

G. Hot Weather: As defined in ACI 305.1.

H. Hydraulic Structure: Liquid containment structure.

I. New Concrete: Less than 60 days old.

J. Slurry Mixture: Mixture of sand, 3/8-inch maximum nominal aggregate size, cement, and water for wall construction joints with waterstop.

1.03 SYSTEM DESCRIPTION

A. Performance Requirements:

1. General:
   a. Except as otherwise specified, provide concrete composed of Portland cement, fine aggregate, coarse aggregate, and water so proportioned and mixed as to produce plastic, workable mixture in accordance with requirements as specified in this Section and suitable to specific conditions of placement.
   b. Proportion materials in a manner such as to secure the lowest water-cement ratio which is consistent with good workability, plastic, cohesive mixture, and one which is within the specified slump range.
   c. Proportion fine and coarse aggregate in a manner such as not to produce harshness in placing nor honeycombing in structures.
2. Watertightness of Concrete work: It is the intent of this Section to secure for every part of the Work concrete and grout of a homogeneous structure, which when hardened will have the required strength, watertightness, and durability.
   a. It is recognized that some surface hairline cracks and crazing will develop in the concrete surfaces.

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b. Construction, contraction and expansion joints have been positioned in structures as indicated on the Drawings, and curing methods specified for purpose of reducing the number and size of these expected cracks, due to normal expansion and contraction expected from the specified concrete mixes.
c. Class A, B-1, B-2 and Class D Concrete – Watertight: Repair cracks which develop in walls or slabs and repair cracks which show any signs of leakage until all the leakage is stopped.
d. Except for hairline cracks and crazing, visible cracks shall be pressure-injected in the following areas with epoxy, as specified in Section 03 XX 00B, <<insert title>>:
    1) Floors and walls of water-bearing structures.
    2) Walls and overhead slabs of passageways of occupied spaces, outsides of which are exposed to weather, or may be washed down and are not specified to receive a separate waterproof membrane.
    3) Other Items Not Specified to Receive a Separate Waterproofing Membrane: Slabs over water channels, wet wells, and other similar surfaces.
e. Walls or slabs as specified above that leak or sweat because of porosity or cracks too small for successful pressure grouting: Seal on water or weather side by coatings of surface sealant system as specified in this Section.
f. Grouting and Sealing: Continue as specified above until structure is watertight and remains watertight for not less than one year after final acceptance or date of final repair, whichever occurs later in time.
g. Workmanship and methods: Provide concrete work, including detailing of reinforcing conforming with the best standard practices and as set forth in ACI 318, Manuals, and Recommended Practices.

1.04 SUBMITTALS

A. Action Submittals:

1. Mix Designs:
    a. Contain proportions of materials and admixtures to be used on Project, signed by mix designer.
    b. Documentation of average strength for each proposed mix design in accordance with ACI 301.
    c. Manufacturer’s Certificate of Compliance, in accordance with Section 01 43 33, Manufacturers’ Field Services, for the following:
        1) Portland cement.

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2) Fly ash.
3) Slag cement.
4) Aggregates, including specified class designation for coarse aggregate.
5) Admixtures.
6) Concrete producer has verified compatibility of constituent materials in design mix.

d. Test Reports:
1) Cement: Chemical analysis report.
2) Supplementary Cementitious Materials: Chemical analysis report and report of other specified test analyses.
3) Water-Soluble Chloride-Ion Content in Hardened Concrete: Unless otherwise permitted, in accordance with ASTM C1218/C1218M at an age between 28 days and 42 days.
4) Shrinkage Test Results: In accordance with ASTM C157/C157M as modified herein.

e. Aggregates:
1) Coarse Aggregate Gradation: List gradings and percent passing through each sieve.
2) Fine Aggregate Gradation: List gradings and percent passing through each sieve.
3) Combined gradation for coarse and fine aggregates. List gradings and percent passing through each sieve.
4) Deleterious substances in fine aggregate per ASTM C33/C33M, Table 2.
5) Deleterious substances in coarse aggregate per ASTM C33/C33M, Table 4.

f. Test Reports:
1) Alkali Aggregate Reactivity: Aggregate shall be classified as nonpotentially reactive in accordance with Article Concrete Mix Design. Include documentation of test results per applicable standards.

g. Admixtures:
1) Manufacturer’s catalog cut sheets and product data sheets for each admixture used in proposed mix designs.
2) Color Pigment: Product data including application rate and color chart.

2. Product Data: Specified ancillary materials.
a. Name and manufacturer of each cementitious material, aggregate source, admixture, and curing compound.

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1) The ENGINEER reserves the right to require submission of manufacturer's test data and certification of compliance with specification.
2) The ENGINEER reserves the right to require submission of samples of concrete materials for testing before or during use in concrete.
3) Detailed plan for curing and protection of concrete placed and cured in cold weather. Details shall include, but not be limited to, the following:

b. Procedures for protecting subgrade from frost and accumulation of ice or snow on reinforcement, other metallic embeds, and forms prior to placement.
c. Procedures for measuring and recording temperatures of reinforcement and other embedded items prior to concrete placement.
d. Methods for temperature protection during placement.
e. Types of covering, insulation, housing, or heating to be provided.
f. Curing methods to be used during and following protection period.
g. Use of strength accelerating admixtures.
h. Methods for verification of in-place strength.
i. Procedures for measuring and recording concrete temperatures.
j. Procedures for preventing drying during dry and windy conditions.

3. Detailed plan for hot weather placements including curing and protection for concrete placed in ambient temperatures over 80 degrees F. Plan shall include, but not be limited to, the following:
   a. Procedures for measuring, and recording temperatures of reinforcement and other embedded items prior to concrete placement.
   b. Use of retarding admixture.
   c. Methods for controlling temperature of reinforcement and other embedded items and concrete materials before and during placement.
   d. Types of shading and wind protection to be provided.
   e. Curing methods, including use of evaporation retardant.
   f. Procedures for measuring and recording concrete temperatures.
   g. Procedures for preventing drying during dry, windy conditions.
4. [Thermal Control Plan: For concrete sections with a minimum specified dimension that is greater than [2 feet 6 inches] [_____].]
   a. Samples:
   b. Prior to starting work on mockup panel, one Sample of each type of architectural concrete wall finish and color, 24 inches by 24 inches square by 1-1/2 inches thick.
   c. Prior to starting work on mockup panels, one Sample for slab finish Type S-4, 24 inches by 24 inches square by 1-1/2 inches thick.

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5. Concrete repair techniques.
    a. Concrete Placement Drawings and Schedule:
    b. Drawings for each individual concrete placement. An individual concrete placement is defined as a portion of concrete work placed in one continuous operation between specified lines or joints.
        1) Show locations, dimensions, blockouts, openings, recesses, waterstops, and finishes. Identify construction joints, control joints, contraction joints and expansion joints. Submit concrete placement drawing with or prior to reinforcement placing drawing.
        2) Show details of items embedded in or associated with placement, except reinforcing steel.
        3) Include a separate drawing showing placement sequence.
        4) Place a title block with CONTRACTOR's name, contract title and number, placement identification, and identifying drawing number in lower right corner of each drawing.
    1) List reference drawings from which details shown on placement drawing were obtained on each drawing.
    2) Reference related steel reinforcement drawings associated with placement on each drawing.
    3) Complete, detailed concrete placement schedule showing the CONTRACTOR's plan for reinforcement of individual features, units, and other elements of concrete work.
    4) Detail as necessary to show location, sequence, and date of concrete placements scheduled for each item of concrete work.
    5) Show submittal of detail drawings and placement of reinforcement and embedded items.
2. Material Approval Data for Joint filler: Name and manufacturer of joint filler. The ENGINEER reserves the right to require submission of manufacturer's test data and certification of compliance with specifications.

B. Informational Submittals:

1. Pre-installation conference minutes of meeting.
2. Manufacturer's application instructions for bonding agent and bond breaker.
3. Manufacturer's Certificate of Compliance to specified standards:
    a. Bonding agent.
    b. [Bond breaker.]
    c. [Repair materials.]
4. Statement of Qualification:
    a. Batch Plant: Certification as specified herein.
    b. Mix designer.

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c. Installer.
d. Testing agency.

5. Field test reports.
6. Recorded temperature data from concrete placement where specified.
7. Tightness test results.
8. Concrete Delivery Tickets:
   a. For each batch of concrete before unloading at Site.
   b. In accordance with ASTM C94/C94M, including requirements 14.2.1. through 14.2.10.
   c. Indicate amount of mixing water withheld and maximum amount that may be permitted to be added at Site.
   d. On-Site Contractor Quality Control Plan.
   e. On-Site Quality Control Reports.
9. Project Record Documents:
   a. Accurately record as-built concrete dimensions and tolerances and location sof embedded utilities and components on placement drawings and submit to ENGINEER prior to final completion.

1.05 QUALITY ASSURANCE

A. Concrete construction shall conform to requirements of ACI 117 and ACI 301, except as modified herein.

B. Comply with ACI 305R when concreting during hot weather.

C. Comply with ACI 306R when concreting during cold weather.

D. Maintain one copy of ACI 301 on Site.

E. Acquire cement and aggregate from same source for all Work.

F. Qualifications:

1. Batch Plant: NRMCA Program for Certification of Ready-Mixed Concrete Production Facilities or approved equivalent program.
2. Mix Designer: Person responsible for developing concrete mixture proportions certified as NRMCA Concrete Technologist Level 2 or DOT certified mix designer in jurisdiction of the Work. Requirement may be waived if individual is CONTRACTOR's Licensed Design Engineer.
3. Flatwork Finisher: Unless otherwise permitted, at least one person on finishing crew shall be certified as an ACI Flatwork Finisher, or equivalent.

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4. Testing Agency: Unless otherwise permitted, an independent agency, [acceptable to authorities having jurisdiction,] qualified according to ASTM C1077 and ASTM E329 for testing indicated.
    a. Where field testing is required of CONTRACTOR, personnel conducting field tests shall be qualified as ACI Concrete Field Testing Technician, Grade 1, according to ACI CP-1 or an equivalent certification program.
    b. Personnel performing laboratory tests shall be ACI-certified Concrete Strength Testing Technician and Concrete Laboratory Testing Technician - Grade I. Testing Agency laboratory supervisor shall be an ACI-certified Concrete Laboratory Testing Technician - Grade II.]

G. Thermal Control Plan: When required, shall include the following minimum requirements:

1. Calculated or measured adiabatic temperature rise of concrete.
2. Upper limit for concrete temperature at time of placement.
3. Description of specific measures and equipment that will be used to ensure maximum temperature in placement will not exceed specified maximum temperature limit.
4. Calculated maximum temperature in placement based on expected conditions at time of placement and use of proposed measures to control temperatures.
5. Description of specific measures and equipment that will be used to ensure temperature difference will not exceed specified temperature difference limit.
6. Calculated maximum temperature difference in placement based on expected conditions at time of placement and use of proposed measures to control temperature differences.
7. Description of equipment and procedures that will be used to monitor and log temperatures and temperature differences.
8. Drawing showing locations for temperature sensors in placement.
9. Description of format and frequency of providing temperature data to ENGINEER.
10. Description of measures to address and reduce excessive temperatures and temperature differences, if they occur.
11. Description of curing procedures, including materials and methods, and curing duration.
12. Description of formwork removal procedures to ensure temperature difference at temporarily exposed surface will not exceed temperature difference limit, and how curing will be maintained.
13. Alternate temperature limits when permitted by ENGINEER.

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a. Determination of alternate temperature limits shall be based on detailed thermal and crack analyses.
b. Analyses shall be stamped by CONTRACTOR's Licensed Design Engineer.

14. If concrete design mixture is changed, thermal control plan must be updated.

H. Mockup Panels:

1. [Construct one panel for each form liner type specified in Section 03 10 00, Concrete Forming and Accessories.]
2. Construct in accordance with requirements of Contract Documents to demonstrate wall finish Type W-7 [, W-8] [, W-9] [, W-10] [, and W-11] [and slab finish Type S-4 [, S-5] [, and S-6]].
   a. Dimensions: 10 feet by 8 feet, minimum.
   b. [Demonstrate sandblasting on Type W-10 and Type W-11 to show how uniform appearance will be achieved regardless of age of concrete.]
3. Before concrete work starts, construct panels with specified materials, forming systems, reinforcing details, and leakage prevention techniques.
4. Show architectural details, joints, form ties, form liners, and rebar spacers to produce finished surface required.
5. Test form release agent on one mockup panel to ensure no adverse effects are caused on form or form liner materials.
6. Cast panels from minimum of 3-cubic-yard truck mixer load.
7. Surface finish and color shall be uniform in appearance to Samples.
8. Approved panels shall establish standards of quality by which Work will be judged.
9. Replace panels if not representative of Work as specified.
10. Panels may be incorporated into Work if approved by ENGINEER.
11. Use [mockup panel(s) or] ENGINEER-selected portion of as-cast wall surface hidden from view to develop and test patching techniques and mixes.
    a. Obtain ENGINEER approval prior to using material to repair project structures.
    b. Demonstrate application, curing, and finishing procedures of repair material.
    c. Approved repairs shall establish standards of quality by which Work will be judged.

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I. Preinstallation Conference:

1. Required Meeting Attendees:
   a. CONTRACTOR, including pumping, placing and finishing, and curing subcontractors.
   b. Ready-mix producer.
   c. Admixture representative.
   d. Testing and sampling personnel.
   e. ENGINEER's representative.
2. Schedule and conduct prior to incorporation of respective products into Project. Notify ENGINEER of location and time. Give attendees 4 days advance notice of the meeting time and place.
3. Agenda shall include:
   a. Introduction of personnel and responsibilities.
   b. Work sequence.
   c. Approved concrete mix designs.
   d. Discussion of batch ticket to be presented with each truck.
   e. Admixture types, dosage, performance, and redosing at Site.
   f. Placement methods, techniques, equipment, consolidation, and form pressures.
   g. Slump and placement time to maintain slump.
   h. Testing procedures including frequency.
   i. Transmitting test reports from OWNER's testing lab.
   j. Transmitting field testing information on concrete.
   k. Storage of cylinders on Site for OWNER's testing lab.
   l. Finish, curing, and water retention.
   m. Protection procedures for weather conditions.
   n. Other specified requirements requiring coordination.
4. Conference minutes as specified in Section 01 31 19, Project Meetings.

1.06 SEQUENCING AND SCHEDULING

A. Notify the ENGINEER at least 48 hours prior to commencing concrete work.

B. Allow ENGINEER to perform an immediate inspection of concrete surfaces upon removal of forms.

C. Notify the ENGINEER upon discovery of any honeycombing, foreign-embedded items and defective concrete.

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PART 2 - PRODUCTS

2.01 MATERIALS

A. Cementitious Materials:

1. Cement:
   a. Portland Cement: Unless otherwise specified, conform to requirements of ASTM C150/C150M, Type II cement.
   b. Meet equivalent alkalis requirements of ASTM C 150, Table 2.
   c. Meet false-set requirement of ASTM C150, Table 4.
   d. Blended Hydraulic Cement:
      1) Unless otherwise specified, conform to requirements of ASTM C595/C595M.
      2) Portland cement used in blended hydraulic cement, conform to requirements of ASTM C150/C150M.
   e. Furnish from one source.
2. Supplementary Cementitious Materials (SCM):
   a. Fly Ash (Pozzolan): Class F fly ash in accordance with ASTM C618, except as modified herein:
      1) Shall not be produced from process that has utilized hazardous or potentially hazardous materials.
      2) ASTM C618, Table 1, Loss on Ignition: Unless permitted otherwise, maximum 2.5 percent.
      3) Do not decrease sulfate resistance of concrete by use of pozzolan.
         a) Demonstrate pozzolan will have an "R" factor less than 2.5, where:
            (1) R = (C-5) /F
            (2) C: Calcium oxide content of pozzolan determined in accordance with ASTM C114.
            (3) F: Ferric oxide content of pozzolan in percent determined in accordance with ASTM C114.
      4) Pozzolan when tested in accordance with ASTM C441, shall conform to the following: 65 percent minimum reduction in mortar expansion at 14 days, and 0.02 percent maximum mortar expansion at 14 days. Expansion shall be less than control sample expansion.
      5) Pozzolan content shall not be less than 15 percent or more than 20 percent by weight of the total cementitious materials.
      6) Store and batch pozzolan and cement separately:

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a) Slag Cement: In accordance with ASTM C989, Grade 100 or Grade 120.

7) Shall not be produced from process that has utilized hazardous or potentially hazardous materials.

8) Slag content shall not be less than 15 percent or more than 20 percent by weight of the total cementitious materials.

9) Total SCM Content in Mix Design shall not be less than 15 percent or more than 20 percent by weight of the total cementitious materials.

B. Aggregates: Unless otherwise permitted, furnish from one source for each aggregate type used in a mix design.

1. Fine and coarse aggregate shall not be of a carbonate-based rock. Coarse and fine aggregates shall not contain any materials that are deleteriously reactive with the alkalis in the cement in an amount sufficient to cause excessive expansion of mortar or concrete. The amount of coal and lignite in the fine aggregate shall be less than 0.5 percent.
2. Normal-Weight Aggregates:
   a. In accordance with ASTM C33/C33M, except as modified herein.
   b. Free of materials and aggregate types causing popouts, discoloration, staining, or other defects on surface of concrete.
   c. Alkali Silica Reactivity: See Article Concrete Mix Design.
3. Fine Aggregates:
   a. Clean, sharp, natural sand.
   b. ASTM C33/C33M.
   c. Limit deleterious substances in accordance with ASTM C33/C33M, Table 2 and as follows: Limit material finer than 75-µm (No. 200) sieve to 3 percent mass of total sample.
4. Coarse Aggregate:
   a. Natural gravels, combination of gravels and crushed gravels, crushed stone, or combination of these materials containing no more than 15 percent flat or elongated particles (long dimension more than five times the short dimension).
   b. ASTM C33/C33M, Size No. 67.
   c. Limit deleterious substances in accordance with ASTM C33/C33M, Table 4 for specified class designation.
5. Nonslip Aggregate:
   a. Hard, homogeneous, nonglazing, rustproof, unaffected by freezing, moisture, or cleaning compounds.

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b. Fully graded between 1/32-inch to 1/4-inch size and composed of minimum 60 percent aluminum oxide or silicon carbide abrasive bonded by vitreous ceramic material.

6. [Special Aggregates for Exposed Aggregate Finishes:
   a. Uniform, hard, sound, and clean, color shall match Sample.
   b. Furnish [_____]].

C. Admixtures: Unless otherwise permitted, furnish from one manufacturer.

1. Characteristics:
   a. Compatible with other constituents in mix.
   b. Contain at most, only trace amount chlorides in solution.
   c. Do not use admixtures known to be toxic after concrete is 30 days.
   d. Furnish type of admixture as recommended by manufacturer for anticipated temperature ranges.
2. Air-Entraining Admixture: ASTM C260/C260M.
3. Water-Reducing Admixture: ASTM C494/C494M, Type A or Type D.
   a. Use a neutralized vinsol resin formulation for air-entraining admixture used with ASTM C494, type F or G; and ASTM C1017, Type I or II chemical admixtures.
   b. Manufacturers and Products:
      1) BASF Admixtures Inc., Shakopee, MN; Pozzolith Series or PolyHeed Series.
      2) Euclid Chemical Co., Cleveland, OH; Eucon Series.
      3) W. R. Grace & Co., Cambridge, MA; Daracem Series or Mira Series.
4. Retarding Admixture: ASTM C 494/C 494M, Type B.
   a. Approval does not relax hot-weather placement requirements.
5. Accelerating Admixture: ASTM C 494/C 494M, Type C.
   a. Approval does not relax cold-weather placement requirements. Calcium chloride is prohibited.
6. High-Range, Water-Reducing Admixture: ASTM C494/C494M, Type A, D, F or Type G, to achieve workability without exceeding specified water/cement ratio and slump.
   a. Manufacturers and Products:
      1) BASF Admixtures Inc., Shakopee, MN; Glenium Series, PS 1460, or Rheobuild 1000.
      2) Euclid Chemical Co., Cleveland, OH; Eucon Series or Plastol Series.
      3) W. R. Grace & Co., Cambridge, MA; ADVA Series, Daracem Series, or EXP 950.
7. [Corrosion Inhibiting Admixtures: ASTM C1582/C1582M.]

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8. [Shrinkage Reducing Admixture:
   a. Manufacturers and Products:
      1) BASF Admixtures Inc., Shakopee, MN; Tetraguard AS20.
      2) Euclid Chemical Co., Cleveland, OH; Eucon SRA Series.
   b. W. R. Grace & Co., Cambridge, MA; Eclipse Series.]
9. Color Pigment: ASTM C979/C979M, ACI 303.1 and ASTM C494, inert, synthetic mineral or metaloxide pigments or colored water-reducing admixtures; color stable, free of carbon black, nonfading, and resistant to lime and other alkalis.
   a. Color: As selected by Architect from manufacturer's full range.
      1) Color admixture for electrical duct bank shall be a red colored, water reducing admixture.
      2) Raw pigments are not an equivalent and may not be substituted.
      3) Curing and sealing compound shall comply with ASTM C309 and be of the same manufacturer as the colored admixture, for use with integrally colored concrete.
10. Do not use calcium chloride as an admixture.
11. Admixtures with no standard, ASTM or other, designation may be used where permitted.

D. Water and Ice: Mixing water for concrete and water used to make ice shall be potable water, unless alternative sources of water are permitted.

1. Water shall be clean and free from injurious amounts of oils, acids, alkalis, salts, organic materials, or other substances that may be deleterious to concrete or reinforcement, with limits for each as indicated below.
2. Water from alternative sources shall comply with requirements of ASTM C1602/C1602M, including optional requirements of Table 2, and concentration of chemicals in combined mixing water shall be less than:
   a. Chloride Content: 500 ppm.
   b. Sulfate Content as SO_4: 3,000 ppm.
   c. Alkalis as (Na_2O + 0.658 K_2O): 600 ppm.
   d. Total Solids by Mass: Less than 50,000 ppm.

2.02 ANCILLARY MATERIALS

A. Bonding Agent: Unless otherwise specified, in accordance with the following:

1. ASTM C881/C881M, Type V.
2. Two-component, moisture insensitive, 100 percent solids epoxy.
3. Consult manufacturer for surface finish, pot life, set time, vertical or horizontal application, and forming restrictions.

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4. Manufacturers and Products:
   a. BASF Building Systems Inc., Shakopee, MN; Concresive Standard LVI.
   b. Euclid Chemical Co., Cleveland, OH; Euco # 352 Epoxy System LV.
   c. Prime Resins, Conyers, GA; Prime Bond 3000 to 3900 Series.
   d. Sika Chemical Corp., Lyndhurst, NJ; Sikadur 32 Hi-Mod.

B. [Bond Breaker:

1. Nonstaining type, providing positive bond prevention.]
2. Manufacturers and Products:
   a. Dayton Superior Corporation, Kansas City, KS; EDOCO Clean Lift Bond Breaker.
   b. Nox-Crete Products Group, Omaha, NE; Silcoseal Select.

C. Repair Material:

1. In accordance with requirements of Section 03 01 32, Repair of Vertical and Overhead Concrete Surfaces.
2. In accordance with requirements of Section 03 01 33, Repair of Horizontal Concrete Surfaces.

D. Crack Repair: In accordance with requirements of Section 03 64 23, Crack Repair Epoxy Injection Grouting.

E. Epoxy Grout: Two-component epoxy resin bonding system capable of developing a minimum bond strength of 1,100 psi in 48 hours; ASTM C881 Type IV, Grade 3, Class B and C; Euclid Chemical Company EUCO 452 GEL; or as approved.

F. Sealant: Follow Section 07 92 00.

G. Concrete Sealer:

1. Product and Manufacturers – One of the following or equal:
   a. SEAL 341 by Hilyard Chemical Company, St Joseph , Missouri
   b. Horn Clear Seal EM-180 by A.C. Horn, Inc.

2.03 CONCRETE MIX DESIGN

A. General:

1. See Supplement at the end of this section for mix design requirements for each class of concrete used on Project.

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2. Prepare design mixtures for each type and strength of concrete, selecting and proportioning ingredients in accordance with requirements of ACI 301, unless otherwise specified.
3. Selection of constituent materials and products in mix design are optional, unless specified otherwise.
4. Unless otherwise permitted, use water-reducing admixture or water-reducing admixture and high-range, water-reducing admixture in pumped concrete, in concrete with a water-cementitious materials ratio below 0.50, and in concrete that is part of a liquid-containment structure.
5. Unless otherwise permitted, use water-reducing admixture and high-range, water-reducing admixture in columns, piers, pilasters, and walls.
6. Use water-reducing admixture or high-range, water-reducing admixture to achieve fresh properties that facilitate handling, placing, and consolidating of concrete, and specified hardened properties.
7. Use water-reducing and retarding admixture when anticipated high temperatures, low humidity, or other adverse placement conditions can adversely affect fresh properties of concrete.
8. Unless otherwise specified, desired fresh properties of concrete shall be determined by CONTRACTOR, and coordinated with concrete producer. Fresh properties of concrete shall remain stable to satisfaction of CONTRACTOR, for duration of placement and consolidation, and shall remain in conformance with requirements of Contract Documents.
9. CONTRACTOR is encouraged to consider using environmentally sustainable concrete mix design technologies such as use of supplementary cementitious materials and aggregate packing.
10. Color Pigment: Where required in Supplement, add color pigment to concrete mixture according to manufacturer's written instructions and to result in hardened concrete color consistent with approved mockup.

B. Potential alkali-aggregate reactivity of concrete:

1. Do not use aggregates known to be susceptible to alkali-carbonate reaction (ACR).
2. Aggregates shall have been tested to determine potential alkali-aggregate reactivity in concrete in accordance with ASTM C1260 or ASTM C1567.
    a. Aggregates that indicate expansion greater than 0.10 percent at 16 days after casting shall not be used unless they have been shown to be non-deleteriously reactive in accordance with ASTM C227 or ASTM C1293, with less than 0.04 percent expansion at 1 year for cement-aggregate combinations or less than 0.04 percent expansion at 2 years for combinations with pozzolan or slag.

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b. Alkali content of cement used in proposed concrete mixture shall not be greater than alkali content of cement used in test for potential alkali-aggregate reactivity.
c. Use low-alkali cement or incorporate pozzolan into concrete mixture as necessary to satisfy testing for potential alkali reactivity

C. Proportions:

1. Concrete Proportions: Comply with ACI 301, 4.2.
2. Design mix to meet aesthetic, durability, and strength requirements.
3. Where fly ash is included in mix, minimum fly ash content shall be a minimum of 15 percent of weight of total cementitious materials.

D. Concrete Shrinkage Limits: Where shrinkage limits are specified, design mix for following shrinkage limits and test in accordance with ASTM C157/C157M, with the following modifications:

1. Prisms shall be moist cured for 7 days prior to 28-day drying period.
2. Comparator reading at end of 7-day moist cure shall be used as initial length in length change calculation.
3. Reported results shall be average of three prisms.
4. If shrinkage of a specimen departs from average of that test age by more than 0.004 percent, disregard results obtained from that specimen.
5. Unless otherwise specified, results at end of 28-day drying period shall not exceed 0.040 percent if 3-inch prisms are used, or exceed 0.038 percent if 4-inch prisms are used. Aggregate will be rejected if test values exceed these limits.

E. Slump Range at Site:

1. Slump value to be 3 inches at point of delivery due to water alone.
2. Add high-range, water-reducing admixture at site only to increase slump to 6 inches +/- ½ inches.
3. Slump tolerance shall meet requirements of ACI 117.

F. Combined Aggregate Gradation:

1. Combined Gradation Limits: Fine aggregate shall be in range of 36 percent to 40 percent of total aggregate weight.
2. Combined Gradation Limits: Limits shown are for coarse aggregates and fine aggregates mixed together (combined). Select one of the gradations shown in the following table:

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Sieve Sizes	Combined Gradation Percentage Passing		
	1-1/2" Max.	**1" Max.**	**3/4" Max.**
2"	100	-	-
1-1/2"	95 - 100	100	-
1"	65 - 85	90 – 100	100
3/4"	55 - 75	70 – 90	92 - 100
1/2"	-	-	68 - 86
3/8"	40 - 55	45 – 65	57 - 74
No. 4	30 - 45	31 – 47	38 - 57
No. 8	23 - 38	23 – 40	28 - 46
No. 16	16 - 30	17 – 35	20 - 36
No. 30	10 - 20	10 – 23	14 - 25
No. 50	4 - 10	2 – 10	5 - 14
No. 100	0 - 3	0 – 3	0 - 5
No. 200	0 - 2	0 – 2	0 - 2

3. [Architectural Concrete with Type W-10, Fractured Fin Finish: 3/4-inch maximum size aggregate.]

G. Concrete Mixes

1. Proportioning of Concrete Mix: Proportion mixes on required average on compressive strength f'cr, for each class of concrete, using calculated standard deviation and its corresponding specified compressive strength f'c, in accordance with ACI 318, Part 3, Chapter 5.
2. Mixes:
   a. Adjusting of Water: After acceptance, do not change mixes without acceptance by ENGINEER, except that at all times adjust batching of water to compensate for free moisture content of fine aggregate.
   b. Total Water Content of Each Concrete Class: Not exceed those specified in Table A in this Section.
   c. Checking Moisture Content Fine Aggregate: Furnish satisfactory means at batching plant for checking moisture content of fine aggregate.
3. Change in Mixes: Undertake new trial batch and test program as specified in this Section.

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4. Hand Mixed Concrete:
   a. Hand mix concrete only when acceptable to the ENGINEER.
   b. Prepare hand mixed concrete on watertight, level platform in batches not to exceed 1/3 cubic yard each.
   c. Aggregate:
      1) First spread required amount of coarse aggregate on platform in an even and uniform layer, and then over such aggregate spread the proper proportion of fine aggregate.
      2) Combined Depth of Both Such Layers: Not greater than one foot.
   d. Cement:
      1) First evenly spread required quantity of cement over fine aggregate.
      2) Then turn entire batch with shovels at least twice before adding water.
   e. Water:
      1) Following step d.1) above uniformly sprinkle or spray proper amount of water over batched materials.
      2) Then turn with shovels not less than three times before being removed from the platform.
5. Classes of Concrete:
   a. Provide concrete consisting of 6 classes, referred herein as Classes A, B-1, B-2, C, D, and CE specified in this Section and use where specified or indicated on the Drawings.
   b. Weight of Concrete Classes: Provide classes of concrete having minimum weight of 140 pounds per cubic foot.
   c. Class B-2 Concrete: class B-2 concrete may be substituted for Class B-1 concrete, when high early strength concrete is needed in areas specifically accepted by the ENGINEER, and that do not require sulfate resistant concrete.
   d. Class C Concrete: Class C concrete may be used for fill for unauthorized excavation, for thrust blocks and ground anchors for piping, for bedding of pipe, and where indicated on the Drawings.
   e. Class D Concrete: Use for precast concrete items.
   f. Class CE Concrete: Use for electrical conduit encasements.
   g. All Other Concrete, unless otherwise specified (herein below) or indicated on the Drawings: Use Class A concrete.
   h. Use Class B-1 concrete for the following structures:
      1) TCS Loop Injection and Extraction Well and Well Casing Vaults.
      2) IRZ Injection and Extraction Well and Well Casing Vaults.

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3) Inner Recirculation Loop Injection and Extraction Well and Well Casing Vaults.
4) MW-20 Bench Storage Tank Foundation.
5) MW-20 Bench Building Foundation.
6) MW-20 Bench Unloading Pad.
7) TW Bench Storage Tank Foundation.
8) TW Bench Building Foundation.

i. Pumped Concrete: Provide pumped concrete that complies with all requirements of this Section.

j. Do not place concrete with slumps outside the limits indicated in Table A.

k. Classes:
1) Classes A, B-1, C, D and CE Concrete: Make with Type V [II ??] low alkali cement.
2) Class B-2 Concrete: Make with Type V low alkali cement.
3) Admixtures: Provide admixtures as specified in this Section.

l. Air Entraining Admixture:
1) Add agent to batch in portion of mixing water.
2) Batch solution by means of mechanical batcher capable of accurate measurement.

TABLE A: CONCRETE WITH AIR ENTRAINMENT*

Class	Specified Compressive Strength f'c at 28 Days (Pounds per Square Inch)	Maximum Net Water to Cement Ratio	Maximum Cement per Cubic Yard of Concrete by Weight (Pounds)	Slump Range** (Inches)
A	5,000	0.42	??	2 to 4
B-1	4,000	0.45	564	3
B-2 (Type V Cement)	4,000	0.45	564	2 to 4
C	3,000	0.6	564	2 to 4
D	4,500	0.45	658	3
CE	2,500	0.62	564	3 to 6

NOTE: *Class B-1 and D to have air entrainment of 6% +/-1%.
**Slump due to water alone. See section 2.3E "Slump Range at Site"

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2.04 CONCRETE MIXING

A. General: In accordance with ACI 301, except as modified herein.

B. Truck Mixers:

1. For every truck, test slump of samples taken per ASTM C94/C94M, paragraph 12.5.1.
2. Where specified slump is more than 4 inches, and if slump tests differ by more than 2 inches, discontinue use of truck mixer, unless causing condition is corrected and satisfactory performance is verified by additional slump tests.

2.05 [TEMPERATURE LIMITS

A. For concrete sections with a minimum specified dimension that is greater than [2 feet 6 inches] [_____], and unless otherwise permitted:

1. Provide documentation that maximum concrete temperature in structure will not exceed [158] [_____] degrees Fahrenheit, and maximum temperature differential between center of section and external surfaces of concrete will not exceed [35] [_____] degrees Fahrenheit.

2.06 SPONGE RUBBER JOINT FILLER

A. ASTM D1752, Type 1, except as otherwise specified or shown on the Drawings.

B. Test specimen compression Load: 50 to 15 pounds per square inch.

C. Joint filler Adhesive: Non-bituminous adhesive recommended by filler manufacturer.

D. Pre-molded sponge rubber fully compressible with recovery rate of minimum 95 percent.

2.07 SOURCE QUALITY CONTROL

A. Source Quality Control Inspection: ENGINEER shall have access to and have right to inspect batch plants, cement mills, and supply facilities of suppliers, manufacturers, and Subcontractors, providing products included in this section.

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PART 3 - EXECUTION

3.01 EXAMINATION

A. Verify that joint locations conform to the approved placement drawings.

B. Verify requirements for concrete cover over reinforcement are met.

C. Verify waterstops are providing in joints called for on contract drawings.

D. Verify that anchors, seats, plates, reinforcement, embeds, openings, and other items to be cast into concrete are accurately placed, positioned securely, and will not cause hardship in placing concrete.

E. Verify appropriate mix design for designated placement, see Section 2.3G.5.

F. ENGINEER's inspection and approval of foundations are required prior to any concrete being placed. Verify with ENGINEER that all surfaces on which concrete is to be placed has been inspected and is adequate for concrete placement.

3.02 PREPARATION

A. Meet requirements of ACI 301, except as modified herein.

B. Remove standing water, ice, mud, and debris from foundation surfaces to be covered by concrete.

C. Prepare rock surfaces free from oil, objectionable coatings, and loose, semi-detached and unsound fragments. Immediately before placement of concrete, wash rock surfaces with an air-water jet and dry to a uniform surface-dry condition.

D. Prepare earth foundations free from frost or ice.

E. Thoroughly moisten surfaces of absorptive foundations to be covered with concrete so that moisture will not be drawn from fresh concrete.

F. Remove hardened concrete, wood chips, ice and other debris from the interior of forms.

G. Place form release agent or wet forms just prior to placing concrete. Form release agent or any other deleterious material are not acceptable on previously placed concrete surfaces.

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H. Treat surfaces of mud mat concrete as construction joints, in accordance with subparagraph__ of this Section.

I. Install vapor retarder under interior building slabs-on-grade. Lap joints minimum 6 inches and seal water-tight by taping edges and ends.

J. Slope positively floors containing sumps, gutters, or floor drains.

K. Construct isolation joints in slabs-on-grade at points of contact between slabs-on-grade and vertical surfaces such as column pedestals, foundation walls, or as indicated. Use joint filler and a sealant as specified in Section 07 92 00.

L. Place epoxy grout in full accordance with manufacturer's instructions, including compressed air cleaning of all contact surfaces.

3.03 PLACING CONCRETE

A. Inspection: Notify ENGINEER and Special Inspector at least 72 hours prior to starting to place concrete. The ENGINEER shall inspect all surfaces on which concrete is to be placed.

B. Placement into Formwork:

1. Place concrete in accordance with ACI 301, ACI 304, ACI 309 ACI 318.
2. Do not place concrete until all formwork, installation of items to be embedded, and preparation of surfaces involved in the placement have been approved. Moistened and keep moist formwork and foundation surfaces on which cast-in-place concrete is placed until overlying concrete is placed.
3. Do not place concrete during heavy rain (more than 0.3 inch per hour or 0.03 inch in 6 minutes). If unusual adverse weather such as heavy rain, severe cold, heavy snow, high wind, or other adverse conditions occurs, or is forecast to occur during placement, an interruption in placing operations may be approved or directed. Fully consolidate all placed concrete materials before stopping work. Allow for construction schedule risk and added expense that could occur as a result of adverse weather. Weather delays shall receive no additional compensation. Conform to ACI 306.1 for additional cold weather placement requirements.
4. Concrete temperature at placing: 50 to 80 degrees F.
5. Where vapor retarder or barrier is required, coordinate subgrade preparation with requirements in [Division 07] of Specifications.
6. Place concrete as soon as possible after leaving mixer, without segregation or loss of ingredients, without splashing forms or steel above, and in layers not over 1.5 feet deep, except for slabs which shall be placed full depth.

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Place and consolidate successive layers prior to initial set of first layer to prevent cold joints.

7. Place concrete in as nearly a continuous operation as practical and in a manner to produce a concrete mass with sufficient continuity and continuance so that it shall harden and act as a monolithic mass with no discontinuous joints or potential places of separation or weakness.
8. Provide sufficient concrete placing capacity and equipment to deliver and place concrete without undue delay; do not permit cold joints to occur. Discharge concrete into forms within 90 minutes following the first introduction of water and cement or cement and aggregates, whichever occurs first. If the air temperature is 85 degrees F or higher, the time limit specified above shall be reduced to 60 minutes unless the ENGINEER's approval has been obtained for means to maintain acceptable concrete quality without such time reduction.
9. Do not use concrete that has been subjected to more than 250 total revolutions of any combination of mixing and agitating equipment following the first introduction of aggregates to the mixer.
10. Placement frequency shall be such that lift lines will not be visible in exposed and architectural] concrete finishes.
    a. Place concrete on prepared foundation or previously completed concrete materials in near horizontal layers.
    b. The depth of the first layer shall not exceed 12 inches and for subsequent layers it shall not exceed 18 inches.
    c. Place each successive layer as soon as practicable after the preceding layer is completed.
11. Use placement devices, for example chutes, pouring spouts, and pumps as required to prevent segregation, deposits concrete as close as practicable to its final position, and that produces layers of widths and thicknesses as necessary for compaction to the required dimensions.
12. Vertical Free Fall Drop to Final Placement: Not more than 3 feet.
13. For placements where drops are greater than specified:
    a. Use placement device such that free fall below placement device conforms to required value.
    b. Limit free fall to prevent segregation caused by aggregates hitting steel reinforcement.
14. Do not use aluminum conveying devices.
15. Provide sufficient illumination in the interior of forms so concrete deposition is visible, permitting confirmation of consolidation quality.
16. When Class I concrete arrives at the Project with slump below 3 inches, water may be added only if neither the maximum permissible water-cement

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ratio nor the maximum slump is exceeded. Slump adjustment, with water, shall be made only one time.

17. Start wall lifts with 2 to 3 inches of grout.
18. Placement of concrete under water is not permitted.
19. Deposit and consolidate concrete slabs in a continuous operation, within limits of construction joints, until the placing of a panel or section is completed.
    a. Consolidate concrete during placing operations so that concrete is thoroughly worked around reinforcement and other embedded items and into corners.
    b. Bring slab surfaces to correct level with straight-edge and strike-off. Use bullfloats or darbies to smooth surface, free of humps and hollows. Do not disturb slab surfaces prior to beginning finishing operations.
    c. Maintain reinforcing in proper position during concrete placement operations
20. Joints in Footings and Slabs:
    a. Ensure space beneath plastic waterstop completely fills with concrete.
    b. During concrete placement, make visual inspection of entire waterstop area.
    c. Limit concrete placement to elevation of waterstop in first pass, vibrate concrete under waterstop, lift waterstop to confirm full consolidation without voids, and place remaining concrete to full height of slab.
    d. Apply procedure to full length of waterstop.
21. Trowel and round off top exposed edges of walls with 1/4-inch radius steel edging tool.
22. Cure concrete as specified in Section 03 39 00, Concrete Curing.

C. Conveyor Belts and Chutes:

1. Design and arrange ends of chutes, hopper gates, and other points of concrete discharge throughout conveying, hoisting, and placing system for concrete to pass without becoming segregated.
2. Do not use chutes longer than 50 feet.
3. Minimum Slopes of Chutes: Angled to allow concrete to readily flow without segregation.
4. Conveyor Belts:
    a. Approved by ENGINEER.
    b. Wipe clean with device that does not allow mortar to adhere to belt.
    c. Cover conveyor belts and chutes.

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D. Retempering: Not permitted for concrete where cement has partially hydrated.

E. Pumping of Concrete:

1. Provide standby pump, conveyor system, crane and concrete bucket, or other system onsite during pumping, for adequate redundancy to ensure completion of concrete placement without cold joints in case of primary placing equipment breakdown.
2. Minimum Pump Hose (Conduit) Diameter: 4 inches.
3. Replace pumping equipment and hoses (conduits) that are not functioning properly.

F. Concrete sections with a minimum specified dimension that is greater than 2 feet 6 inches:

1. Cure and protect concrete in accordance with accepted thermal control plan and as follow:
   a. Minimum curing period shall be 14 days.
   b. Unless otherwise permitted, preserve moisture by maintaining forms in place.
2. Strength measurement shall be representative of in-place concrete within 2 inches of concrete surface.
3. Concrete strength shall be verified through correlation of concrete temperature and compressive strengths established by cylinder compressive tests and in accordance with ASTM C1074.
4. Unless otherwise specified, control concrete temperatures to within specified limits from time concrete is placed until time internal temperature has cooled from its maximum, such that difference between average daily ambient and maximum internal concrete temperature at time of protection removal, is less than specified temperature difference limit.
5. Unless otherwise specified, place one temperature sensor at center of mass of placement and one temperature sensor at a depth 2 inches from center of nearest exterior surface. Place additional sensor at each location to serve as a backup in event that other temperature sensor fails. In addition, provide temperature sensor in shaded location for monitoring ambient onsite temperature.
   a. Unless otherwise specified, monitor temperatures hourly using electronic sensors capable of measuring temperature from 32 degrees F to 212 degrees F to an accuracy of 2 degrees F.
   b. Ensure temperature sensors are operational before placing concrete.
   c. Unless otherwise specified, provide data from sensors to ENGINEER on a daily basis, until requirements are met.

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d. Compare temperatures and temperature differences with maximum limits specified in Article Temperature Limits every 12 hours, unless otherwise permitted. If either exceeds specified limits, take immediate action as described in accepted thermal control plan to remedy situation. Do not place additional mass concrete until cause of excessive temperature or temperature difference has been identified and corrections are accepted.

G. Consolidation and Visual Observation:

1. Consolidation Equipment and Methods: ACI 301 and ACI 309.
   a. Consolidation equipment shall be flexible, electric or pneumatic-drive immersion type vibrators with a minimum operating speed of 7,000 rpm when immersed.
2. Provide at least one standby vibrator and one extra generator in operable condition at Site at all times prior to placing concrete and during placement, to be used in the event of a breakdown of primary equipment.
3. Do not place vibrator against reinforcing or forms, or use vibrator to transport concrete within forms.
4. Provide sufficient windows in forms or limit form height to allow for concrete placement through windows and for visual observation of concrete.
5. Vibrate concrete in vicinity of joints to obtain impervious concrete.

H. Hot Weather:

1. Prepare ingredients, mix, place, cure, and protect in accordance with ACI 301, ACI 305.1, and as follows:
   a. Maintain concrete temperature below 80 degrees F at time of placement, or furnish test data or other proof that admixtures and mix ingredients do not produce flash set plastic shrinkage, or cracking as a result of heat of hydration. Cool ingredients before mixing to maintain fresh concrete temperatures as specified or less.
   b. Provide for windbreaks, shading, fog spraying, sprinkling, ice, wet cover, or other means as necessary to maintain concrete at or below specified temperature.
2. Concrete Curing: As specified in Section 03 39 00, Concrete Curing.

I. Cold Weather Placement:

1. Unless otherwise permitted, shall be in accordance with requirements of ACI 306.1 and as follows:

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a. Cold weather requirements shall apply when ambient temperature is below 40 degrees F or approaching 40 degrees F and falling.
b. Do not place concrete over frozen earth or against surfaces with frost or ice present. Frozen earth shall be thawed to acceptance of ENGINEER.
c. Unless otherwise permitted, do not place concrete in contact with surfaces less than 35 degrees F; requirement is applicable to all surfaces including reinforcement and other embedded items.
d. Provide supplemental external heat as needed when other means of thermal protection are unable to maintain minimum surface temperature of concrete as specified in ACI 306.1.
e. Maintain minimum surface temperature of concrete as specified in ACI 306.1 for no less than 3 days during cold weather conditions.
f. Cure concrete as specified in Section 03 39 00, Concrete Curing.
    1) Protect concrete from freezing until end of curing period and until concrete has attained a compressive strength of 3,500 psi or design compressive strength if less than 3,500 psi.

2. Provide maximum and minimum temperature sensors placed on concrete surfaces spaced throughout Work to allow monitoring of concrete surface temperatures representative of Work. Unless otherwise permitted, record surface temperature of concrete at least once every 12hours during specified curing period.
3. External Heating Units: Do not exhaust heater flue gases directly into enclosed area as it causes concrete carbonation as a result of concentrated carbon dioxide.
4. Maintain curing conditions as specified in Section 03 39 00, Concrete Curing.

3.04 JOINTS

A. General - Maximum Size of Concrete Placements:

1. Limit size of each placement to allow for strength gain and volume change as a result of shrinkage.
2. Locate expansion, control, and contraction joints where shown on Drawings.

B. Construction Joints (CJ):

1. Construction joints are joints which are purposely placed in concrete to facilitate construction; to reduce initial shrinkage stresses and cracks; to

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allow time for the installation of embedded metalwork; or to allow for subsequent placing of other concrete.

2. Bond is required at construction joints regardless of whether or not reinforcement is continuous across the joint.
3. Unless otherwise shown or permitted, locate construction joints as follows:
4. Locate construction joints as shown on Drawings or where approved by the ENGINEER in joint location submittal required in Section 03 15 00, Concrete Joints and Accessories.
    a. Provide vertical construction joints in walls and slabs at maximum spacing of 40 feet, unless shown or approved otherwise.
    b. When vertical expansion, contraction, or control joint spacing does not exceed 60 feet, intermediate construction joints are not required.
    c. Uniformly space vertical construction joints within straight sections of walls and slabs, avoiding penetrations.
5. Consider beams, girders, brackets, column capitals, and haunches as part of floor or roof system and place monolithically with floor or roof system.
6. Should placement sequence result in cold joint located below finished water surface, install waterstop in joint.
7. Relocation, addition, or elimination of construction joints shall be subject to the approval by the ENGINEER.
8. Clean, roughen, and surface dry surfaces of construction joints to be covered with fresh concrete. The roughened surface shall meet the requirements of ACI 318, Section 11.7.9.
    a. Remove laitance, loose or defective concrete, coatings, sand, curing compound and other foreign material.
    b. Sandblast, steel shot-blast, or high-pressure water jet surfaces, or use other method approved by the ENGINEER to create a surface equivalent to or larger than CSP 5 in accordance with ICRI 03732. Wash surface thoroughly, and surface dry immediately before placement of adjoining concrete.
    c. Do not use a mortar layer on construction joints.

C. Contraction Joints (CRJ):

1. Contraction Joints are joints placed in concrete to provide for volumetric shrinkage of a monolithic unit or movement between monolithic units.
2. Construct contraction joints so no bond exists between concrete surfaces forming the joint.

D. Minimum Time between Adjacent Placements:

1. Construction or Control Joints: 7 days unless otherwise specified.

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2. Construction joint between top of footing or slab, and column or wall: As soon as can safely be done without damaging previously cast concrete or interrupting curing thereof, but not less than 24 hours.
3. Expansion or Contraction Joints: 1 day.
4. For columns and walls with a height in excess of 10 feet, wait at least 2 hours before depositing concrete in beams, girders, or slabs supported thereon.
5. For columns and walls 10 feet in height or less, wait at least 1 hour prior to depositing concrete in beams, girders, brackets, column capitals, or slabs supported thereon.

3.05 REPAIRING CONCRETE

A. General:

1. Inject cracks that leak with crack repair epoxy as specified in Section 03 64 23, Crack Repair Epoxy Injection Grouting.
2. Repair surface defects, including tie holes, immediately after form removal.
3. Remove honeycombed and other defective concrete down to sound concrete.
4. [Repair horizontal concrete surfaces in accordance with Section 03 01 33, Repair of Horizontal Concrete Surfaces.]
5. [Repair vertical and overhead concrete surfaces in accordance with Section 03 01 32, Repair of Vertical and Overhead Concrete Surfaces.]
6. Use manufactured, non-shrink, cementitious materials specifically formulated for patching concrete in conjunction with a compatible bonding material. The complete repair procedure along with a list of all materials to be used must be submitted to and approved by ENGINEER before any repair work is started. Preparation of defective areas to be approved by ENGINEER prior to patching. ENGINEER
7. Develop repair techniques with material manufacturer on surface that will not be visible in final construction [or on mockup panels] prior to starting actual repair work and show how finish color will blend with adjacent surfaces. Obtain approval from ENGINEER.
8. Obtain quantities of repair material and manufacturer’s detailed instructions for use to provide repair with finish to match adjacent surface or apply sufficient repair material adjacent to repair to blend finish appearance.
9. Repair of concrete shall provide structurally sound surface finish, uniform in appearance or upgrade finish by other means until acceptable to ENGINEER.

B. Tie Holes:

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1. Unless otherwise specified, fill with specified repair material. Prepare substrate, liberally coat with a bonding agent, and then thoroughly fill with the repair material per manufacturer's written recommendations.
2. When required, color of tie-hole patch shall match adjacent concrete.
    a. Demonstrate patch of tie hole on mockup panels.
    b. Clean and dampen tie holes before applying mortar. Do not use separate bonding agent.
    c. Fill with site-mixed Portland-cement repair mortar per ACI 301.
    d. Cure repair mortar with water.

C. Alternate Form Ties, Through-Bolts:

1. Mechanically roughen entire interior surface of through hole.
2. Apply bonding agent to roughened surface and drive elastic vinyl plug to half depth.
3. Dry pack entire hole from both sides of plug with nonshrink grout, as specified in Section 03 62 00, Nonshrink Grouting.
4. Use only enough water to dry pack grout.
5. Dry pack while bonding agent is still tacky.
6. If bonding agent has dried, remove bonding agent by mechanical means and reapply new coat of bonding agent.
7. Compact grout using steel hammer and steel tool to drive grout to high density.
8. Cure grout with water.
9. When specified, color of alternate form tie-hole patch shall match adjacent concrete.
    a. Demonstrate patch of hole on mockup panels.
    b. Fill hole with nonshrink grout as described in paragraph above, except hold materials back 1 inch from concrete surfaces.
    c. Allow nonshrink grout to fully cure.
    d. Remove dried bonding agent by mechanical means.
    e. Clean and dampen remaining depressions before applying mortar.
    f. Do not use separate bonding agent on existing surfaces in remaining depression.
    g. Fill with site-mixed Portland-cement repair mortar per ACI 301.
    h. Cure repair mortar with water.

D. Exposed Metal Objects:

1. Remove metal objects not intended to be exposed in as-built condition of structure including wire, nails, and bolts, by chipping back concrete to depth of 1 inch and then cutting or removing metal object.

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2. Repair area of chipped-out concrete as specified for defective areas.

E. Blockouts at Pipes or Other Penetrations: Where shown install in accordance with requirements of Drawings.

3.06 CONCRETE WALL FINISHES

A. Type W-1 (Ordinary Wall Finish):

1. Patch tie holes.
2. Knock off projections.
3. Repair defective areas.
4. Inject cracks in accordance with requirements of Section 03 64 23, Crack Repair Epoxy Injection Grouting.

B. Type W-2 (Smooth Wall Finish):

C. All interior formed surfaces shall have a smooth form finish as defined in ACI 301 and specified herein.

1. Patch tie holes.
2. Grind off fins and other projections.
3. Repair defective areas to provide smooth uniform appearance.
4. Inject cracks in accordance with requirements of Section 03 64 23, Crack Repair Epoxy Injection Grouting.

D. [Type W-3 (Controlled Permeability Form Liner):

1. Apply Controlled Permeability Form Liner, as specified in Section 03 10 00, Concrete Forming and Accessories, to each face of wall section.
2. Patch tie holes.
3. Grind off fins and other projections.
4. Repair defective areas to provide smooth uniform appearance.
5. Inject cracks in accordance with requirements of Section 03 64 23, Crack Repair Epoxy Injection Grouting.]

E. [Type W-4 (Finish for Cementitious Coatings):

1. In accordance with requirements for Type W-2 except as follows: Leave surface ready for cementitious coating specified in Section 09 97 26, Cementitious Coatings.]

F. [Type W-5 (Finish for Painting):

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1. In accordance with requirements for Type W-2 except as follows: Leave surface ready for painting as specified in Section 09 90 00, Painting and Coating.]

G. [Type W-7 (Smooth Rubbed Wall Finish):

1. All exposed, exterior vertical surfaces shall have a smooth rubbed finish as defined in ACI 301 and specified herein.
2. Only water curing will be permitted on walls scheduled to be rubbed.
3. Perform rubbing while green concrete can be physically worked and smoothed without adding other materials, if structurally possible, the day following placement. Finish no later than 3 days after placement has been completed.
4. Remove forms at such a rate that finishing, form tie filling, fin removal, and patching can be completed on same day forms are removed while curing wall.
5. After patches have set sufficiently to permit working on surface, thoroughly saturate entire surface with water for period of 3 hours and rub until uniform surface is obtained.
6. Rub either by hand with carborundum stone of medium-coarse grade or abrasive of equal quality, or mechanically operated carborundum stone.
7. Mechanically operated carborundum stones shall be approved by ENGINEER before concrete finishing.
8. No cement grout, other than cement paste drawn from concrete itself by rubbing process shall be used.
9. Finish paste formed by rubbing by either brushing or floating as follows:
    a. Brushing:
        1) Carefully strike with clean brush.
        2) Brush in long direction of surface being finished.
    b. Floating:
        1) Spread uniformly over surface and allow to reset.
        2) Finish by floating with canvas, carpet face, or cork float, or rub down with dry burlap.
10. Continue water curing of wall during finishing operation in areas not being rubbed.
11. Move water curing onto rubbed areas as soon as water will not erode rubbed surface.

H. [Type W-8 (Rubbed Wall Finish):

1. Meet requirements for Type W-7, except allow paste obtained from rubbing to set at least 24 hours.

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2. After thoroughly saturating with water, coat surface with mixture of 85 percent cement and 15 percent lime with sufficient water to give creamy consistency. Demonstrate on sample panel prior to production finishing.
3. Rub this mixture into surface with coarse carborundum stone and brush with damp brush.
4. Brush in long direction of surface being finished.
5. Latex bonding admixture may be used. Consult with Euclid Chemical Co., Cleveland, OH or BASF Building Systems Inc., Shakopee, MN.]

I. [Type W-9 (Grout Cleaned Wall Finish):

1. Meet requirements for Type W-7, except that finish must be accomplished within 7 days of placement.
2. Grout: Mixed with one part Portland cement and one and one half parts fine sand and bonding agent to produce grout with consistency of thick paint. White Portland cement shall be substituted for part of gray Portland cement in order to produce color matching color of surrounding concrete, as determined by trial patch.
3. Wet surface of concrete sufficiently to prevent absorption of water from grout and apply grout uniformly with brushes or spray gun.
4. Immediately after applying grout, scrub surface vigorously with cork float or stone to coat surface and fill air bubbles and holes.
5. While grout is still plastic, remove excess grout by working surface with rubber float, burlap, or other means. After surface whitens from drying, about 30 minutes at 70 degrees F, rub vigorously with clean burlap. Continue to water cure wall until curing period of 7 days is complete.
6. Latex bonding admixture may be used.]

J. [Type W-10 (Fractured Fin Wall Finish):

1. Form exterior surface of walls with approved form liner.
2. Use stainless steel form ties and place at valleys.
3. Patch form tie holes.
4. Achieve final texture by light sandblast and then breaking off tips of ridge with light bush hammering, or other approved process.
5. Same person starting bush hammering shall complete process for any given structure and match approved mockup panel.]

K. [Type W-11 (Abrasive Blast Wall Finish):

1. Repair cracks before abrasive blasting.

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2. Perform abrasive blasting on concrete surfaces in same area of view, at same time, to obtain uniformity of appearance.
3. Same person shall accomplish sandblasting on one structure and on concrete in same area.
4. Perform abrasive blasting to match approved mockup panel.
5. Abrasive: Use clean silica sand, free of foreign materials, and supplied in sealed sacks.
6. When specified, begin abrasive blasting to expose aggregate when concrete has a compressive strength of at least 2,000 psi and after safe removal of forms and supports. Blast to match mockup. Achieve degree of abrasive blasting as specified in Contract Documents:
   a. Brush: Dull surface sheen.
   b. Light: Exposure of fine aggregate.
   c. Medium: Coarse aggregate exposure.
   d. Heavy: Coarse aggregate revealed.
7. When abrasive grits contain free water for dust abatement, wash abrasive blasting debris off finished wall surface before drying occurs.

L. Prepare concrete surfaces to be water-proofed as specified in Section 07 11 00? in strict accordance with the water-proofing manufacturer's instructions. On surfaces to be water-proofed, defects shall include, but not be limited to, voids, air holes, and honeycomb that the normal application of water-proofing will not fill or otherwise seal effectively

M. Surface Sealant System: Apply as recommended by the manufacturer’s published instructions. Where concrete continues to sweat or leak, apply additional coats of surface sealant until the sweating or leaks stop.

3.07 CONCRETE SLAB FINISHES

A. General:

1. Use manual screeds, vibrating screeds, or roller compacting screeds to place concrete level and smooth.
2. Do not use “jitterbugs” or other special tools designed for purpose of forcing coarse aggregate away from surface and allowing layer of mortar, which will be weak and cause surface cracks or delamination, to accumulate.
3. Finish slab in accordance with specified slab finish.
4. Do not dust surfaces with dry materials nor add water to surfaces.
5. Cure concrete as specified in Section 03 39 00, Concrete Curing.

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6. All exterior slab surfaces shall be sloped a minimum of1/8 inch in 1 foot or as indicated on the Drawings. All exterior slab surfaces shall have a troweled finish as defined in ACI 301.
7. Edges:
    a. Chamfer edges of permanently exposed concrete, except slabs and top edges of walls, with a 45 degree bevel ¾ inch by ¾ inch, unless otherwise shown on the Drawings.
    b. Tool exposed edges of slabs and top edges of walls to a radius of ¼ inch unless otherwise shown on the Drawings.

B. Type S-1 (Steel Troweled Finish):

1. Finish by screeding and floating with straightedges to bring surfaces to required finish elevation.
2. Wood float to true, even plane with no coarse aggregate visible.
3. Use sufficient pressure on wood floats to bring moisture to surface.
4. After surface moisture has disappeared, hand steel trowel concrete to produce smooth, smooth dense surface, free from trowel marks.
5. Provide light steel-troweled finish (two trowelings) at air-entrained slabs. Provide hard steel-troweled finish (ringing sound from the trowel) for nonair-entrained slabs.
6. Do not use dry cement or additional water during troweling, nor will excessive troweling be permitted.
7. Power Finishing:
    a. Approved power machine may be used in lieu of or in addition to hand finishing in accordance with directions of machine manufacturer.
    b. Do not use power machine when concrete has not attained necessary set to allow finishing without introducing high and low spots in slab.
    c. Do first steel troweling for slab S-1 finish by hand.

C. Type S-2 (Wood Float Finish):

1. Finish slab to receive fill and mortar setting bed by screeding with straightedges to bring surface to required finish plane.
2. Wood float finish to compact and seal surface.
3. Remove laitance and leave surface clean.
4. Coordinate with other finish procedures.

D. Type S-3 (Underside Elevated Slab Finish): When forming is removed, grind off projections on underside of slab and repair defective areas, including small shallow air pockets where schedule of concrete finishes requires:

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1. [Prepare surfaces to match Type W-2 (Smooth Wall Finish).]
2. [Prepare surfaces to match [Type W-7 (Smooth Rubbed Wall Finish)] [_____].]
3. [Prepare surfaces to match Type W-4 (Finish for Cementitious Coatings).]
4. [Prepare surfaces to match Type W-5 (Finish for Painting).]

E. Type S-5 (Broomed Finish):

1. Finish as specified for Type S-1 floor finish, except use only a light-steel troweled finish, and then finish surface by drawing fine-hair broom lightly across surface.
2. Broom in same direction and parallel to expansion joints, or, in case of inclined slabs, perpendicular to slope, except for round roof slab, broom surface in radial direction.

F. Type S-6 (Sidewalk Finish):

1. Slope walks down 1/4 inch per foot away from structures, unless otherwise shown.
2. Strike off surface by means of strike board and float with wood or cork float to true plane, then flat steel trowel before brooming.
3. Broom surface at right angles to direction of traffic or as shown.
4. Lay out sidewalk surfaces in blocks, as shown or as directed by ENGINEER, with grooving tool.

G. Concrete Curbs:

1. Float top surface of curb smooth, and finish all discontinuous edges with steel edger.
2. After concrete has taken its initial set, remove front form and give exposed vertical surface an ordinary wall finish, Type W-1.

3.08 CONCRETE SLAB TOLERANCES

A. [Slab Tolerances:

1. Exposed Slab Surfaces: Comprise of flat planes as required within tolerances specified.
2. Slab Finish Tolerances and Slope Tolerances: Crowns on floor surface not too high as to prevent 10-foot straightedge from resting on end blocks, nor low spots that allow block of twice the tolerance in thickness to pass under supported 10-foot straightedge.
3. Slab Type S-A: Steel gauge block 5/16 inch thick.

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4. Slab Type S-B: Steel gauge block 1/8 inch thick.
5. Slab Type S-A and S-B: Finish Slab Elevation: Slope slabs to floor drain and gutter, and shall adequately drain regardless of tolerances.
6. Thickness: Maximum 1/4 inch minus or 1/2 inch plus from thickness shown. Where thickness tolerance will not affect slope, drainage, or slab elevation, thickness tolerance may exceed 1/2 inch plus.]
7. [Slab Flatness and Levelness:
   a. Floor finish tolerances shall meet requirements specified herein, and as measured in accordance with ASTM E1155.
   b. Levelness tolerance, FL, shall not apply to slabs placed on unshored form surfaces or shored form surfaces after removal of shores.
   c. Levelness tolerances, FL, shall not apply to cambered or inclined surfaces, and shall be measured within 72 hours after slab concrete placement.

Slab Type S-A			
Minimum Overall F Numbers		Minimum Local F Numbers	
Flatness, FF	Levelness, FL	Flatness, FF	Levelness, FL
20	15	15	10
Slab Type S-B			
Minimum Overall F Numbers		Minimum Local F Numbers	
Flatness, FF	Levelness, FL	Flatness, FF	Levelness, FL
30	20	15	10
Slab Type S-C			
Minimum Overall F Numbers		Minimum Local F Numbers	
Flatness, FF	Levelness, FL	Flatness, FF	Levelness, FL
50	30	25	15]

B. Slab Elevation and Thickness:

1. Finish Slab Elevation: Slope slabs to floor drains and gutter. Slabs shall adequately drain regardless of tolerances.
2. Thickness: Maximum 1/4 inch minus or 1/2 inch plus from thickness shown. Where thickness tolerance will not affect slope, drainage, or slab elevation, thickness tolerance may exceed 1/2 inch plus.

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3.09 BEAM AND COLUMN FINISHES

A. Type B-1: Match wall Type W-1.

B. Type B-2: Match wall Type W-2.

C. Type B-3:

1. Repair rock pockets.
2. Fill air voids.
3. Match wall Type [W-3] [W-4] [W-5].

D. Type C-1: Match wall Type W-1.

E. Type C-2: Match wall Type W-2.

F. Type C-3:

1. Fill air pockets.
2. Match wall Type [W-3] [W-4] [W-5].

3.10 BACKFILL AGAINST STRUCTURES

A. Do not backfill against walls until concrete has obtained specified 28-day compressive strength.

B. Refer to General Structural Notes on the Drawings for additional requirements, including elevated slab and diaphragm completion prior to backfill.

C. Unless otherwise permitted, place backfill simultaneously on both sides of structure, where such fill is required, to prevent differential pressures.

3.11 CURING

A. Immediately after placement, protect concrete from premature drying, excessively hot or cold temperatures, and mechanical injury.

B. Comply with the requirements specified in Section 03 30 00, Concrete Curing.

3.12 FIELD QUALITY CONTROL

A. General:

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1. Furnish a batch ticket (delivery ticket) for each load of concrete received. Concrete delivered without a batch ticket containing complete information as specified below shall be rejected. Collect and complete the batch ticket at the placement site and deliver all batch tickets to the ENGINEER on a daily basis. The ENGINEER shall have access to the batch tickets at any time during placement. Provide the following information on each batch ticket:
    a. Supplier's name and date.
    b. Truck number.
    c. Project number and location.
    d. Concrete class designation and item number.
    e. Cubic yards batched.
    f. Time batched.
    g. Mix design number.
    h. Type, brand and amount of each admixture.
    i. Type, brand and amount of cement and pozzolan.
    j. Mass (weights) of fine and coarse aggregate, respectively.
    k. Moisture of fine and coarse aggregate, respectively.
    l. Gallons of batch water (including ice).
2. Add the following information to the batch ticket at the placement site:
    a. Gallons of water added by truck operator plus quantity of concrete in the truck each time water is added.
    b. Number of revolutions of drum at mixing speed (for truck mixed concrete).
    c. Discharge time.
    d. Location of batch in placement.
    e. Water cement ratio.
3. The CONTRACTOR will be allowed to add water to the batched concrete once at the site, provided that the specified water to cement ratio is not exceeded and the amount of water withheld at the batch plant is on the delivery ticket.
4. Provide adequate facilities for safe storage and proper curing of concrete test specimens onsite for first 24 hours, and for additional time as may be required before transporting to test lab.
5. Unless otherwise specified, sample concrete for testing for making test specimens, from point of delivery.
    a. Maintain records of placed concrete items. Record truck number, date and stop times, location of placed concrete, quantity, air temperature, concrete placement temperature, slump, air content, admixture quantities, test samples collected and times, and cast test cylinder numbers.

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6. When concrete is pumped, sample and test air content at point of delivery and at point of placement.
    a. For Each Concrete Mixture: Provided results of air content tests for first load of the day are within specified limits, testing need only be performed at point of delivery for subsequent loads of that concrete mixture except that testing should be performed at point of placement every 4 hours.
7. Evaluation will be in accordance with ACI 301 and Specifications.
8. Test specimens shall be made, cured, and tested in accordance with ASTM C31/C31M and ASTM C39/C39M.
9. Frequency of testing may be changed at discretion of ENGINEER.
10. Pumped Concrete: Take concrete samples for slump, ASTM C143/C143M, and test specimens, ASTM C31/C31M and ASTM C39/C39M, [and shrinkage specimens (ASTM C157/C157M) at placement (discharge) end of line].
11. If measured air content at delivery is greater than specified limit, check test of air content will be performed immediately on a new sample from delivery unit. If check test fails, concrete has failed to meet requirements of Contract Documents. If measured air content is less than lower specified limit, adjustments will be permitted in accordance with ASTM C94/C94M, unless otherwise specified. If check test of adjusted mixture fails, concrete has failed to meet requirements of Contract Documents. Concrete that has failed to meet requirements of Contract Documents shall be rejected.

B. Concrete Strength Test:

1. Unless otherwise specified, one specimen at age of 7 days for information, and two 6-inch diameter or when permitted three 4-inch diameter test specimens at age of 28 days for acceptance.
2. If result of 7-day concrete strength test is less than 50 percent of specified 28-day strength, extend period of moist curing specified in Section 03 39 00, Concrete Curing, by 7 additional days.
3. Provide a minimum of one spare test specimen per sample. Test spare cylinder as directed by ENGINEER.

C. Shrinkage Tests:

1. When required to conform to shrinkage limits, collect actual concrete materials being batched and before liquids have been added to mix.
2. Mix sampled material in a laboratory at proportions matching batched concrete.

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3. Test shrinkage characteristics every 5,000 cubic yards of concrete used on job and every 3 months during construction when compression test cylinders are made.
4. Concrete Shrinkage Limits: Test in accordance with ASTM C157/C157M, with the following modifications:
    a. Prisms shall be moist cured for 7 days prior to 28-day drying period.
    b. Comparator reading at end of 7-day moist cure shall be used as initial length in length change calculation.
    c. Reported results shall be average of three prisms.
    d. If drying shrinkage of a specimen departs from average of that test age by more than 0.004 percent, disregard results obtained from that specimen.
    e. Results at end of 28-day drying period shall not exceed 0.040 percent if 3-inch prisms are used, or exceed 0.038 percent if 4-inch prisms are used.
    f. If 7-day or 14-day shrinkage tests results exceed shrinkage limits established by design mix testing, furnish additional 14 days of water curing beyond original curing period, for concrete surfaces of hydraulic structures represented by prisms. Modify concrete mix design to reduce shrinkage prior to casting additional concrete on Project.
5. Cold Weather Placement Tests:
    a. During cold weather concreting, cast cylinders for field curing as follows. Use method that will produce greater number of specimens:
        1) Six extra test cylinders from last 100 cubic yards of concrete.
    b. Minimum three specimens for each 2 hours of placing time or for each 100 cubic yards.
6. These specimens shall be in addition to those cast for lab testing.
7. Protect test cylinders from weather until they can be placed under same protection provided for concrete of structure that they represent.
8. Keep field test cylinders in same protective environment as parts of structure they represent to determine if specified strength has been obtained.
9. Test cylinders in accordance with applicable sections of ASTM C31/C31M and ASTM C39/C39M.
10. Use test results to determine specified strength gain prior to falsework removal or for prestressing.

D. Tolerances:

1. Walls: Measure and inspect walls for compliance with tolerances specified in Section 03 10 00, Concrete Forming and Accessories.
2. [Slab Finish Tolerances and Slope Tolerances:

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a. Make floor flatness measurements day after floor is finished and before shoring is removed to eliminate effects of shrinkage, curing, and deflection.
b. Support 10-foot long straightedge at each end with steel gauge blocks of thicknesses equal to specified tolerance.
c. Compliance with designated limits in four of five consecutive measurements is satisfactory, unless defective conditions are observed.]

3. [Slab Finish Tolerances and Slope Tolerances:
   a. Slab Flatness and Levelness: Make measurements within 72 hours of concrete placement.
   b. Flatness measurements are not applicable to unshored form surfaces or shored form surfaces after removal of shores.
   c. Levelness measurements are not applicable to cambered or sloped surfaces.
   d. Slab flatness and levelness shall be determined in accordance with ASTM E1155.]

E. Liquid Tightness Tests:

1. Purpose: To determine integrity and liquid-tightness of finished exterior and interior concrete surfaces of liquid containment structures.
2. Test the following structures for liquid-tightness:
   a. [_____]
   b. [_____]
3. [Water] for initial tightness test [will] [shall] be provided by [OWNER] [CONTRACTOR].
   a. Water source will be [_____].
   b. Provide means to transport water to structure to be tested.
   c. If additional tightness tests are required because of failure to meet criteria, provide water for subsequent tests.
4. After testing has been completed,[dispose of test water in a manner approved by OWNER Requirement:
   a. Perform tightness tests in accordance with ACI 350.1 and as specified herein.
   b. Do not place backfill or install brick facing, grout topping slab, coatings, or other work that will cover concrete surfaces until tightness testing has been completed and approved.
   c. Measure evaporation, precipitation, and temperature as specified.
5. Measure water surface at two points 180 degrees apart when possible where attachments, such as ladders exist, at 24-hour intervals.
6. Acceptance Criteria:

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a. Volume loss shall not exceed [0.050] [_____] percent of contained liquid volume per 24-hour period, adjusted for evaporation, precipitation, and temperature.
b. Acceptance that structure has passed tightness test shall be based on total volume loss at end of specified test period.

7. Repairs When Test Fails:
a. Dewater structure; fill leaking cracks with crack repair epoxy as specified in Section 03 64 23, Crack Repair Epoxy Injection Grouting.
b. Patch areas of damp spots previously recorded, and repeat water leakage test in its entirety until structure successfully passes test.]

F. Defective Concrete:

1. Defective Concrete: Concrete not conforming to required lines, levels, details elevations, dimensions, tolerances or specified requirements.
2. Defective concrete will be determined by the ENGINEER and shall be repaired or replaced at no additional cost to the OWNER. Perform repair in accordance with Guide to Concrete Repair (USBR) and as specified in the Article "Repairing Concrete" above.
3. Repair of Hardened Concrete Not Within Specified Tolerances. Accomplish such repair to bring it within the specified tolerances in a manner approved by the ENGINEER, after consultation with the ENGINEER regarding the repair method. Notify the ENGINEER sufficiently in advance to enable his attendance as to the time when the repair shall be performed.
4. Defective concrete that shall be exposed to public view shall be repaired in a manner that shall result in a concrete surface with a uniform appearance. Grinding of concrete surface exposed to view shall be limited in depth such that no aggregate particles are exposed more than 1/6 inch in cross section at the finished surface. Where grinding has caused or will cause exposure of aggregate particles greater than 1/6 inch in cross section at the finished surface, repair the concrete by excavating and replacing the concrete at no additional cost to the OWNER.
5. Prevention of Repeated Failure to Meet Tolerances: When concrete placements result in hardened concrete that does not meet specified tolerances, the CONTRACTOR shall upon request submit to the ENGINEER an outline of all preventative actions, such as modifications to forms, modified procedure for setting screeds, and different finishing techniques, to be implemented by the CONTRACTOR to avoid repeated failures. The ENGINEER reserves the right delay concrete placements until the CONTRACTOR implements such preventive actions that are approved by the ENGINEER.

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6. Modify or replace concrete not conforming to required levels and lines, details, and elevations.
7. Repair or replace concrete not properly placed or not of the specified type.
8. Disposal of defective concrete removed will be the responsibility of the CONTRACTOR and shall be conducted in accordance with local, state and federal laws and regulations.

3.13 MANUFACTURER'S SERVICES

A. Provide representative at Site in accordance with Section 01 43 33, Manufacturers' Field Services, for installation assistance, inspection, and certification of proper installation for concrete ingredients, mix design, mixing, and placement.

1. Concrete Producer Representative:
   a. Assist with concrete mix design, performance, placement, weather problems, and problems as may occur with concrete mix throughout Project, including instructions for redosing.
   b. Establish control limits on concrete mix designs.
   c. Provide equipment for control of concrete redosing for air entrainment or high-range, water-reducing admixture, superplasticizers, at Site to maintain proper slump and air content if needed.
2. Admixture Manufacturer's Representative: Available for consultations as required to ensure proper installation and performance of specified products.
3. Bonding Agent Manufacturer's Representative: Available for consultations as required to ensure proper installation and performance of specified products.

3.14 PROTECTION OF INSTALLED WORK

A. Protect finished work under provisions of ACI 301.

B. After curing as specified in Section 03 39 00, Concrete Curing, and after applying final floor finish, cover slabs with plywood or particle board or plastic sheeting or other material to keep floor clean and protect it from material and damage as a result of other construction work.

1. Protect concrete from damage until final acceptance of the Work by the ENGINEER.
   a. Do not load, remove forms or shoring, or backfill against concrete until concrete has gained sufficient strength to safely support its weight and imposed loads.

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b. Protect fresh concrete against erosion from rain, hail, sleet, or snow; contamination from foreign materials; and damage from foot traffic until the concrete has hardened.
c. Remove and dispose of temporary covering when no longer required.

C. Protect concrete when freezing temperatures are imminent:

1. Maintain concrete at a temperature of 50 degrees F or greater for 72 hours, minimum, after placement. Vent heater and prevent concrete from drying where artificial heat is employed.
2. Protect concrete from freezing during water curing. After discontinuance of water curing, maintain at a temperature of 50 degrees F or greater for the next 72 hours.
3. Discontinue protection against cold weather such that the drop in temperature of the concrete will be gradual and will not exceed 5 degrees F per hour and 40 degrees F in 24 hours for thin sections and 5 degrees F per hour and 20 degrees F in 24 hours for massive section greater than 36 inches in thickness.

D. Maintain concrete with minimal moisture loss at relatively constant temperature for a period of time necessary for satisfactory hydration of cement and hardening of concrete.

E. Remove formwork in accordance with the requirements of Section 03 10 00, Concrete Forming and Accessories.

F. Repair areas damaged by construction, using specified repair materials and approved repair methods.

3.15 SCHEDULE OF CONCRETE FINISHES

A. Form Tolerances: As specified in Section 03 10 00, Concrete Forming and Accessories.

B. Special Floor Finishes: As specified in Section 03 35 00, Concrete Finishing.

C. Provide concrete finishes as scheduled:

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Area	Type of Finish	Required Form Tolerances
Exterior Wall Surfaces		
Abovegrade/exposed (above point 6" below finish grade)	W-2	W-B
Abovegrade/covered with brick veneer or other finish material	W-1	W-A
Backfilled/waterproofed (below point 6" below finish grade)	W-1	W-A
Backfilled/not waterproofed (below point 6" below final grade)	W-1	W-A
Walls to receive cementitious coatings	W-4	W-B
Interior Wall Surfaces		
Open top water-holding tanks and basins/not painted or coated	W-2	W-A
Covered water-holding tanks and basins/not painted or coated	W-1	W-A
Water-holding tanks, channels, and basins/painted or coated	W-5	W-A
Buildings, pipe galleries, and other dry areas/not painted or coated	W-2	W-A
Buildings, pipe galleries, and other dry areas/painted or coated	W-5	W-A
Exterior Slabs		
Roof slab/exposed	S-5	S-B
Roof slab/covered with roofing material	S-1	S-A
Water-holding tanks and basins/top of wall	S-5	S-B
Top of footing	S-2	S-A
Clarifier slabs	S-2, S-7	S-A
Other water-holding tanks and basins	S-1	S-A
Stairs and landings	S-5	S-B
Sidewalks	S-6	S-B

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Area	Type of Finish	Required Form Tolerances
Other exterior slabs	S-5	S-A
Interior Slabs		
Buildings, pipe galleries, and other dry areas	S-1	S-B
Slabs to receive mortar setting bed for tile	S-2	S-A
Slabs to receive resilient flooring or carpet	S-1	S-A
Hydraulic channels	S-1	S-A
Underside of elevated slabs	S-3	S-A
Beams and Columns		
Beams/coated	B-3	B-A
Beams/not coated	B-2	B-A
Columns/coated	C-3	C-A
Columns/not coated	C-2	C-A

END OF SECTION

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SUPLLMENETAL INFORMATION

[Concrete Mix Design, Class 5000F3S1P2C2

A. Mix Locations: [Typical, unless otherwise specified.]

B. Exposure Categories and Classifications: F3S1P2C2.

C. Mix Properties:

1. Limit water to cementitious materials ratio (W/Cm) in mix design to maximum value of 0.40.
2. Minimum concrete compressive strength (f'c) shall be 4,000 psi at 28 days and 5,000 psi at 56 days.
3. [Designed to conform to shrinkage limits.]
4. Air-entraining admixtures are prohibited in concrete mixtures and total air content shall not be greater than 3 percent, for the following:
   a. Slabs to receive hard-troweled finish.
   b. Slabs to receive dry shake floor hardener.
   c. Slabs to receive topping placed monolithically as two-course floor on top of plastic concrete.
5. Unless otherwise specified, provide air content based on nominal maximum size of aggregate as follows:

Nominal Maximum Aggregate Size in.‡	**Air Content (%)***
3/8	7.5
1/2	7.0
3/4	6.0
1	6.0
1-1/2	5.5
2§	5.0
3§	4.5

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Nominal Maximum Aggregate Size in.‡	Air Content (%)*
‡See ASTM C33/C33M for tolerance on oversize for various nominal maximum size designations. *Tolerance of air content is ±1-1/2 percent. §Air contents apply to total mixture. When testing concretes, however, aggregate particles larger than 1-1/2 inches are to be removed by sieving and air content will be measured on sieved fraction (tolerance on air content as delivered applies to this value). Air content of total mixture is computed from value measured on the sieved fraction passing the 1-1/2-inch sieve in accordance with ASTM C231/C231M.	

6. Limit supplementary cementitious materials measured as a percent of weight of total cementitious materials in mix design, as follows:
   a. Fly Ash and other Pozzolans: 25 percent.
   b. Slag Cement: 50 percent.
   c. [Silica Fume: 10 percent.]
   d. Combined Fly Ash and other Pozzolans [and Slag Cement] [, Slag Cement, and Silica Fume]: 50 percent, with fly ash and other pozzolans not exceeding 25 percent [, and silica fume not exceeding 10 percent].
   e. [Combined Fly Ash and other Pozzolans and Silica Fume: 35 percent, with fly ash and other pozzolans not exceeding 25 percent, and silica fume not exceeding 10 percent.]
   f. Total cementitious materials include ASTM C150/C150M and ASTM C595/C595M cement.
      1) Fly ash and other pozzolans in Type IP, blended cement, ASTM C595/C595M.
      2) Slag used in the manufacture of an IS blended cement, ASTM C595/C595M.
      3) [Silica fume, ASTM C1240, present in blended cement.]
7. Provide cementitious materials in accordance with one of the following:
   a. ASTM C150/C150M Type II; inclusion of supplementary cementitious materials in design mix is optional.
   b. ASTM C150/C150M types other than Type II, plus supplementary cementitious materials in accordance with one of the following:
      1) Tricalcium Aluminate Content of Total Cementitious Materials: Maximum 8 percent by weight.

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2) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.

c. ASTM C595/C595M Type IP or Type IS (less than 70), tested to comply with moderate sulfate resistance option (MS).

1) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.

8. Unless otherwise permitted, minimum cementitious materials content in mix design shall be as follows:
   a. 515 pounds per cubic yard for concrete with 1-1/2-inch nominal maximum size aggregate.
   b. 535 pounds per cubic yard for 1-inch nominal maximum size aggregate.
   c. 560 pounds per cubic yard for 3/4-inch nominal maximum size aggregate.
   d. 580 pounds per cubic yard for 1/2-inch nominal maximum size aggregate.
   e. 600 pounds per cubic yard for 3/8-inch nominal maximum size aggregate.
   f. Unless otherwise permitted, limit cementitious materials content to 100 pounds per cubic yard greater than specified minimum cementitious materials content in mix design.
9. Limit water-soluble, chloride-ion content in hardened concrete to 0.10 percent, unless otherwise specified.
   a. [Regardless of assigned C Exposure Class, for prestressed and post-tensioned concrete: 0.06 percent.]
   b. Limits are stated in terms of chloride ions in percent by weight of cement.
   c. Unless otherwise permitted, provide documentation from concrete tested in accordance with ASTM C1218/C1218M at an age between 28 days and 42 days.

D. Refer to PART 1 through PART 3 of this section for additional requirements.]

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Concrete Mix Design, Class 4500F2S1P1C1

A. Mix Locations: Where specified in Contract Documents.

B. Exposure Categories and Classifications: F2S1P1C1.

C. Mix Properties:

1. Limit water to cementitious materials ratio (W/Cm) in mix design to maximum value of 0.45.
2. Minimum concrete compressive strength (f'c) shall be 4,000 psi at 28 days and 4,500 psi at 56 days.
   a. Designed to conform to shrinkage limits.
   b. Air-entraining admixtures are prohibited in concrete mixtures and total air content shall not be greater than 3 percent, for the following:
      1) Slabs to receive a hard-troweled finish.
      2) Slabs to receive a dry shake floor hardener.
      3) Slabs to receive a topping placed monolithically as a two-course floor on top of plastic concrete.
   c. Unless otherwise specified, provide air content based on nominal maximum size of aggregate as follows:

Nominal Maximum Aggregate Size in. ‡	**Air Content (%)***
3/8	7.5
1/2	7.0
3/4	6.0
1	6.0
1-1/2	5.5
2§	5.0
3§	4.5

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Nominal Maximum Aggregate Size in. ‡	Air Content (%)*
‡See ASTM C33/C33M for tolerance on oversize for various nominal maximum size designations. *Tolerance of air content is ±1-1/2 percent. §Air contents apply to total mixture. When testing concretes, however, aggregate particles larger than 1-1/2 inches are to be removed by sieving and air content will be measured on sieved fraction (tolerance on air content as delivered applies to this value). Air content of total mixture is computed from value measured on sieved fraction passing 1-1/2-inch sieve in accordance with ASTM C231/C231M.	

3. Provide cementitious materials in accordance with one of the following:
   a. ASTM C150/C150M Type II; inclusion of supplementary cementitious materials in design mix is optional.
   b. ASTM C150/C150M types other than Type II, plus supplementary cementitious materials in accordance with one of the following:
      1) Tricalcium Aluminate Content of Total Cementitious Materials: Maximum 8 percent by weight.
      2) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.
      3) ASTM C595/C595M Type IP or Type IS (less than 70), tested to comply with moderate sulfate resistance option (MS).
4. Limit water-soluble, chloride-ion content in hardened concrete to 0.30 percent, unless otherwise specified.
   a. [Regardless of assigned C Exposure Class, for prestressed and post-tensioned concrete: 0.06 percent.]
   b. Limits are stated in terms of chloride ions in percent by weight of cement.
   c. Unless otherwise permitted, provide documentation from concrete tested in accordance with ASTM C1218/C1218M at an age between 28 days and 42 days.

D. Refer to PART 1 through PART 3 of this section for additional requirements.]

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[Concrete Mix Design, Class SM00F2S1P2C1

A. Mix Locations: Slurry mixture at horizontal construction joints with waterstop in wall.

B. Exposure Categories and Classifications: F2S1P2C1.

C. Mix Properties:
   1. Limit water to cementitious materials ratio (W/Cm) in mix design to maximum value of 0.42.
   2. Minimum concrete compressive strength (f'c) shall be same as concrete mix for wall.
   3. Maximum Nominal Aggregate: 3/8 inch.
   4. Unless otherwise specified, provide 7.5 percent air content.
      a. See ASTM C33/C33M for tolerance on oversize for various nominal maximum size designations.
      b. Tolerance of air content is plus or minus 1.5 percent.
   5. Provide cementitious materials in accordance with one of the following:
      a. ASTM C150/C150M Type II; inclusion of supplementary cementitious materials in design mix is optional.
      b. ASTM C150/C150M types other than Type II, plus supplementary cementitious materials in accordance with one of the following:
         1) Tricalcium Aluminate Content of Total Cementitious Materials: Maximum 8 percent by weight.
         2) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.
      c. ASTM C595/C595M Type IP or Type IS (less than 70), tested to comply with moderate sulfate resistance option (MS).
         1) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.
   6. Unless otherwise permitted, minimum cementitious materials content in mix design shall be 600 pounds per cubic yard for 3/8-inch nominal maximum size aggregate.
   7. Limit water-soluble, chloride-ion content in hardened concrete to 0.10 percent, unless otherwise specified.
      a. [Regardless of assigned C Exposure Class, for prestressed and post-tensioned concrete: 0.06 percent.]
      b. Limits are stated in terms of chloride ions in percent by weight of cement.

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c. Unless otherwise permitted, provide documentation from concrete tested in accordance with ASTM C1218/C1218M at an age between 28 days and 42 days.]

E. Refer to PART 1 through PART 3 of this section for additional requirements.]

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[Concrete Mix Design, Class 4500F1S1P0C1

A. Mix Locations:

1. Electrical duct banks.
2. Pipe encasements that are not cast monolithically with concrete base mats or slabs.
3. Where specified in Contract Documents.

B. Exposure Categories and Classifications: F1S1P0C1.

C. Mix Properties:

1. Limit water to cementitious materials ratio (W/Cm) in mix design to maximum value of 0.45.
2. Minimum concrete compressive strength (f'c) shall be 3,500 psi at 28 days and 4,500 psi at 56 days.
3. Air-entraining admixtures are prohibited in concrete mixtures and total air content shall not be greater than 3 percent, for the following:
   a. Slabs to receive hard-troweled finish.
   b. Slabs to receive dry shake floor hardener.
   c. Slabs to receive topping placed monolithically as two-course floor on top of plastic concrete.
4. Unless otherwise specified, provide air content based on nominal maximum size of aggregate as follows:

Nominal Maximum Aggregate Size in. ‡	**Air Content (%)***
3/8	6.0
1/2	5.5
3/4	5.0
1	4.5
1-1/2	4.5
2§	4.0
3§	3.5

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Nominal Maximum Aggregate Size in. ‡	Air Content (%)*
‡See ASTM C33/C33M for tolerance on oversize for various nominal maximum size designations. *Tolerance of air content is ±1-1/2 percent. §Air contents apply to total mixture. When testing concretes, however, aggregate particles larger than 1-1/2 inches are to be removed by sieving and air content will be measured on the sieved fraction (tolerance on air content as delivered applies to this value). Air content of total mixture is computed from value measured on the sieved fraction passing the 1-1/2-inch sieve in accordance with ASTM C231/C231M.	

5. Provide cementitious materials in accordance with one of the following:
   a. ASTM C150/C150M Type II; inclusion of supplementary cementitious materials in design mix is optional.
   b. ASTM C150/C150M types other than Type II, plus supplementary cementitious materials in accordance with one of the following:
      1) Tricalcium Aluminate Content of Total Cementitious Materials: Maximum 8 percent by weight.
      2) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.
      3) ASTM C595/C595M Type IP or Type IS (less than 70), tested to comply with moderate sulfate resistance option (MS).
         a) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.
6. Limit water-soluble, chloride-ion content in hardened concrete to 0.30 percent, unless otherwise specified.
   a. Limits are stated in terms of chloride ions in percent by weight of cement.
   b. Unless otherwise permitted, provide documentation from concrete tested in accordance with ASTM C1218/C1218M at an age between 28 days and 42 days.]

D. Refer to PART 1 through PART 3 of this section for additional requirements.]

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[Concrete Mix Design, Class CF00F1S1P0C1

A. Mix Locations: Where specified in Contract Documents.

B. Exposure Categories and Classifications: F1S1P0C1.

C. Mix Properties:

1. Limit water to cementitious materials ratio (W/Cm) in mix design to maximum value of 0.45.
2. Minimum concrete compressive strength (f'c) shall be 3,500 psi at 28 days and 4,500 psi at 56 days.
3. [Concrete mix shall be designed to conform to shrinkage limits.]
4. Air-entraining admixtures are prohibited in concrete mixtures and total air content shall not be greater than 3 percent, for the following:
   a. Slabs to receive hard-troweled finish.
   b. Slabs to receive dry shake floor hardener.
   c. Slabs to receive topping placed monolithically as two-course floor on top of plastic concrete.
5. Unless otherwise specified, provide air content based on nominal maximum size of aggregate as follows:

Nominal Maximum Aggregate Size in. ‡	**Air Content (%)***
3/8	6.0
½	5.5
¾	5.0
1	4.5
1-1/2	4.5
2§	4.0
3§	3.5

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Nominal Maximum Aggregate Size in. ‡	Air Content (%)*
‡See ASTM C33/C33M for tolerance on oversize for various nominal maximum size designations. *Tolerance of air content is ±1-1/2 percent. §Air contents apply to total mixture. When testing concretes, however, aggregate particles larger than 1-1/2 inches are to be removed by sieving and air content will be measured on the sieved fraction (tolerance on air content as delivered applies to this value). Air content of total mixture is computed from value measured on the sieved fraction passing the 1-1/2-inch sieve in accordance with ASTM C231/C231M.	

6. Provide cementitious materials in accordance with one of the following:
7. ASTM C150/C150M Type II; inclusion of supplementary cementitious materials in design mix is optional.
8. ASTM C150/C150M types other than Type II, plus supplementary cementitious materials in accordance with one of the following:
    a. Tricalcium Aluminate Content of Total Cementitious Materials: Maximum 8 percent by weight.
    b. Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.
    c. ASTM C595/C595M Type IP or Type IS (less than70), tested to comply with moderate sulfate resistance option (MS).
        1) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.
9. Limit water-soluble, chloride-ion content in hardened concrete to 0.10 percent, unless otherwise specified.
    a. Limits are stated in terms of chloride ions in percent by weight of cement.
    b. Unless otherwise permitted, provide documentation from concrete tested in accordance with ASTM C1218/C1218M at an age between 28 days and 42 days.
10. [Fiber Reinforcement:

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a. Where required, provide polypropylene micro-fibers in design mix in accordance with Section 03 24 00, Fibrous Reinforcing.
b. Add fiber-reinforcement to mix in concrete plant.]

D. Refer to PART 1 through PART 3 of this section for additional requirements.]

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[Concrete Mix Design, Class 4500F3S1P1C2

A. Mix Locations: Concrete curbs and sidewalks.

B. Exposure Categories and Classifications: F3S1P1C2.

C. Mix Properties:

1. Limit water to cementitious materials ratio (W/Cm) in mix design to maximum value of 0.42.
2. Minimum concrete compressive strength (f'c) shall be 3,500 psi at 28 days and 4,500 psi at 56 days.
3. Air-entraining admixtures are prohibited in concrete mixtures and total air content shall not be greater than 3 percent, for the following:
   a. Slabs to receive hard-troweled finish.
   b. Slabs to receive dry shake floor hardener.
   c. Slabs to receive topping placed monolithically as two-course floor on top of plastic concrete.
4. Unless otherwise specified, provide air content based on nominal maximum size of aggregate as follows:

Nominal Maximum Aggregate Size in. ‡	**Air Content (%)***
3/8	7.5
½	7.0
¾	6.0
1	6.0
1-1/2	5.5
2§	5.0
3§	4.5

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Nominal Maximum Aggregate Size in. ‡	Air Content (%)*
‡See ASTM C33/C33M for tolerance on oversize for various nominal maximum size designations. *Tolerance of air content is ±1-1/2 percent. §Air contents apply to total mixture. When testing concretes, however, aggregate particles larger than 1-1/2 inches are to be removed by sieving and air content will be measured on the sieved fraction (tolerance on air content as delivered applies to this value). Air content of total mixture is computed from value measured on the sieved fraction passing the 1-1/2-inch sieve in accordance with ASTM C231/C231M.	

5. Limit supplementary cementitious materials measured as a percent of weight of total cementitious materials in a mix design, as follows:
   a. Fly Ash and other Pozzolans: 25 percent.
   b. Slag Cement: 50 percent.
   c. [Silica Fume: 10 percent.]
   d. Combined Fly Ash and other Pozzolans [and Slag Cement] [, Slag Cement, and Silica Fume]: 50 percent, with fly ash and other pozzolans not exceeding 25 percent [and silica fume not exceeding 10 percent].
   e. [Combined Fly Ash and other Pozzolans and Silica Fume: 35 percent, with fly ash and other pozzolans not exceeding 25 percent and silica fume not exceeding 10 percent.]
   f. Total cementitious materials include ASTM C150/C150M and ASTM C595/C595M cement.
      1) Fly ash and other pozzolans in Type IP, blended cement, ASTM C595/C595M.
      2) Slag used in the manufacture of an IS blended cement, ASTM C595/C595M.
      3) [Silica fume, ASTM C1240, present in blended cement.]
6. Provide cementitious materials in accordance with one of the following:
   a. ASTM C150/C150M Type II.
   b. ASTM C150/C150M types other than Type II, plus supplementary cementitious materials in accordance with one of the following:
      1) Tricalcium Aluminate Content of Total Cementitious Materials: Maximum 8 percent by weight.
      2) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious

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materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.

c. ASTM C595/C595M Type IP or Type IS (less than 70), tested to comply with moderate sulfate resistance option (MS).

1) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.

7. Limit water-soluble, chloride-ion content in hardened concrete to 0.15 percent, unless otherwise specified.

a. Limits are stated in terms of chloride ions in percent by weight of cement.

b. Unless otherwise permitted, provide documentation from concrete tested in accordance with ASTM C1218/C1218M at an age between 28 days and 42 days.

8. [Fiber Reinforcement:

a. Where required, provide polypropylene micro-fibers in design mix in accordance with Section 03 24 00, Fibrous Reinforcing.

b. Add fiber-reinforcement to mix in concrete plant.]

D. Refer to PART 1 through PART 3 of this section for additional requirements.]

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[Concrete Mix Design, Class 4000F0S1P0C0

A. Mix Locations: Concrete curbs and sidewalks.

B. Exposure Categories and Classifications: F0S1P0C0.

C. Mix Properties:

1. Limit water to cementitious materials ratio (W/Cm) in mix design to maximum value of 0.50.
2. Minimum concrete compressive strength (f'c) shall be 3,000 psi at 28 days and 4,000 psi at 56 days.
3. There are no restrictions on air content except that air-entraining admixtures are prohibited in concrete mixtures and total air content shall not be greater than 3 percent, for the following:
    a. Slabs to receive hard-troweled finish.
    b. Slabs to receive dry shake floor hardener.
    c. Slabs to receive topping placed monolithically as two-course floor on top of plastic concrete.
4. Provide cementitious materials in accordance with one of the following:
    a. ASTM C150/C150M Type II.
    b. ASTM C150/C150M types other than Type II, plus supplementary cementitious materials in accordance with one of the following:
        1) Tricalcium Aluminate Content of Total Cementitious Materials: Maximum 8 percent by weight.
        2) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.
    c. ASTM C595/C595M Type IP or Type IS (less than 70), tested to comply with moderate sulfate resistance option (MS).
        1) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.
5. Limit water-soluble, chloride-ion content in hardened concrete to 1 percent, unless otherwise specified.
    a. Limits are stated in terms of chloride ions in percent by weight of cement.

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b. Unless otherwise permitted, provide documentation from concrete tested in accordance with ASTM C1218/C1218M at an age between 28 days and 42 days.

6. [Fiber Reinforcement:
   a. Where required, provide polypropylene micro-fibers in design mix in accordance with Section 03 24 00, Fibrous Reinforcing.
   b. Add fiber-reinforcement to mix in concrete plant.]

D. Refer to PART 1 through PART 3 of this section for additional requirements.]

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[Concrete Mix Design, Class TC00F0S1P1C1

A. Mix Locations: Tremie concrete.

B. Exposure Categories and Classifications: F0S1P1C1.

C. Mix Properties:
   1. Limit water to cementitious materials ratio (W/Cm) in mix design to maximum value of 0.42.
   2. Minimum concrete compressive strength (f'c) shall be 4,000 psi at 28 days and 4,500 psi at 56 days.
   3. Use natural round gravel.
   4. Fine Aggregate Range: 40 percent to 50 percent of total aggregates by weight.
   5. There are no restrictions on air content.
   6. Proportion mix for design strength and slump range of 6 inches to 9 inches with maximum water-cement ratio.
   7. Use high-range, water-reducing admixture or plasticizing admixture.
   8. Use antiwashout admixture in accordance with manufacturer's recommendations.
   9. Provide cementitious materials in accordance with one of the following:
      a. ASTM C150/C150M Type II; inclusion of supplementary cementitious materials in design mix is optional.
      b. ASTM C150/C150M types other than Type II, plus supplementary cementitious materials in accordance with one of the following:
         1) Tricalcium Aluminate Content of Total Cementitious Materials: Maximum 8 percent by weight.
         2) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.
      c. ASTM C595/C595M Type IP or Type IS (less than70), tested to comply with moderate sulfate resistance option (MS).
         1) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.
   10. Unless otherwise permitted, minimum cementitious materials content in mix design shall be 600 pounds per cubic yard.
   11. Limit water-soluble, chloride-ion content in hardened concrete to 0.10 percent, unless otherwise specified.

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a. [Regardless of assigned C Exposure Class, for prestressed and post-tensioned concrete: 0.06 percent.]
b. Limits are stated in terms of chloride ions in percent by weight of cement.
c. Unless otherwise permitted, provide documentation from concrete tested in accordance with ASTM C1218/C1218M at an age between 28 days and 42 days.

D. Refer to PART 1 through PART 3 of this section for additional requirements.]

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[Concrete Mix Design, Class GT00F1S1P0C1

A. Mix Locations: Grout topping slab in [Clarifiers] [, Floatation Thickeners] [_____].

B. Exposure Categories and Classifications: F1S1P0C1.

C. Mix Properties:
   1. Limit water to cementitious materials ratio (W/Cm) in mix design to maximum value of 0.40.
   2. Minimum compressive strength (f'c) shall be 3,500 psi at 28 days and 4,500 psi at 56 days.
   3. Design mix shall be designed to conform to shrinkage limits except as follows:
      a. Results at end of 28 day drying period shall not exceed 0.030 percent if 3-inch prisms are used, or exceed 0.028 percent if 4-inch prisms are used. Aggregate will be rejected if test values exceed these limits.
   4. Aggregate Grading: Aggregate shall conform to requirements for fine aggregate in accordance with ASTM C33/C33M.
   5. Air-entraining admixtures are prohibited in concrete mixtures and total air content shall not be greater than 3 percent, for the following:
      a. Slabs to receive hard-troweled finish.
      b. Slabs to receive dry shake floor hardener.
      c. Slabs to receive topping placed monolithically as two-course floor on top of plastic concrete.
   6. Unless otherwise specified, provide 6 percent air content.
      a. See ASTM C33/C33M for tolerance on oversize for various nominal maximum size designations.
      b. Tolerance of air content is plus or minus 1.5 percent.
   7. Provide cementitious materials in accordance with one of the following:
      a. ASTM C150/C150M Type II; inclusion of supplementary cementitious materials in design mix is optional.
      b. ASTM C150/C150M types other than Type II, plus supplementary cementitious materials in accordance with one of the following:
         1) Tricalcium Aluminate Content of Total Cementitious Materials: Maximum 8 percent by weight.
         2) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.

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c. ASTM C595/C595M Types IP or IS (less than 70), tested to comply with moderate sulfate resistance option (MS).
   1) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.

8. Unless otherwise permitted, minimum cementitious materials content in mix design shall be 600 pounds per cubic yard.
9. Limit water-soluble, chloride-ion content in hardened concrete to 0.10 percent, unless otherwise specified.
   a. Limits are stated in terms of chloride ions in percent by weight of cement.
   b. Unless otherwise permitted, provide documentation from concrete tested in accordance with ASTM C1218/C1218M at an age between 28 days and 42 days.
10. Fiber Reinforcement:
   a. Provide polypropylene micro-fibers in design mix in accordance with Section 03 24 00, Fibrous Reinforcing.
   b. Add fiber-reinforcement to grout topping in concrete plant.
   c. Slump as required to maintain homogeneous mix and to allow placement to meet equipment manufacturer's placing tolerance.
   d. Mix fiber reinforced grout topping to consistency, easily screeded with [clarifier] [, flotation thickener] [_____] mechanism, but not too thin that topping will not maintain to required thickness.]

D. Grout Strength Tests:
   1. Make three 2-inch by 2-inch cubes for each 150 cubic feet of grout. Use restraining caps for cube molds in accordance with ASTM C109/C109M.
   2. Independent testing laboratory shall prepare, store, cure, and test cubes in accordance with ASTM C109/C109M, except that the proposed grout topping mix design shall be tested in lieu of the mix specified in ASTM C109/C109M.
   3. Store cubes at 70 degrees F.
   4. Nonshrink grout cubes shall test equal to or greater than minimum strength specified.
   5. Strength Test Failures: Unless otherwise permitted, grout work failing strength tests shall be removed and replaced.]

E. Refer to PART 1 through PART 3 of this section for additional requirements.]

END OF SUPPLEMENTAL INFORMATION

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SECTION 03 35 00
CONCRETE FINISHING

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM): C109, Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-In. or 50-Mm Cube Specimens).

1.02 SUBMITTALS

A. Action Submittals: Manufacturer's product data sheet(s).

B. Informational Submittals:

1. Agenda: Conference prior to slab placement.
2. Manufacturer's written procedures for slab preparation, product application, protection of finished surface, and post-application cleanup.
3. Product manufacturers representatives' names and phone numbers.
4. Manufacturer's Certificate of Compliance for products to be furnished.
5. Manufacturer's Certificate of Proper Installation.
6. Statement of Qualifications:
   a. Manufacturer's Product Service Record.
   b. Application personnel.
   c. Manufacturer's representative.
7. Manufacturer's installation instructions.
8. Manufacturer's written instructions for maintenance and repair of floor finishes installed.

1.03 QUALITY ASSURANCE

A. Qualifications:

1. Manufacturer's Product Service Record: Five previous projects at least 5 years old where product was used at representative coverage per square foot.
2. Floor Product Manufacturer: Manufacture components of floor material, except the epoxy, in own plant and under control of trained quality control manager.

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3. Application Personnel: Four previous projects of successful installation of specified materials or manufacturer's training.

B. Preinstallation Training: Manufacturer-approved training of application personnel and quality control inspectors for these floor finishes.

C. Conference Prior to Slab Placement:

1. Conducted by CONTRACTOR.
2. Agenda:
   a. Concrete mix design.
   b. Placing techniques.
   c. Finishing techniques.
   d. Floor hardener application procedures.
   e. Equipment required for these procedures.
3. Attendees:
   a. CONTRACTOR's superintendent.
   b. Subcontractor's representative involved in slab installation and finishing.
   c. ENGINEER.

D. Mockups: Install one 10-foot by 20-foot area for each type of finish floor to demonstrate that the material and methods produce a finished product acceptable to the ENGINEER.

1. Mockup will establish the standard of quality for floor finishes.
2. Use specified materials at a location designated by ENGINEER or OWNER.
3. Notify ENGINEER 5 days in advance of commencement of mockup floor slab application and training.
4. Do not purchase floor materials until mockup slab installation has been accepted by the ENGINEER or OWNER.

E. Color Samples: Minimum 2-inch by 2-inch Sample applications of floor finishes available.

1.04 EXTRA MATERIALS

A. Furnish, tag, and box for shipment and storage the following materials:

Quantity	Item
[_____]	[_____]

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B. Deliver to Site and store in the location directed by ENGINEER or OWNER.

PART 2 - PRODUCTS

2.01 CLEAR LIQUID SEALER DUST PROOFER

A. Colorless, aqueous solution of zinc and magnesium fluorosilicate.

B. Each gallon of solution shall contain a minimum of 2 pounds of fluorosilicate compound.

C. Manufacturers:

1. Master Builders Co., Cleveland, OH.
2. Sonneborn, Minneapolis, MN.
3. Euclid Chemical Co., Cleveland, OH.

2.02 DRY SHAKE HARDENERS

A. Mix: Surface hardener with metallic or natural aggregate, premixed and packaged at factory, delivered to Site ready to apply.

B. Natural Aggregate: Mixture of specially processed graded iron aggregate, selected portland cement, and necessary plasticizing agents formulated, processed, and packaged under stringent quality control at the manufacturer's factory.

1. Manufacturer and Product:
   a. [Natural concrete gray, "Surflex" by Euclid Chemical Co. or "Mastercron" by Master Builders, Cleveland, OH.]
   b. [Colored and high reflective (white) "Surflex" by Euclid Chemical Co. or "Colorcron" by Master Builders, Cleveland, OH.]
   c. [Light reflective, (off-white) 50 percent light reflective "Surflex" by Euclid Chemical Co. or "Light Reflective Mastercron" by Master Builders, Cleveland, OH.]

C. Metallic Aggregate: Metallic aggregate, cementitious binder, plasticizer, water-reducing admixtures, and other ingredients free from nonferrous particles, rust, and material intended to disguise rust.

1. Manufacturer and Product:
   a. [Natural, concrete gray, and colored "Euco-Plate HD" by Euclid Chemical Co. or "Masterplate 200" by Master Builders, Cleveland, OH.]

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b. [Light reflective, (off-white) 50 percent to 57 percent reflectivity "Light Reflective Euco-Plate HD" or "Light Reflective Masterplate 200" by Master Builders, Cleveland, OH.]

c. ["Light Reflective Nonoxidizing" (off-white) 50 percent to 57 percent reflectivity. Composed of specially processed nonoxidizing metallic aggregate and other proprietary ingredients with light reflective properties; "Lumiplate" by Master Builders, Cleveland, OH, or "Light Reflective Diamond Plate" by Euclid Chemical Co., Cleveland, OH.]

2.03 METALLIC AGGREGATE TOPPING

A. Topping Mix: Ready-to-use cement, iron aggregate, and plasticizing agent premixed and prepackaged, requiring only addition of water.

1. Manufacturer and Product: Euco-Top (screedable formulation) by Euclid Chemical Co. or ANVIL-TOP 300 by Master Builders, Cleveland, OH.

B. Topping Compressive Strength: 5,000 psi at 24 hours, 8,800 psi at 7 days, and 12,000 psi at 28 days.

C. Bonding Agent: 100 percent reactive, two-component, modified aliphatic/amine type epoxy resin bonding agent to dry base concrete; "Euco Epoxy No. 452MV" by Euclid Chemical Co. or ANVIL-BOND, manufactured by Master Builders, Cleveland, OH.

D. Membrane Curing Compound: "Super Floor Coat" by Euclid Chemical Co. or [Masterkure] [Masterkure CR] by Master Builders, Cleveland, OH.

E. Epoxy Joint Filler: The epoxy joint filler shall be a two-component, 100 percent solids compound, with a minimum shore D hardness of 50, "Euco 700" by Euclid Chemical Co., "MM-80" Metzger/McGuire.

PART 3 - EXECUTION

3.01 CLEAR LIQUID SEALER DUST PROOFER APPLICATION

A. Before application, thoroughly cure floors to receive treatment for minimum 28 days, keep clean, unpainted, free from membrane curing compounds, and perfectly dry with all Work above them completed.

B. Apply hardener evenly to surface, using three coats, allowing 24 hours between coats.

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1. First coat 1/3 strength, second coat 1/2 strength, and third coat 2/3 strength, mix with water.
2. Apply each coat so as to remain wet on surfaces for 15 minutes.
3. Apply approved treatment in accordance with manufacturer's instructions.
4. After final coat is completed and dry, remove surplus hardener from surface by scrubbing and mopping with water.

3.02 INSTALLATION OF DRY SHAKE HARDENERS

A. Application:

1. Application Rate: [2] [_____] pounds per square foot or as recommended by manufacturer.
2. Penetration: Top 1/8-inch to 3/16-inch depth of floor slab.
3. Commence application immediately upon completion of floating surface area; bleed water shall not be present during and after application.
4. Distribute 2/3 of specified total quantity evenly on concrete surface to receive treatment by mechanical spreader; do not throw shake product.
5. Apply first to areas adjacent to forms, entry ways, columns, and walls where rapid moisture loss may occur.

B. Finishing:1

1. Commence first mechanical float with finishing machines using float blades as soon as shake has absorbed moisture, as indicated by darkening of the surface area.
2. Float until moisture from base slab penetrates through first shake application.
3. Immediately distribute remaining 1/3 of total required shake by spreader and commence second mechanical float, as specified above.
4. Compact surface further by third mechanical float as time and setting characteristics of concrete allow.
5. Do not add water to surface area. In drying conditions, an evaporation retarder may be used to prevent plastic shrinkage cracking and rapid surface drying, subject to manufacturer's recommendations and approval of ENGINEER.
6. Hand or mechanically trowel surface while stiffening progresses, as indicated by loss of sheen with blades relatively flat.
7. Run trowel blades as soon as possible to achieve representative finish obtained on mockup panel.
8. Avoid excessive trowel blade speed which may "burn" or darken floor surface resulting in loss of wear.
9. Remove marks and pinholes in final raised trowel operation.

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C. Curing:

1. Cure treated floor surface to meet the recommendations of the dry shake hardener manufacturer. Apply curing compounds as soon as possible without marring the slab surface.
2. Commence slab protection when curing compound is dry.
   a. Cover slab with nonstaining kraft building paper to protect area from droppings.
   b. Maintain floor free of traffic and loads for at least 10 days after completion.

3.03 INSTALLATION OF METALLIC AGGREGATE TOPPING

A. Existing Concrete Surface Preparation:

1. Conduct vapor transmission test as specified, prior to application of bonding agent.
2. Prepare surface using Blastrac by Wheelabrator-Frye, Inc. or Porta-Shotblast by Nelco Manufacturing Corp. to depth that leaves dry, clean, surface free of unsound areas.
3. Apply bonding agent to dry base concrete slab just prior to placement of topping mix.

B. Armored Joint Treatment:

1. Cut down and remove concrete at joint lines to depth of 1/2 inch and taper back to surface level over 4-inch wide line for joints to receive armor.
2. Hand float cutdown area, working up sufficient paste at surface to ensure integral bond.
3. Mix metallic aggregate dry shake with sufficient water to produce a stiff mortar.
4. Place mortar into prepared joint; screed and float to top of form.
5. Use 2.25 pounds of metallic aggregate dry shake on each side of joint per linear foot.
6. Apply dry shake surface hardener as specified over designated floor area, including armored joint area after armored joint is in place.

C. Mixing: Mix in concrete mixer or ready-mix truck.

1. First add 3/4 of specified water quantity as recommended on product data sheet to mixer.
2. Proceed to add topping mix to water in a slow steady stream, followed by addition of remaining 1/4 of water.

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3. Mix for 3 minutes or as recommended by manufacturer to provide 5-inch to 7-inch slump.
4. Mix shall be screedable and workable similar to concrete and shall not require compaction to attain specified strengths and density.
5. Perform slump test on each placement to ensure compliance with specified slump.
6. Place topping within 1 hour of water addition to mix and prior to loss of required slump.

D. Placement of Aggregate:

1. Application Rate: [1] [_____] inch thick with a minimum of 18 pounds of material per square foot per inch of thickness.
2. Place topping mixture by pump, bucket, or flow and screed level.
3. Finish with wooden bull float, one power floating, and one power troweling, or to meet the manufacturer's recommendations. Do not over finish.

E. Curing:

1. Commence curing immediately after completion of finish operation.
2. Wet cure by continuous water sprinkling or use wet burlap covered with polyethylene for minimum 2-day wet cure.
   a. Apply membrane curing compound specified as recommended by topping manufacturer.

3.04 TESTS AND INSPECTION

A. Vapor Transmission Test: Conduct test on new and existing concrete to show that no surface moisture exists prior to application of specified special floor treatment, as follows:

1. Place polyethylene plastic sheet, minimum 4 feet by 4 feet and sealed along four sides with duct tape to prevent moisture transmission by evaporation, over concrete floor area for 24 hours.
2. Indication of moisture transmission will be apparent by accumulation of moisture on enclosed surface of polyethylene plastic sheet.
3. Do not apply concrete bonding agent until test results indicate moisture is not being transmitted from concrete surface.

B. Strength Tests: Test metallic aggregate topping for compressive strength by making 2-inch by 2-inch cubes in accordance with ASTM C109.

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B. Epoxy Joint Filler:
   1. Allow 90 days after slab placement before filling joints.
   2. Mix and install in accordance with manufacturer's instructions.
   3. Fill contraction or construction joints in areas receiving armored joint treatment.

3.05 MANUFACTURER'S SERVICES

A. Provide manufacturer's representative at Site in accordance with Section 01 43 33, Manufacturers' Field Services, for installation assistance, inspection and certification of proper installation, and training of application personnel.

   1. Technical assistance with design and adjustment of concrete mixes to receive floor finishes and toppings.
   2. Technical assistance to assure and certify application and installation of system being used.
   3. Consultation, direction, and certification of mockup, for full-scale application of floor finishes, and at other times as needed.
   4. Attendance at the conference prior to slab placement to finalize proper methods and procedures.

END OF SECTION

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SECTION 03 39 00
CONCRETE CURING

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM):
   a. C309, Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete.
   b. C1315, Standard Specification for Liquid Membrane-Forming Compounds Having Special Properties for Curing and Sealing Concrete.
2. NSF International: 61, Drinking Water System Components – Health Effects.

1.02 SUBMITTALS

A. Action Submittals:

1. Manufacturers' data indicating compliance with the requirements specified herein for the following products:
   a. Exposed aggregate finish retardant on formed surface.
   b. Evaporation retardant.
   c. Curing compound.
   d. Clear sealer.
   e. Clear floor hardener.
2. Curing methods proposed for each type of element such as slab, walls, beams, and columns in each facility.

B. Informational Submittals:

1. Manufacturer's Certificate of Compliance, in accordance with Section 01 43 33, Manufacturers' Field Services for the following:
   a. Curing compound showing moisture retention requirements.
   b. Retardants for exposed aggregate finish

1.03 QUALITY ASSURANCE

A. Comply with ACI 301 and ACI 302.

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PART 2 - PRODUCTS

2.01 MATERIALS

A. Water-based, high-solids content, non-yellowing, clear, curing compound meeting requirements of ASTM C309 Type I, Class A & B .

B. Curing compound shall be compatible with coatings (including sealer, water-proofing, bonded cementitious topping, or floor tile) which are to be applied to the concrete surface.

C. Manufacturers and Products:

1. BASF Construction Chemicals, Shakopee, MN; Kure 1315.
2. Euclid Chemical Co., Cleveland, OH; Super Diamond Clear VOX.
3. WR Meadows, Inc., Hampshire, IL; VOCOMP-30.
4. BASF Construction Chemicals., Shakopee, MN; Kure-N-Seal.
5. Euclid Chemical Co., Cleveland, OH; Kurez VOX.

D. Evaporation Retardant:

1. Optional: Fluorescent fugitive dye color tint that disappears completely upon drying.
2. Manufacturers and Products:
   a. Master Builders Co., Cleveland, OH; Confilm.
   b. Euclid Chemical Co., Cleveland, OH; Eucobar.

E. Clear Sealer (One-Component Penetrating Silane Sealer):

1. Manufacturers and Products:
   a. Chemrex, Inc., Shakopee, MN; Masterseal SL.
   b. Euclid Chemical Co.; Eucoguard 200.

F. Clear Floor Hardener:

1. Colorless, aqueous solution of zinc and magnesium fluorosilicate.
2. Each gallon of solution shall contain a minimum of 2 pounds of fluorosilicate compound.
3. Manufacturers:
   a. Chemrex, Inc., Shakopee, MN.
   b. Euclid Chemical Co., Cleveland, OH.
   c. Sonneborn, Minneapolis, MN.

G. Retardant for Exposed Aggregate Finish on Slabs:

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1. Manufacturers and Products:
   a. Sika Chemical Corp., Lyndhurst, NJ; Rugasol.
   b. Conrad Sovig Co., San Francisco, CA; Conreveal Top Surface.
   c. Burke Co., San Mateo, CA; Burke True Etch Surface Retarder.
   d. Euclid Chemical Co., Cleveland, OH; Surface Retarder S.
2. Retardant for Exposed Aggregate Finish on Formed Surface:
   a. Manufacturers and Products:
   b. L. M. Scofield Co., Los Angeles, CA; Lithotex Top Surface Retarder.
   c. Conrad Sovig Co., San Francisco, CA; Control Set.
   d. Burke Co., San Mateo, CA; Burke True Etch Surface Retarder.
   e. Euclid Chemical Co., Cleveland, OH; Surface Retarder F.

H. Absorptive Mats: Burlap-polyethylene, minimum 8 ounces per square yard bonded to prevent separation during handling and placing.

I. Water: Clean and potable, containing less than 500 ppm of chlorides.

PART 3 - EXECUTION

3.01 CONCRETE CURING

A. General:

1. Where surfaces are to receive coatings, painting, cementitious material, or other similar finishes, use only water curing procedures. Refer to Interior Finish Schedule for surfaces to receive coatings.
2. Use only water curing on potable water structures.
3. Where curing compound cannot be used, water curing as described below or special methods using moisture shall be agreed upon by ENGINEER prior to placing concrete.
4. As required in Section 03 30 00, Cast-in-Place Concrete, if result of 7-day concrete strength test is less than 50 percent of specified 28-day strength, extend period of moist curing specified below, by 7 additional days.

B. Use one of the following methods as approved by ENGINEER:

1. Walls:
   a. Method 1: Leave concrete forms in place and keep surfaces of forms and concrete wet for 7 days.
   b. Method 2: Continuously sprinkle with water 100 percent of exposed surfaces for 7 days starting immediately after removal of forms.
   c. Method 3: Apply curing compound, where allowed, immediately after removal of forms.

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2. Slabs, Pavements, Sidewalks, and Curbs:
   a. Method 1: Protect surface by water ponding for 7 days.
   b. Method 2: Cover with burlap or cotton mats and keep continuously wet for 7 days.
   c. Method 3: Cover with 1-inch layer of wet sand, earth, or sawdust, and keep continuously wet for 7 days.
   d. Method 4: Continuously sprinkle exposed surface for 7 days.
   e. Method 5 (For Pavements, Sidewalks, and Curbs only; Methods 1 thru 4 only for slabs): Apply curing compound, where allowed, immediately after final finishing when surface will no longer be damaged by traffic.

3.02 EVAPORATION RETARDANT APPLICATION

A. Use on flatwork when environmental conditions are anticipated to cause rapid drying of the concrete surface. Do not use evaporation retardant on potable water structures, unless product is NSF 61 approved.

B. Spray onto surface of fresh flatwork concrete immediately after screeding to react with surface moisture.

C. Reapply as needed to ensure a continuous moist surface until final finishing is completed.

3.03 PRESTRESSED TANK CONCRETE CURING

A. Keep concrete surfaces and form continuously wet for 7 days where portland cement is used, or 3 days where high-early-strength cement is used.

B. Begin curing immediately after initial concrete set has occurred.

C. Do not use curing compounds.

3.04 CLEAR SEALER APPLICATION

A. Apply to floor slabs.

B. Before application and with Work above completed, water cure concrete walls and floors for a minimum of 28 days to receive sealer, keep clean, unpainted, and free from membrane curing compounds.

C. Apply with stiff brush, short nap roller, squeegee, garden sprayer, or conventional paint spray equipment.

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D. Apply at a coverage rate of 125 square feet per gallon to 200 square feet per gallon. Cure sealer on slabs for the following minimum cure time at ambient temperatures shown prior to allowing foot traffic:

1. 90 degrees F: 2 hours.
2. 75 degrees F: 4 hours.
3. 50 degrees F: 8 hours.
4. 35 degrees F: 16 hours.

3.05 CLEAR FLOOR HARDENER APPLICATION

A. [Apply where indicated in Interior Finish Schedule.] [Apply to floor slabs.]

B. Before application and with Work above completed, water cure concrete walls and floors for a minimum of 28 days to receive sealer, keep clean, unpainted, and free from membrane curing compounds.

C. Apply hardener evenly, using three coats, allowing 24 hours between coats.

1. First coat 1/3 strength, second coat 1/2 strength, and third coat 2/3 strength, mix with water.
2. Apply each coat so as to remain wet on surface for 15 minutes.
3. Apply approved hardener in accordance with manufacturer's instructions.
4. After final coat is completed and dry, remove surplus hardener from surface by scrubbing and mopping with water.

3.06 RETARDANT FOR EXPOSED AGGREGATE SURFACES

A. [Apply where indicated on [Interior] [Exterior] Finish Schedule.] [Apply to floor slabs.]

B. Apply in accordance with manufacturer's product instructions.

3.07 MANUFACTURER'S SERVICES

A. Provide manufacturer's representative at Site [in accordance with Section 01 43 33, Manufacturers' Field Services,] for installation assistance, inspection, and certification of proper installation for products specified.

B. Provide clear sealer manufacturer's representative to demonstrate proper application of product.

C. Provide clear floor hardener manufacturer's representative to demonstrate proper mixing and application of product.

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D. Provide curing compound manufacturer's representative to demonstrate proper application of curing compound to show coverage in one coat.

E. Provide retardant for exposed aggregate surfaces manufacturer's representative to demonstrate proper application and surface mortar removal procedures.

END OF SECTION

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SECTION 03 40 00
PRECAST CONCRETE

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Concrete Institute (ACI):
   a. 304R, Guide for Measuring, Mixing, Transporting, and Placing Concrete.
   b. 318, Building Code Requirements for Reinforced Concrete.
2. ASTM International (ASTM):
   a. A36, Standard Specification for Structural Steel.
   b. A416, Standard Specification for Steel Strand, Uncoated Seven-Wire for Prestressed Concrete.
   c. C31, Standard Practice for Making and Curing Concrete Test Specimens in the Field.
   d. C857, Practice for Minimum Structural Design Loading for Underground Precast Concrete Utility Structures.
3. Precast/Prestressed Concrete Institute (PCI):
   a. MNL-117, Manual for Quality Control for Plants and Production of Architectural Precast Concrete Products.
   b. MNL-120, Design Handbook for Precast and Prestressed Concrete, Third Edition.

1.02 SUBMITTALS

A. Action Submittals:

1. Retardant for Exposed Aggregate Finish:
   a. Technical data.
   b. Instructions for product application.
2. Bond Breaker for Tilt-Up Walls:
   a. Technical data.
   b. Evidence of successful use in this type of application.
   c. Instructions for product mixing/application.
3. Sealer for Exterior Surfaces: Product data with mixing/application instructions.
4. Form Liners: Manufacturer’s literature and product data.

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5. Calculations and Technical Data: Proposed details and design calculations for stresses in all critical sections of precast members for all loading conditions including transportation, handling, and erection.
6. Tilt-Up Panel Walls: Show type and location of inserts, extra reinforcement for handling, and other pertinent data for proposed tilt-up construction.
7. Precast Concrete Underground Utility Trench System:
    a. Engineering layout drawings, including: Dimensions of components and identification and location of each trench part in the trench layout.
    b. Bill of Materials.
    c. Detailed catalog cuts for bases, covers, standard miters, tee sections, cross sections, end walls, reducers, radius corners, lifting bars, sealants and tie plates.

B. Informational Submittals:

1. For Precasting Manufacturers Not Listed in Article Quality Assurance:
    a. Experience record on production of precast concrete as shown, with information on precasting plant that will indicate capability to satisfactorily perform the Work.
    b. Evidence of current PCI plant certification.
    c. Complete list of architectural panelwork accomplished in past 2 years, including:
        1) Type of structure.
        2) Name of OWNER.
        3) Address of completed work.
2. Certificate of Compliance: Certify admixtures and concrete do not contain calcium chloride.
3. Test Reports:
    a. For precast manufacturer’s concrete test cylinders.
    b. Inspection of installed panels.
4. Precast Concrete Underground Utility Trench System: Manufacturer’s printed instructions for installation of the precast concrete trench system components.

1.03 QUALITY ASSURANCE

A. Qualifications of Precasting Manufacturers:

1. Precast Concrete and Precast Prestressed Concrete: Product of manufacturer with 3 years experience of producing precast concrete products of quality specified.
2. Precast Plant: PCI certified plant with current certification.

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3. Precasting Manufacturers with Apparent Capability to Meet the Specifications of this Section.
4. Calculations stamped by an ENGINEER registered in the state of California.

B. Samples for Exposed Aggregate Finish:

1. Before starting tilt-up panels, provide two Sample concrete panels for each aggregate finish required, 4 feet square and 3 inches thick for ENGINEER's approval.
2. Vary amounts of retardant to be used.
3. Approved Finish: Constitutes standard of quality required in completed Work.

C. Mockup Panels for Architectural Precast Panels:

1. Review Sample in ENGINEER's office as a guide in preparation of mockup panels.
2. Construct:
   a. One full-size mockup panel for each different type of color or finish as shown to be used and installed in their respective places after approval of final precast Shop Drawings and calculations.
   b. In accordance with details shown using materials, forming systems, reinforcing details, cast-in inserts, and mix proportions, and as specified and approved.
3. Finish:
   a. Uniform in appearance and similar in all respects to Samples on display in ENGINEER's office.
   b. Constitutes standard of quality required in completed Work.
4. If mockup panel does not represent quality required, construct additional mockup panels until approved by ENGINEER.
5. Protect and maintain approved mockup panels at location selected by ENGINEER or until ENGINEER approves installation in their respective locations in the Project.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Formwork:

1. One-piece, full-length, and without seams.
2. As specified in Section 03 10 00, Concrete Forming and Accessories.

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B. Reinforcing Steel: As specified in Section 03 21 00, Reinforcing Steel.

C. Cement: As specified in Section 03 30 00, Cast-in-Place Concrete.

D. Pretensioning Strands: Seven-wire, uncoated, stress relieved, ASTM A416, Grade 270.

E. Aggregates: As specified in Section 03 30 00, Cast-in-Place Concrete, for 3/4-inch maximum size. Furnish of consistent quality, gradation, and color for precast architectural panels to produce uniformity of appearance in all panels.

F. Admixtures: As specified in Section 03 30 00, Cast-in-Place Concrete.

G. Embedded Items:

1. ASTM A36 steel.
2. Anchor Studs: Headed anchor studs (HAS), deformed bar anchors (DBA), or threaded studs as manufactured by Nelson Stud Welding Co., Lorain, OH.
3. Furnish inserts for lifting tilt-up walls, bolting stiffeners, attaching braces, and as otherwise required.
4. Tie Plates in Precast Concrete Utility Trench: hot dipped galvanized.

H. Grout: Nonshrink, nonmetallic Type II grout as specified in Section 03 62 00, Nonshrink Grouting.

I. Retardant for Exposed Aggregate Finish Manufacturers:

1. Sika Chemical Corp.; Rugasol.
2. Burke Co.; Exposed Aggregate Compound.

J. Sealer for Exterior Surfaces:

1. Silane Sealer: One-component penetrating sealer, hydrophilic (isopropyl alcohol as a carrier) with 40 percent active ingredients.
2. Manufacturers:
   a. Master Builders Co.
   b. Euclid Chemical Co.

K. Bond Breaker for Tilt-up Walls: Nonstaining, effective as a parting compound, will not leave film, quick drying, nontacky, rainproof, and provides reasonable abrasion resistance.

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1. Manufacturers:
   a. Cresset Chemical Co.
   b. The Burke Co.

L. Precast Prestressed Concrete Members: [girders,] [single tees,] [double tees,] [voided slabs,] [_____,] [_____] feet wide by [_____] feet deep.

2.02 CONCRETE MIX

A. As specified in Section 03 30 00, Cast-in-Place Concrete.

B. Design Strength: 5,000psi at 28 days.

C. Water/Cement Ratio: 0.38 maximum.

D. For colored precast concrete, coordinate ingredients and procedures to achieve uniformity of color.

2.03 DESIGN REQUIREMENTS

A. Precast Architectural Wall Panels:

1. Crack Control: PCI MNL-120.
2. Stresses: Limit tensile stress in the panels, from all handling and installation loads, to that less than that which would cause cracking on the exposed face.
3. Impact Design: Minimum 50 percent of member weight.
4. Tensile Stresses: Do not exceed those recommended in Chapter 5 of above referenced manual for a safety factor of 1.5 in critical sections under all loading conditions.
5. Design and reinforce to withstand handling and erection loads.

B. Structural Precast and Prestressed Members, Except for Architectural Panels:

1. Meet applicable sections of PCI MNL-120.
2. Design for spans and superimposed live and dead loads shown plus dead loads of members.

C. Precast Concrete Underground Utility Trench System:

1. Components shall be designed to conform to requirements of ASTM C857, ASYM C858, and ACI 318, and as specified herein.
2. Provide a one-piece trench section with solid bottom having all components designed for AASHTO HS20, 32,000 pound axle loads.

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3. Provide trench system cross-section dimensions as detailed and per indicated location shown on the Drawings.
4. Provide the precast base in 10 foot lengths unless otherwise approved by the ENGINEER or required to satisfy the horizontal and vertical alignment, or to complete closures, shown on the Drawings.
5. Provide steel reinforced concrete lids on all length of trench section except where galvanized steel lid is shown on the drawings at a specific location. Length of the galvanized steel lid shall be as indicated on the Drawings.
6. Provide bolted tie plates with 6-inch minimum length channel strut embedded in the bases to connect the sections together to minimize shifting and/or differential settlement. Provide a tie plate every 50 feet minimum designed with capability for accommodating thermal expansion and contraction anticipated at the Project site conditions.
7. Manufacturer:
   a. Trenwa, Ft. Thomas, Kentucky.
   b. Barkman, Winnipeg, Canada.
   c. Modern Precast Concrete, Pennsylvania.
   d. Or approved equal

2.04 FABRICATION

A. General:

1. Comply with PCI MNL-117.
2. Reinforcing Steel and Pretensioning Strands:
   a. Place in position before concrete is cast.
   b. Keep clean and free from form oil or other substances harmful to bond.
3. Pretensioning Force, if Used: Determine by elongation and by gauge pressure.
   a. Method: Meet requirements of Prestressed Concrete Institute.
   b. Forms: Produce smooth surfaces.
   c. Concrete: Deposit, vibrate, finish, and cure in accordance with recommended practices of ACI 304R. Steam curing is permitted.
4. Release Strength for Pretensioning Method: Minimum 4,000 psi, unless otherwise approved.
5. Coordinate dimensions, determine type, quantity, size, and location of, and furnish necessary embedded items in precast concrete. Coordinate location of embedded items in cast-in-place concrete necessary to connect precast items.

B. Surface Finish for Precast Structural Units:

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1. Furnish concrete finish, as specified in Section 03 30 00, Cast-in-Place Concrete, to additional concrete field placed on precast units.
2. Other Surfaces: Smooth screeded finishes, unless otherwise shown.

C. Surface Finish for Precast Architectural Panels or Tilt-Up Walls:

1. Exposed Surfaces in Building Interior: As shown.
2. Panel Interior Surface: [As shown.] [Steel trowel, Type S-1, as specified in Section 03 30 00, Cast-in-Place Concrete.]
3. Meet standard of quality represented by approved mockup panel.
4. Furnish panels from same manufacturer.

D. Sealer:

1. Apply to panels or walls as indicated on the Drawings or specified herein, at Site in accordance with manufacturer's instructions.
2. Protect surface until installed in the Work.
3. Repair damage as approved by manufacturer.

2.05 SOURCE QUALITY CONTROL

A. Prepare minimum three standard concrete test cylinders for each 50 cubic yards or fraction thereof of concrete placed in the precast work in accordance with ASTM C31.

B. Test and record concrete strengths.

PART 3 - EXECUTION

3.01 ERECTION

A. Verify that anchorage inserts are in correct locations.

B. Handle and erect precast concrete with care as recommended by manufacturer.

C. Erect precast units plumb, straight, level, square, and in proper alignment.

D. Fasten units securely in place and brace to maintain position, stability, and alignment until permanently connected and structure is complete and stable.

E. Field Cutting: Not allowed without prior approval of ENGINEER.

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3.02 TILT-UP PANEL WALLS

A. General: Plan operation so no equipment for raising slabs is placed on concrete floors.

B. Casting Slab:

1. Use finished concrete floor.
2. Cast tilt-up panels on this slab, unless otherwise approved.
3. Do not cast panels on warped surfaces, across construction joints, or surfaces pitched to drain outlets.
4. Bond Breaker: Apply in accordance with manufacturer's recommendations.

C. Casting Slab:

1. Finished Slab: True and level plane with smooth trowel finish.
2. Bond Breaker: Apply in accordance with manufacturer's recommendations as approved.

D. Reglets: Install in forms in straight lines in accordance with manufacturer's recommendations.

E. Exposed Aggregate Finish:

1. Retardant Application:
   a. Shake uniformly over freshly placed concrete surface immediately following finishing process and before all surface water has disappeared.
   b. Rate: To affect a depth of 1/8 inch or more exposure of aggregate, as approved.
   c. In accordance with manufacturer's recommendations.
2. Curing: Cover with wet burlap or other acceptable covering and maintain in a moist state.
3. Hose or brush off retarded concrete surface to expose clean aggregate.
4. After retarded concrete has been removed, cure panels in the manner specified in Section [03 39 00, Concrete Curing] [_____].
5. Where sides of panels are to be exposed aggregate, paint forms with two coats of retardant before placing concrete.
6. Finish: To match Sample approved by ENGINEER.

F. Lifting and Setting Panels in Position:

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1. Caution: Walls or panels are not stable in themselves against lateral loads, such as wind until construction is complete. Provide bracing as required.
2. Do not move panels until concrete has obtained the design field strength required by design calculation for handling stresses, including impact. Field strength shall be determined by test cylinders.
3. Pickup Lines: Provide equal lifting force at panel pickup points, applied simultaneously and acting at right angles to panel.
4. Excessive Stresses or Shock Loading: Prevent when lifting panel from casting surface, consider form suction and impact using Part 5 of PCI MNL-120 Design Handbook.
5. Lifting Equipment: Of size and capacity to prevent damage to panel.
6. Set panels on carefully leveled shims.
7. Position, plumb and align true to line, and brace securely.
8. Bottom Joint Space: Fill with nonshrink nonmetallic grout as shown and as specified in Section 03 62 00, Nonshrink Grouting, as soon as panels are placed and braced.
9. Insert Holes: Fill with nonshrink nonmetallic grout.
10. Holes in Exposed Surfaces: Patch to match adjacent surfaces.
11. Make welded connections.

G. Cast-In-Place Pilasters and Closing Sections: As specified in Section 03 30 00, Cast-in-Place Concrete.

3.03 PRECAST CONCRETE TRENCH SYSTEMS

A. Install the precast concrete trench system in strict accordance with the manufacturer’s printed instructions and as shown on the Drawings to provide a completed system in accordance with the grades and horizontal alignment as shown on the Drawings.

B. Set the trench bases on a minimum 4-inch depth bed of sand to ensure continuous, uniform support. Ensure no protruding rocks in the trench bottom or sides are closer than 4 inches to the precast concrete sections.

C. Provide mitered ends, tee sections, cross sections, and end walls to construct a fully enclosed trench base section for a completed system as shown on the Drawings.

D. Handle the base sections and covers when transporting and installing in the prepared trench in a manner that prevents damage to any component of the completed system. Remove and replace any damaged (in the opinion of the ENGINEER) component.

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E. All joints between sections shall be water-resistant. Provide joint sealant material provided by the system manufacturer. Install in accordance with the trench system manufacturer's printed instructions.

F. After the bases have been securely set in the prepared trench and pulled together bolt together the furnished tie plates.

G. Backfill the space between the exterior walls of precast sections and the side walls of the prepared trench as shown on the Drawings with Class __ material as specified in Section ____ and compact to the requirements for pipe installation as specified in Section ____.

H. Provide corner guards on all corners of tees, crosses and interior corners of turns 45 degrees and greater to protect contained pipe from abrasion.

I. After the base section installation has been completed and the trench backfilled and compacted, install the trench lids.

1. On trenches with concrete lids, furnish and install a neoprene gasket the full length of the horizontal lid bearing surface on each side of the base to minimize movement that may chip the lid sections. Clean the bearing surface of any foreign material before installing the neoprene gasket and then clean the exposed surface of the gasket before setting the lid to ensure a continuous, uniform bearing surface.
2. Avoid overlapping the joints as this may cause an uneven bearing surface that could result in damage to the lid.

J. Fill the recessed cavity surrounding each lifting eye with sealant in accordance with the requirements specified in Section _____.

3.04 PATCHING

A. To minimize shrinkage, mix and place patching mixture to match color and texture of surrounding concrete.

B. Demonstrate patching method and obtain acceptance and approval.

3.05 CLEANING

A. After installation, clean soiled precast concrete surfaces with detergent and water, using fiber brush and sponge.

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B. Use acid solution only to clean particularly stubborn stains after more conservative methods have been tried unsuccessfully.

C. Use extreme care to prevent damage to precast concrete surfaces and to adjacent materials.

D. Rinse thoroughly with clean water immediately after using cleaner.

3.06 FIELD QUALITY CONTROL

A. Inspection:

1. With ENGINEER, inspect precast architectural wall panels for chips, cracks, discoloration, and other damage.
2. Compare every panel to approved mockup panel and finish sample panel.
3. Record location and condition of damaged or nonmatching panels.

B. Resolution:

1. Repair damage to satisfaction of ENGINEER and OWNER.
2. Remove panels with damage or repairs not acceptable to ENGINEER.
3. Install new acceptable panels in place of those removed.
4. Perform reinspection and obtain acceptance by ENGINEER.

3.07 PROTECTION

A. Protect precast units from chipping, spalling, cracking, or other damage to the units after delivery to Site.

B. After erection, protect units from damage.

END OF SECTION

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SECTION 03 62 00
NONSHRINK GROUTING

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM):
   a. C230, Standard Specification for Flow Table for Use in Tests of Hydraulic Cement.
   b. C621, Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrinkable).
   c. C939, Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method).
   d. C1107/C1107M, Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink).

1.02 SUBMITTALS

A. Action Submittals:

1. Product data of grouts.
2. Proposed method for keeping existing concrete surfaces wet prior to placing grout.
3. Forming method for fluid grout placements.
4. Curing method for grout.

B. Informational Submittals:

1. Manufacturer's Written Instructions:
   a. Adding fiber reinforcing to batching.
   b. Cement-water ratio of grout topping.
   c. Mixing of grout.
2. Manufacturer's proposed training schedule for grout work.
3. Manufacturer's Certificate of Compliance:
   a. Grout free from chlorides and other corrosion-causing chemicals.
   b. Nonshrink grout properties of Category II and Category III, verifying expansion at 3 days or 14 days will not exceed the 28-day expansion and nonshrink properties are not based on gas or gypsum expansion.
4. Manufacturer's Certificate of Proper Installation.

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5. Statements of Qualification: Nonshrink grout manufacturer's representative.
6. Test Reports:
   a. Test report for 24-hour evaluation of nonshrink grout.
   b. Test results and service report from demonstration and training session.
   c. Field test reports and laboratory test results for field-drawn Samples.

1.03 QUALIFICATIONS

A. Nonshrink Grout Manufacturer's Representative: Authorized and trained representative of grout manufacturer. Minimum of 1-year experience that has resulted in successful installation of grouts similar to those for this Project.

B. For grout suppliers not listed herein, provide completed 24-hour Evaluation of Nonshrink Grout Test Form, attached at the end of this section. Independent testing laboratory to certify that testing was conducted within last 18 months.

1.04 GUARANTEE

A. Manufacturer's guarantee shall not contain disclaimer on the product data sheet, grout bag, or container limiting responsibility to only the purchase price of products and materials furnished.

B. Manufacturer guarantees participation with CONTRACTOR in replacing or repairing grout found defective as a result of faulty materials, as determined by industry standard test methods.

PART 2 - PRODUCTS

2.01 NONSHRINK GROUT SCHEDULE

A. Furnish nonshrink grout for applications in grout category in the following schedule:

Application	Temperature Range	Max. Placing Time	
	40 deg F to 100 deg F	20 Min.	Greater Than 20 Min.
Filling tie holes	I	I	I
Blockouts for gate guides	I or II		II

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Application	Temperature Range	Max. Placing Time	
	40 deg F to 100 deg F	20 Min.	Greater Than 20 Min.
Precast joints	I or II		II
Column baseplates single-story	I or II		II
Machine bases 25 hp or less	II	II	II
Bases for precast wall sections	II	II	II
Baseplates for columns over one story	II	II	II
Precast base joints higher than one story	II	II	II
Through-bolt openings	II	II	II
Machine bases 26 hp and up	III	III	III
Baseplates and/or soleplates with vibration, thermal movement, etc.	III	III	III

2.02 NONSHRINK GROUT

A. Category I:

1. Nonmetallic and nongas-liberating.
2. Prepackaged natural aggregate grout requiring only the addition of water.
3. Test in accordance with ASTM C1107/C1107M:
   a. Grout shall have flowable consistency.
   b. Flowable for 15 minutes.
4. Grout shall not bleed at maximum allowed water.
5. Minimum strength of flowable grout, 3,000 psi at 3 days, 5,000 psi at 7 days, and 7,000 psi at 28 days.
6. Manufacturers and Products:
   a. BASF Building Systems, Inc., Shakopee, MN; Construction Grout.

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b. Euclid Chemical Co., Cleveland, OH; NS Grout.
c. Dayton Superior Corp., Kansas City, KS; 1107 Advantage Grout.
d. US MIX Co., Denver, CO; US Spec MP Grout.
e. L & M Construction Chemicals, Inc., Omaha, NE; Duragrout.

B. Category II:

1. Nonmetallic, nongas-liberating.
2. Prepackaged natural aggregate grout requiring only the addition of water.
3. Aggregate shall show no segregation or settlement at fluid consistency at specified times or temperatures.
4. Test in accordance with ASTM C1107/C1107M:
   a. Fluid consistency 20 seconds to 30 seconds in accordance with ASTM C939.
   b. Temperatures of 40 degrees F, 80 degrees F, and 100 degrees F.
5. 1 hour after mixing, pass fluid grout through flow cone with continuous flow.
6. Minimum strength of fluid grout, 3,500 psi at 1 day, 4,500 psi at 3 days, and 7,500 psi at 28 days.
7. Maintain fluid consistency when mixed in 1 to 9 yard loads in ready-mix truck.
8. Manufacturers and Products:
   a. BASF Building Systems, Inc., Shakopee, MN; Master Flow 928.
   b. Five Star Products Inc., Fairfield, CT; Five Star Fluid Grout 100.
   c. Euclid Chemical Co., Cleveland, OH; Hi Flow Grout.
   d. Dayton Superior Corp., Kansas City, KS; Sure Grip High Performance Grout.
   e. L & M Construction Chemicals, Inc., Omaha, NE; Crystex.

C. Category III:

1. Metallic and nongas-liberating.
2. Prepackaged aggregate grout requiring only the addition of water.
3. Aggregate shall show no segregation or settlement at fluid consistency at specified times or temperatures.
4. Test in accordance with ASTM C1107/C1107M:
   a. Fluid consistency 20 seconds to 30 seconds in accordance with ASTM C939.
   b. Temperatures of 40 degrees F and 100 degrees F.
5. 1 hour after mixing, pass fluid grout through flow cone with continuous flow.

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6. Minimum strength of fluid grout, 4,000 psi at 1 day, 5,000 psi at 3 days, and 9,000 psi at 28 days.
7. Maintain fluid consistency when mixed in 1 to 9 yard loads in ready-mix truck.
8. Manufacturer and Product:
   a. BASF Building Systems, Inc., Shakopee, MN; EMBECO 885.
   b. L & M Construction Chemicals, Inc., Omaha, NE; Ferrogrout.

PART 3 - EXECUTION

3.01 NONSHRINK GROUT

A. General: Mix, place, and cure nonshrink grout in accordance with grout manufacturer's representative's training instructions.

B. Form Tie or Through-Bolt Holes: Provide nonshrink grout, Category I and Category II, fill space with dry pack dense grout hammered in with steel tool and hammer. Through-bolt holes; coordinate dry pack dense grout application with vinyl plug in Section 03 10 00, Concrete Forming and Accessories, and bonding agent in Section 03 30 00, Cast-in-Place Concrete.

C. Grouting Machinery Foundations:

1. Block out original concrete or finish off at distance shown below bottom of machinery base with grout. Prepare concrete surface by sandblasting, chipping, or by mechanical means to remove any soft material.
2. Set machinery in position and wedge to elevation with steel wedges, or use cast-in leveling bolts.
3. Form with watertight forms at least 2 inches higher than bottom of plate.
4. Fill space between bottom of machinery base and original concrete in accordance with manufacturer's representative's training instructions.

3.02 FIELD QUALITY CONTROL

A. Evaluation and Acceptance of Nonshrink Grout:

1. Provide a flow cone and cube molds with restraining plates onsite. Continue tests during Project as demonstrated by grout manufacturer's representative.
2. Perform flow cone and bleed tests, and make three 2-inch by 2-inch cubes for each 25 cubic feet of each type of nonshrink grout used. Use restraining caps for cube molds in accordance with ASTM C1107/C1107M.

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3. For large grout applications make three additional cubes and one more flow cone test. Include bleed test for each additional 25 cubic feet of nonshrink grout placed.
4. Consistency: As specified in Article Nonshrink Grout. Grout with consistencies outside range requirements shall be rejected.
5. Segregation: As specified in Article Nonshrink Grout. Grout when aggregate separates shall be rejected.
6. Nonshrink grout cubes shall test equal to or greater than minimum strength specified.
7. Strength Test Failures: Nonshrink grout work failing strength tests shall be removed and replaced.
8. Perform bleeding test to demonstrate grout will not bleed.
9. Store cubes at 70 degrees F.
10. Independent testing laboratory shall prepare, store, cure, and test cubes in accordance with ASTM C1107/C1107M.

3.03 MANUFACTURER'S SERVICES

A. General:

1. Coordinate demonstrations, training sessions, and applicable Site visits with grout manufacturer's representative.
2. Provide and conduct onsite, demonstration and training sessions for bleed tests, mixing, flow cone measurement, cube testing, application, and curing for each category and type of nonshrink grout.
3. Necessary equipment and materials shall be available for demonstration.

B. Training:

1. Training is required for all [Type II and] Type III grout installations.
2. Grout manufacturer's representative shall train CONTRACTOR to perform grout work.
3. Establish location at Site and schedule time for grout manufacturer's demonstration and training session of proposed nonshrink grouts. Mix nonshrink grouts to required consistency, test, place, and cure on actual Project, such as, baseplates and tie holes to provide actual on-the-job training.
4. Use minimum of **[**five] **[_____]** bags for each grout [Category II and] Category III. Mix grout to fluid consistency and conduct flow cone and two bleed tests, make a minimum of six cubes for testing of two cubes at 1 day, 3 days, and 28 days. Use remaining grout for final Work.
5. Training shall include methods for curing grout.

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6. [Mix and demonstrate patching through-bolt holes and blockouts for gate guides, and similar items.]
7. Transport test cubes to independent test laboratory and obtain test reports.

3.04 SUPPLEMENTS

A. The supplement listed below, following "End of Section," is part of this Specification.

1. 24-hour Evaluation of Nonshrink Grout Test Form and Grout Testing Procedures.

END OF SECTION

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GROUT TESTING PROCEDURES

A. Bagged Material:

1. List lot numbers. _____

2. List expiration date. _____

3. Weigh bags and record weight. _____

OWNER's Representative will disqualify grout if bag weights have misstated measure plus or minus 2 pounds by more than one out of five bags. (Accuracy of weights is required to regulate amount of water used in mixing since this will affect properties.)

B. Mixing and Consistency Determination:

1. Mix full bag of grout in 10 gallon pail.

2. Use electric drill with a paddle device to mix grout (jiffy or jiffler type paddle).

3. Use maximum water allowed per water requirements listed in bag instructions.

4. Mix grout to maximum time listed on bag instructions.

5. In accordance with ASTM C939 (flow cone) determine time of mixed grout through the flow cone. _____ seconds.

6. Add water to attain 20 to 30 second flow in accordance with ASTM C939.

7. Record time of grout through cone at new water demand. _____ seconds

8. Record total water needed to attain 20 to 30 second flow. _____ pounds

9. Record percent of water. _____ percent

C. When fluid grout is specified and additional water is required beyond grout manufacturer's listed maximum water, ASTM C1107/C1107M will be run at new water per grout ratio to determine whether grout passes using actual water requirements to be fluid. Use new water per grout ratio on remaining tests.

D. Bleed Test:

1. Fill two gallon cans half full of freshly mixed grout at ambient temperatures for each category and at required consistency for each.

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2. Place one can of grout in tub of ice water and leave one can at ambient temperature.

3. Cover top of both cans with glass or plastic plate preventing evaporation.

4. Maintain 38 degrees F to 42 degrees F temperature with grout placed in ice and maintain ambient temperature for second container for 1 hour.

5. Visually check for bleeding of water at 15-minute intervals for 2 hours.

6. Perform final observation at 24 hours.

If grout bleeds a small amount at temperatures specified, grout will be rejected.

E. Extended Flow Time and Segregation Test (for Category II and Category III):

1. Divide the remaining grout into two 3 gallon cans. Place the cans into the 40-degree F and 100-degree F containers and leave for 20, 40, and 60 minutes. Every 20 minutes remove and check for segregation or settlement of aggregate. Use a gloved hand to reach to the bottom of the can, if more than 1/4-inch of aggregate has settled to the bottom or aggregate has segregated into clumps reject the grout.

2. Right after the settlement test mix the grout with the drill mixer for 10 seconds. Take ASTM C939 flow cone test of grout and record flow time. Maintain this process for 1 hour at ambient temperatures of 40 degrees F and 100 degrees F.

   a. 20 min _____, sec. @ 40 degrees F.

   b. 40 min _____, sec. @ 40 degrees F.

   c. 60 min _____, sec. @ 40 degrees F.

   d. 20 min _____, sec. @ 100 degrees F.

   e. 40 min _____, sec. @ 100 degrees F.

   f. 60 min _____, sec. @ 100 degrees F.

All Category II and Category III grout that will not go through the flow cone with continuous flow after 60 minutes will be disqualified.

_____ Qualified

_____ Disqualified

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2. Place one can of grout in tub of ice water and leave one can at ambient temperature.

3. Cover top of both cans with glass or plastic plate preventing evaporation.

4. Maintain 38 degrees F to 42 degrees F temperature with grout placed in ice and maintain ambient temperature for second container for 1 hour.

5. Visually check for bleeding of water at 15-minute intervals for 2 hours.

6. Perform final observation at 24 hours.

If grout bleeds a small amount at temperatures specified, grout will be rejected.

E. Extended Flow Time and Segregation Test (for Category II and Category III):

1. Divide the remaining grout into two 3 gallon cans. Place the cans into the 40-degree F and 100-degree F containers and leave for 20, 40, and 60 minutes. Every 20 minutes remove and check for segregation or settlement of aggregate. Use a gloved hand to reach to the bottom of the can, if more than 1/4-inch of aggregate has settled to the bottom or aggregate has segregated into clumps reject the grout.

2. Right after the settlement test mix the grout with the drill mixer for 10 seconds. Take ASTM C939 flow cone test of grout and record flow time. Maintain this process for 1 hour at ambient temperatures of 40 degrees F and 100 degrees F.

   a. 20 min _____, sec. @ 40 degrees F.

   b. 40 min _____, sec. @ 40 degrees F.

   c. 60 min _____, sec. @ 40 degrees F.

   d. 20 min _____, sec. @ 100 degrees F.

   e. 40 min _____, sec. @ 100 degrees F.

   f. 60 min _____, sec. @ 100 degrees F.

All Category II and Category III grout that will not go through the flow cone with continuous flow after 60 minutes will be disqualified.

_____ Qualified

_____ Disqualified

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F. 24-hour Strength Test:

1. Using grout left in mixing cans in accordance with ASTM C1107/C1107M for mixing and consistency determination test and for extended time flow test, make minimum of nine cube samples.

2. Store cubes at 70 degrees F for 24 hours.

3. Record average compressive strength of nine cubes at 24 hours.

Grout will be disqualified if 24-hour compressive strengths are less than 2,500 psi for grouts claiming fluid placement capabilities.

Grouts that have not been disqualified after these tests are qualified for use on the Project for the application indicated in Nonshrink Grout Schedule.

Signature of Independent Testing Laboratory	Date Test Conducted

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SECTION 05 05 23
WELDING

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards that may be referenced in this section:

1. American Society of Mechanical Engineers (ASME):
   a. BPVC SEC V, Nondestructive Examination.
   b. BPVC SEC IX, Welding and Brazing Qualifications.
2. American Society of Nondestructive Testing (ASNT): SNT-TC-1A, Personnel Qualification and Certification in Nondestructive Testing.
3. ASTM International (ASTM): A370, Standard Test Methods and Definitions for Mechanical Testing of Steel Products.
4. American Welding Society (AWS):
   a. A2.4, Standard Symbols for Welding, Brazing, and Nondestructive Examination.
   b. A3.0, Standard Welding Terms and Definitions.
   c. D1.1/D1.1M, Structural Welding Code - Steel.
   d. D1.2/D1.2M, Structural Welding Code - Aluminum.
   e. D1.3/1.3M, Structural Welding Code - Sheet Steel.
   f. D1.4/D1.4M, Structural Welding Code - Reinforcing Steel.
   g. D1.6/D1.6M, Structural Welding Code - Stainless Steel.
   h. QC1, Standard for AWS Certification of Welding Inspectors.

1.02 DEFINITIONS

A. CJP: Complete Joint Penetration.

B. CWI: Certified Welding Inspector.

C. MT: Magnetic Particle Testing.

D. NDE: Nondestructive Examination.

E. NDT: Nondestructive Testing.

F. PJP: Partial Joint Penetration.

G. PQR: Procedure Qualification Record.

H. PT: Liquid Penetrant Testing.

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I. RT: Radiographic Testing.

J. UT: Ultrasonic Testing.

K. VT: Visual Testing.

L. WPQ: Welder/Welding Operator Performance Qualification.

M. WPS: Welding Procedure Specification.

1.03 SUBMITTALS

A. Shop Drawings:

1. Shop and field WPSs and PQRs.
2. NDT procedure specifications prepared in accordance with ASME BPVC SEC V.
3. Welding Data (Shop and Field): Submit welding data together with shop drawings as a complete package.
    a. Show on Shop Drawings or a weld map complete information regarding base metal specification designation, location, type, size, and extent of welds with reference called out for WPS and NDE numbers in tails of combined welding and NDE symbols as indicated in AWS A2.4.
    b. Distinguish between shop and field welds.
    c. Indicate, by welding symbols or sketches, details of welded joints and preparation of base metal. Provide complete joint welding details showing bevels, groove angles, and root openings for welds.
    d. For pipe fittings, provide a joint weld beveling diagram. Refer to AWS D1.1/D1.1M, Annex P Local Dihedral Angle that can be used to calculate bevels for weld joint details of intersecting pipes.
    e. Welding and NDE symbols shall be in accordance with AWS A2.4.
    f. Welding terms and definitions shall be in accordance with AWS A3.0.

B. Informational Submittals:

1. WPQs.
2. CWI credentials.
3. Testing agency personnel credentials.
4. CWI reports.
5. Welding Documentation: Submit on forms in referenced welding codes.

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1.04 QUALIFICATIONS

A. WPSs: In accordance with [AWS D1.1/D1.1M (Annex N Forms)] for shop or field welding; or ASME BPVC SEC IX (Forms QW-482 and QW-483) for shop welding only.] [_____].

B. WPQs: In accordance with [AWS D1.1/D1.1M (Annex N Forms) ; or ASME BPVC SEC IX (Form QW-484)] [_____].

C. CWI: Certified in accordance with AWS QC1, and having prior experience with specified welding codes. Alternate welding inspector qualifications require approval by Engineer.

D. Testing Agency: Personnel performing tests shall be NDT Level II certified in accordance with ASNT SNT-TC-1A.

1.05 SEQUENCING AND SCHEDULING

A. Unless otherwise specified, Submittals required in this section shall be submitted and approved prior to commencement of welding operations.

PART 2 - PRODUCTS

2.01 SOURCE QUALITY CONTROL

A. CWI shall be present whenever shop welding is performed. CWI shall perform inspection, as necessary, prior to assembly, during assembly, during welding, and after welding. CWI shall perform inspections as required in AWS D1.1/D1.1M or referenced welding code and as follows:

1. Verifying conformance of specified job material and proper storage.
2. Monitoring conformance with approved WPS.
3. Monitoring conformance of WPQ.
4. Inspecting weld joint fit-up and performing in-process inspection.
5. Providing 100 percent visual inspection of welds.
6. Supervising nondestructive testing personnel and evaluating test results.
7. Maintaining records and preparing report confirming results of inspection and testing comply with the Work.

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PART 3 - EXECUTION

3.01 GENERAL

A. Welding and Fabrication by Welding: Conform to governing welding codes referenced in attached Welding and Nondestructive Testing Table.

B. [Welding procedure specifications [for pressure piping] [_____] shall be qualified for notch toughness by limiting heat input; charpy testing of weld metal and heat-affected zone shall be done as a part of the welding procedure qualification. Full-size specimens shall be charpy tested in accordance with ASTM A370 at a test temperature of [30 degrees F] [_____]. The minimum average energy of the test coupons shall not be less than [25 foot-pounds] [_____].]

3.02 NONDESTRUCTIVE WELD TESTING REQUIREMENTS

A. Weld Inspection Criteria:

1. Selection of welds to be tested, unless 100 percent NDT is specified herein, shall be as agreed upon between Engineer and Contractor.
2. Unless otherwise specified, perform NDT of welds at a frequency as shown below and in the attached Table in accordance with referenced welding codes as follows. Perform UT on CJP groove welds that cannot be readily radiographed. In case there is a conflict, higher frequency level of NDT shall apply.
   a. CJP Groove, Butt Joint Welds: [10 percent random RT] [_____].
   b. All other CJP Groove Welds: [10 percent random UT] [_____].
   c. Fillet Welds and PJP Groove Welds: [10 percent random PT or MT] [_____].
   d. All Welds: 100 percent VT.
3. Weld Acceptance:
   a. VT:
      1) Structural Pipe and Tubing: AWS D1.1/D1.1M, Paragraph 6.9, Visual Inspection, Tubular Connections.
      2) All Other Structural Steel: AWS D1.1/D1.1M, Paragraph 6.9, Visual Inspection, Statically Loaded Nontubular Connections.
      3) Stud Connections: AWS D1.1/D1.1M, Paragraph 7.8.1.
   b. UT: Perform on CJP groove welds in accordance with AWS D1.1/D1.1M, Paragraph 6.13.3, Class R Indications.
   c. RT: Perform on CJP butt joint welds in accordance with AWS D1.1/D1.1M, Paragraph 6.12.1.
   d. PT or MT:

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1) Perform on fillet and PJP groove welds in accordance with AWS D1.1/D1.1M, Paragraph 6.10.
2) Acceptance shall be in accordance with VT standards specified above.

3.03 FIELD QUALITY CONTROL

A. CWI shall be present whenever field welding is performed. CWI shall perform inspection, as necessary, prior to assembly, during assembly, during welding, and after welding. CWI shall perform inspections as required in AWS D1.1/D1.1M or referenced welding code and as follows:

1. Verify conformance of specified job material and proper storage.
2. Monitor conformance with approved WPS.
3. Monitor conformance of WPQ.
4. Inspect weld joint fit-up and perform in-process inspection.
5. Provide 100 percent visual inspection of all welds.
6. Supervise nondestructive testing personnel and evaluating test results.
7. Maintain records and prepare report confirming results of inspection and testing comply with the Work.

3.04 WELD DEFECT REPAIR

A. Repair and retest rejectable weld defects until sound weld metal has been deposited in accordance with appropriate welding codes.

3.05 SUPPLEMENTS

A. The supplement listed below, following “End of Section,” is a part of this Specification.

1. Welding and Nondestructive Testing Table.

END OF SECTION

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Welding and Nondestructive Testing						
Specification Section	**Governing Welding Codes or Standards**	**Submit WPS**	**Submit WPQ**	**Onsite CWI Req'd**	**Submit Written NDT Procedure Specifications**	**NDT Requirements**
03 21 00 Reinforcing Steel	AWS D1.4/D1.4M, Structural Welding Code - Reinforcing Steel	Yes	Yes	Yes	Yes	100% MT of all rebar splices; also see Section 03 21 00
03 40 00 Precast Concrete	AWS D1.1/D1.1M, Structural Welding Code - Steel and AWS D1.4/D1.4M, Structural Welding Code - Reinforcing Steel	[Yes] [No]	[Yes] [No]	Yes	[Yes] [No]	100% VT; also see Section 03 40 00
05 12 00 Structural Steel Framing	AWS D1.1/D1.1M, Structural Welding Code - Steel	Yes	Yes	Yes	Yes	10% UT or RT of all groove-and-butt joint welds; 10% MT of all fillet welds; also see Section 05 12 00
05 21 19 Open Web Steel Joists Framing	AWS D1.1/D1.1M, Structural Welding Code - Steel	[Yes] [No]	[Yes] [No]	Yes	[Yes] [No]	100% VT; also see Section 05 21 19
05 31 00 Steel Decking	AWS D1.1/D1.1M, Structural Welding Code - Steel or AWS D1.3/D1.3M, Structural Welding Code - Sheet Steel	Yes	Yes	Yes	[Yes] [No]	100% VT; also see Section 05 31 00
05 41 00 Structural Metal Stud Framing	AWS D1.1/D1.1M, Structural Welding Code - Steel or AWS D1.3/1.3M, Structural Welding Code - Sheet Steel	[Yes] [No]	[Yes] [No]	Yes	[Yes] [No]	100% VT; also see Section 05 41 00
05 50 00 Metal Fabrications	AWS D1.1/D1.1M, Structural Welding Code–Steel or AWS D1.2/D1.2M, Structural Welding Code - Aluminum or AWS D1.6/D1.6M, Structural Welding Code - Stainless Steel	[Yes] [No]	[Yes] [No]	Yes	[Yes] [No]	100% VT; also see Section 05 50 00
05 52 00 Metal Railings	AWS D1.1/D1.1M, Structural Welding Code - Steel or AWS D1.2/D1.2M, Structural Welding Code - Aluminum	No	No	No	No	100% VT; also see Section 05 52 00
05 53 00 Metal Gratings	AWS D1.1/D1.1M, Structural Welding Code - Steel or AWS D1.2/D1.2M, Structural Welding Code - Aluminum	No	No	No	No	100% VT; also see Section 05 53 00
22 12 16 Elevated Potable-Water Storage Tanks	ASME BPV Code, Section IX or AWS D1.1/D1.1M, Structural Welding Code - Steel	[Yes] [No]	[Yes] [No]	Yes	[Yes] [No]	100% VT and AWWA D100; also see Section 22 12 16
22 12 19.01 Welded Steel Tank	ASME BPV Code, Section IX or AWS D1.1/D1.1M, Structural Welding Code - Steel	Yes	Yes	Yes	[Yes] [No]	100% VT and AWWA D100; also see Section 22 12 19.01
22 12 19.02 Bolted Steel Storage Tank	ASME BPV Code, Section IX or AWS D1.1/D1.1M, Structural Welding Code - Steel	[Yes] [No]	[Yes] [No]	Yes	[Yes] [No]	100% VT AND AWWA D103;also see Section 22 12 19.02

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Welding and Nondestructive Testing						
Specification Section	**Governing Welding Codes or Standards**	**Submit WPS**	**Submit WPQ**	**Onsite CWI Req'd**	**Submit Written NDT Procedure Specifications**	**NDT Requirements**
31 41 16 Sheet Piles	AWS D1.1/D1.1M, Structural Welding Code - Steel	[Yes] [No]	[Yes] [No]	Yes	[Yes] [No]	100% VT; also see Section 31 41 16
31 62 16 Steel Piles	AWS D1.1/D1.1M, Structural Welding Code - Steel	Yes	Yes	Yes	[Yes] [No]	100% VT; also see Section 31 62 16
33 05 01.01 Welded Steel Pipe and Fittings	ASME BPV Code, Section IX; and AWS D1.1/D1.1M, Structural Welding Code - Steel	Yes	Yes	Yes	Yes	100% VT; also see Section 33 05 01.01
33 05 01.04 Bar-Wrapped Concrete Cylinder Pipe and Fittings	ASME BPV Code, Section IX; and AWS D1.3/D1.3M, Structural Welding Code – Sheet Steel	[Yes] [No]	[Yes] [No]	[Yes] [No]	[Yes] [No]	100% VT; also see Section 33 05 01.04
33 05 23.16 Utility Pipe Jacking	ASME BPV Code, Section IX; and AWS D1.1/D1.1M, Structural Welding Code - Steel	Yes	Yes	[Yes] [No]	[Yes] [No]	100% VT; also see Section 33 05 23.16
44 44 57 Parallel Plate Settler System	ASME BPV Code, Section IX; and AWS D1.6/D1.6M, Structural Welding Code – Stainless Steel	[Yes] [No]	[Yes] [No]	[Yes] [No]	[Yes] [No]	100% VT; also see Section 44 44 57

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SECTION 05 12 00
STRUCTURAL STEEL FRAMING

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Galvanizers Association (AGA): Quality Assurance Manual.
2. American Institute of Steel Construction (AISC):
   a. 303, Code of Standard Practices for Steel Buildings and Bridges.
   b. 325, Steel Construction Manual.
   c. 341, Seismic Provisions for Structural Steel Buildings.
   d. 360, Specification for Structural Steel Buildings.
   e. AISC Quality Certification Program.
   f. AISC Erector Certification Program.
3. American Welding Society (AWS): D1.1/D1.1M, Structural Welding Code—Steel.
4. ASTM International (ASTM):
   a. A6/A6M, Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling.
   b. A36/A36M, Standard Specification for Carbon Structural Steel.
   c. A53/A53M, Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless.
   d. A123/123M, Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
   e. A143/A143M, Standard Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement.
   f. A153/A153M, Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.
   g. A325, Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength.
   h. A384/A384M, Standard Practice for Safeguarding Against Warpage and Distortion During Hot-Dip Galvanizing of Steel Assemblies.
   i. A385/A385M, Standard Practice for Providing High-Quality Zinc Coatings (Hot-Dip).
   j. A490, Standard Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength.

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k. A500/A500M, Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes.
l. A563, Standard Specification for Carbons and Alloy Steel Nuts.
m. A572/A572M, Standard Specification for High-Strength Low Alloy Columbium-Vanadium Structural Steel.
n. A780/A780M, Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings.
o. A992/A992M, Standard Specification for Structural Steel Shapes.
p. B695, Standard Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel.
q. F436, Standard Specification for Hardened Steel Washers.
r. F959, Standard Specification for Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners.
s. F1852, Standard Specification for "Twist Off" Type Tension Control Structural Bolt/Nut/Washer Assemblies, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength.

5. Occupational Safety and Health Administration (OSHA).
6. Research Council on Structural Connections (RCSC): Specification for Structural Joints using ASTM A325 or ASTM A490 Bolts.

1.02 SUBMITTALS

A. Action Submittals:

1. Provide Shop Drawing details showing:
   a. Erection plans.
   b. Members, including piece numbers, sizes, grades, dimensions, cambers, and connection details.
   c. Anchor bolt layouts.
   d. Hardened washer details.
   e. Joint details for complete penetration welds.
2. Product specifications, including primer and other coatings.
3. [Designation of the members and connections that are part of the seismic load resisting system (SLRS).
4. Connection material specifications.
5. Location of demand critical shop welds.
6. Locations and dimensions of protected zones.
7. Gusset plates drawn to scale when they are detailed to accommodate inelastic rotation.
8. Welding requirements as specified in AISC 341 Appendix W, Section W2.2.]

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B. Informational Submittals:

1. [Schedule for submittal of shop and erection drawings.]
2. Name and address of manufacturer(s).
3. Mill Certificates of tests made in accordance with ASTM A6/A6M.
4. Manufacturers' testing procedures and standards.
5. Preparation and installation or application instructions, as appropriate.
6. Proposed method to resolve misalignment between anchor bolts and bolt holes in steel members.
7. High-Strength Bolts (Plain Noncoated and Hot-Dip Galvanized):
   a. Manufacturer's Certificate of Compliance, in accordance with Section 01 43 33, Manufacturers' Field Services that products meet specified chemical and mechanical requirements.
   b. Manufacturer's inspection test report results for production lot(s) furnished, to include:
      1) Tensile strength.
      2) Yield strength.
      3) Reduction of area.
      4) Elongation and hardness.
   c. Certified Mill Test Reports for Bolts and Nuts:
      1) Name and address of manufacturer.
      2) Bolts correctly marked.
      3) Marked bolts and nuts used in required mill tests and manufacturer's inspection tests.
8. Direct Tension Indicators (DTIs): Manufacturer's test report meeting requirements of ASTM F959.
9. Tension Control (TC) Bolts: Manufacturer's test report meeting requirements of ASTM A325 and ASTM F1852.
10. Welding Procedures, Qualifications, and Inspection Reports: As specified in Section 05 05 23, Welding.
11. [Hot-Dip Galvanizing: Certificate of compliance signed by galvanizer with description of material processed and ASTM standard used for coating.]
12. [AISC Quality Certification: AISC certificate showing name and address of certified firm, effective date, and category of certification; or, for erectors, documentation of similar project experience to include project name, location, date of completion, and name and phone number of owner's contact person.]
13. Charpy V-notch test results.
14. Nondestructive Testing (NDT) report.

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1.03 QUALITY ASSURANCE

A. Qualifications:

1. Welding qualifications as specified in Section 05 05 23, Welding.

1. [Galvanized Coating Applicator: Company specializing in hot-dip galvanizing after fabrication and following procedures of AGA's Quality Assurance Manual.]

B. Certifications:

1. Mill identification marks, heat number, size of section, and length in accordance with ASTM A6/A6M.
2. [AISC Quality Certification for Fabricator: Standard for Steel Building Structures (STD).]
3. [AISC Quality Certification as Certified Steel Erector (CSE) [, or documented experience in erection of at least five similar structural steel facilities over past 10 years in lieu of AISC certification].]

1.04 DELIVERY, STORAGE, AND HANDLING

A. Delivery: Load structural members in such a manner that they will be transported and unloaded without damage to coatings and without being excessively stressed, deformed, or otherwise damaged.

B. Storage:

1. Protect structural steel members and packaged materials from corrosion and deterioration.
2. Store in dry area and not in direct contact with ground.
3. Protect fasteners from dirt and moisture. Do not remove lubricant from bolts and nuts.

C. Handle materials to avoid distortion or damage to members or supporting structures.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Rolled Plates, Shapes except W-Shapes and Bars: ASTM [A36/A36M] [or] [A572/A572M, Grade 50], unless indicated otherwise.

B. W-Shapes: ASTM A992/A992M, unless indicated otherwise on Drawings.

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C. Steel Pipe: ASTM A53/A53M, Grade B.

D. Round Hollow Structural Sections (HSS): ASTM A500/A500M, Grade B (Fy equals 42 ksi).

E. Square and Rectangular Hollow Structural Sections (HSS): ASTM A500/A500M, Grade B (Fy equals 46 ksi).

F. [For hot-dip galvanized steel that is exposed to view and does not receive paint, limit combined phosphorus and silicon content to 0.04 percent. For steels that require a minimum of 0.15 percent silicon, such as plates over 1.5 inches thick for ASTM A36/A36M and ASTM A572/A572M steels, limit maximum silicon content to 0.21 percent and phosphorous content to 0.03 percent].

2.02 FASTENERS

A. Anchor Bolts: As specified in Section 05 50 00, Metal Fabrications.

B. High-Strength Bolts:

1. ASTM A325 or ASTM A490, bolt Type [1, plain uncoated] [_____].
2. Bolt Length and Thread Length: As required for connection type shown, with hardened washers as required.

C. Direct Tension Indicators (DTIs) or Load Indicator Washers:

1. ASTM F959, coating type to match bolt finish.
2. Type A325 or A490, to match bolt type.
3. Manufacturers and Products:
4. TurnaSure LLC, Langhorne, PA; DTIs.
   a. Applied Bolting Technology Products, Ludlow, VT; DTIs, regular or Squirter type.

D. Tension Control (TC) Bolts:

1. High-strength, ASTM A325 and ASTM F1852.
2. Manufacturers:
   a. LeJeune Bolt Company, Burnsville, MN.
   b. Nucor Fastener, Saint Joe, IN.
   c. Haydon Bolts, Philadelphia, PA.
   d. Vermont Fasteners Manufacturing, Swanton, VT.

E. Nuts: ASTM A563, type to match bolt type and finish.

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F. Hardened Steel Flat and Beveled Washers: ASTM F436, type to match bolt finish.

G. Welded Shear Studs: As specified in Section 05 50 00, Metal Fabrications.

2.03 ANCILLARY MATERIALS

A. Surface Preparation and Primer: As specified in Section 09 90 00, Painting and Coating.

B. Grout: As specified in Section 03 62 00, Nonshrink Grouting.

2.04 FABRICATION

A. General:

1. Fabricate as shown and in accordance with AISC 360 and AISC 303.
2. Columns shall be full length members without splices, unless shown otherwise or approved by Engineer.
3. Mark and match mark materials for field assembly.
4. Complete assembly, including bolting and welding of units, before start of finishing operations.
5. Fabricate to agree with field measurements.
6. [Provide camber as indicated on Drawings.]
7. [Fillet re-entrant cuts and corners to radius of not less than 1/2 inch.]
8. [Sheared and flame-cut edges shall be free from rough corners and projections.]

B. Connections:

1. Shop Connections: Weld or bolt as shown on Drawings.
2. Meet requirements of AISC 325 for bolted double-angle shear connections, unless indicated otherwise.
3. Meet OSHA requirements for one independent bolt at beams framing in to column web connections.
4. [Provide oversized holes for anchor bolts in column baseplate in accordance with AISC 325, unless indicated otherwise.]

C. Welded Construction:

1. As specified in Section 05 05 23, Welding.
2. Groove and Butt Joint Welds: Complete penetration, unless otherwise indicated.

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D. [Preheating of Heavy Shapes and Plates:]

1. [For ASTM A6/A6M, steel shapes and plates thicker than 2 inches.]
2. [Minimum Preheat Temperature:]
   a. [Groove Weld Splices: 350 degrees F.]
   b. [Thermal Cutting of Beam Copes and Weld Access Holes: 150 degrees F.]

E. Interface with Other Work:

1. Holes:
   a. As necessary or as indicated for securing other Work to structural steel framing, and for passage of other Work through steel framing members shall be approved by Engineer.
   b. No flame-cut holes are permitted without prior approval of Engineer.
2. Weld threaded nuts to framing members, and other specialty items to receive other Work.

F. [Architecturally Exposed Structural Steel (AESS): Fabricate in accordance with AISC 303, Section 10.]

2.05 FINISHES

A. Shop Paint Primer:

1. Surface Preparation and painting as specified in Section 09 90 00, Painting and Coating.
2. Do not shop prime the following surfaces, unless indicated otherwise:
   a. Faying surfaces of slip critical bolted connections.
   b. Within 2 inches of field-welded connections.
   c. Steel members to be completely encased in reinforced concrete or coated with cementitious fireproofing.
3. Apply shop primer to top flange surfaces of composite steel beams, unless indicated otherwise.
4. [Shop primer for steel members to be coated with intumescent fireproofing shall be compatible with specified fireproofing.]

B. [Galvanizing:

1. Fabricate steel to be galvanized in accordance with ASTM A143/A143M, ASTM A384/A384M, and ASTM A385/A385M. Avoid fabrication techniques that could cause distortion or embrittlement of steel.

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2. Remove welding slag, splatter, burrs, grease, oil, paint, lacquer, and other deleterious material prior to delivery for galvanizing.
3. Remove by blast cleaning or other methods surface contaminants and coatings not removable by normal chemical cleaning process in galvanizing operation.
4. Hot-dip galvanize steel members, fabrications, and assemblies after fabrication in accordance with ASTM A123/A123M.
5. Hot-dip galvanize ASTM A325 bolts, nuts, washers, and hardware components in accordance with ASTM A153/A153M. Oversize holes to allow for zinc alloy growth. Shop-assemble bolts, nuts, and washers with special lubricant and test in accordance with ASTM A325 and ASTM A563.
6. Mechanically zinc coat tension-control (TC) bolts, nuts, and washers in accordance with ASTM F1852 and ASTM B695, Class 50.
7. Galvanize components of bolted assemblies separately before assembly.]

C. Slip Critical Bolted Connections:

1. Mask faying surfaces of slip critical (SC) bolted connections to be shop painted as specified in Section 09 90 00, Painting and Coating.
2. [Roughen galvanized faying surfaces with hand wire brushing.]

D. [Fully Tensioned Bolted Connections:

1. Provide Class A faying surface. Mask faying surfaces of fully tensioned (FT) bolted connections to be shop painted as specified in Section 09 90 00, Painting and Coating.
2. Exclude threads from shear plane, unless approved by Engineer.]

2.06 SOURCE QUALITY CONTROL

A. [Charpy V-notch test for ASTM A6/A6M shapes with flanges 1-1/2 inches thick and thicker, or built up cross section consisting of plates with thickness exceeding 2 inches, in accordance with the following:

1. ASTM A6/A6M, Supplementary Requirement S30.
   a. Minimum average value of 20 foot-pounds absorbed energy at 70 degrees F.
   b. Tested in alternate core location.]
2. [Charpy V-notch test for ASTM A6/A6M shapes with flanges 2 inches thick and thicker, in accordance with the following:
   a. ASTM A6/A6M, Supplementary Requirement S30.

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b. Minimum average value of 20 foot-pounds absorbed energy at 70 degrees F.
c. Tested in the alternate core location.]

B. [Heavy Shapes and Plates: [Thermally cut surfaces of beam copes and weld access holes shall be inspected and tested by an independent testing agency, retained by [Owner] [Contractor and approved by Engineer] [, in accordance with AISC 360, Paragraph J1.6.]

C. Welding:

1. Visually inspect fabrication welds in accordance with AWS D1.1/D1.1M, Section 6 and Table 6.1, Visual Inspection Acceptance Criteria.
2. An independent testing agency [will be retained by Owner] [shall be retained by Contractor and approved by Engineer] to perform the following inspection and testing of fabrication welds as specified in Section 05 05 23, Welding.
   a. Groove welds:
      1) Radiographic (RT) or ultrasonic (UT) testing for [10] [_____] percent of randomly selected welds, unless otherwise indicated.
      2) Use RT only for butt joint groove welds.
   b. Fillet Welds Larger than 5/16-inch: Liquid penetrant (PT) or magnetic particle (MT) for 10 percent of randomly selected welds, unless otherwise indicated.
   c. All Welds: 100 percent visually inspected (VT).
3. Repair and retest defective welds as specified in Section 05 05 23, Welding.

D. [Special inspection of fabrication process and shop welding will be provided by Owner as indicated on Drawings.]

E. [Hot-Dip Galvanizing:]

1. [An independent testing agency [, will be retained by Owner] [, shall be retained by Contractor and approved by Engineer] to inspect and test hot-dip galvanized fabricated items [, except _____] in accordance with ASTM A123/A123M and ASTM A153/A153M.]
2. [Visually inspect and test for thickness and adhesion of zinc coating for minimum of three test samples from each lot in accordance with ASTM A123/A123M and ASTM A153/A153M.]
3. [Reject and retest nonconforming articles in accordance with ASTM A123/A123M and ASTM A153/A153M.]

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PART 3 - EXECUTION

3.01 ERECTION

A. General:

1. Meet requirements of AISC 360 and AISC 303, with exceptions as specified.
2. Install Contractor-designed temporary construction bracing to provide necessary support until components are in place and construction is complete.
3. Provide additional field connection material as required by AISC 303.
4. Splice members only where indicated and accepted on Shop Drawings.
5. [Architecturally Exposed Structural Steel (AESS): Erect in accordance with AISC 303, Section 10.]

B. Field Assembly:

1. Clean bearing surfaces and other surfaces that will be in permanent contact before assembly.
2. Set structural frames accurately to lines and elevations shown.
3. Align and adjust various members forming a part of a complete frame or structure before permanently fastening.
4. Level and plumb individual members of structure within tolerances shown in AISC 303.
5. Establish required leveling and plumbing measurements on mean operating temperature of structure. Make allowances for difference between temperature at time of erection and mean temperature at which structure will be completed and in service.
6. Perform necessary adjustments to compensate for minor discrepancies in elevations and alignment.

C. Setting Baseplates and Bearing Plates:

1. Clean concrete and masonry bearing surfaces of bond reducing materials and roughen to improve bond to surfaces.
2. Clean bottom surface of baseplates and bearing plates.
3. Set loose and attached baseplates and bearing plates for structural members on wedges, shims, leveling nuts, or other adjustable devices. Use leveling plates where indicated.
4. Tighten anchor bolts after supported members have been positioned and plumbed. Do not remove wedges or shims, but if protruding, cut off flush

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with edge of base or bearing plate prior to placing grout. Weld plate washer to baseplate where indicated.

5. Grout Under Baseplate: As specified in Section 03 62 00, Nonshrink Grouting, prior to placing loads on structure.

D. Anchor Bolts:

1. Coordinate installation of anchor bolts and other connectors required for securing structural steel to in-place work.
2. Provide templates and other devices for presetting bolts and other anchors to accurate locations.
3. Projection of anchor bolts beyond face of concrete and threaded length shall be adequate to allow for full engagement of threads of hold-down nuts, adjustment of leveling nuts, washer thicknesses, and construction tolerances, unless indicated otherwise.
    a. Placement Tolerances:
    b. As required by AISC 303, unless indicated otherwise.
    c. Embedded anchor bolts shall not vary from dimensions shown on Drawings by more than the following:
        1) Center to center of any two bolts within an anchor group: 1/8 inch.
        2) Center to center of adjacent anchor bolt groups: 1/4 inch.
        3) Variation from perpendicular to theoretical bearing surface: 1:50.

E. Connections:

1. High-Strength Bolted:
    a. Tighten in accordance with RCSC Specification for Structural Joints Using ASTM A325 or ASTM A490 Bolts.
    b. Hardened Washers:
        1) Provide at locations required by Washer Requirements section of RCSC Specification for Structural Joints Using ASTM A325 or ASTM A490 Bolts, to include slip critical connections using slotted or oversized holes or ASTM A490 bolts.
        2) Use beveled style and extra thickness where required by RCSC Specification.
        3) Use square or rectangular beveled washers at inner flange surfaces of American Standard beams and channels.
        4) Do not substitute DTIs for hardened flat washers required at slotted and oversize holes.

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a) For bearing-type connections not fully tensioned (N, X), tighten to snug tight condition. Use hardened washer over slotted or oversize holes in outer plies.

5) Fully Tensioned Bolted:

c. Use DTIs or TC bolts at slip critical (SC) and fully tensioned (FT) bearing-type connections.

d. DTIs:

1) Position within bolted assembly in accordance with ASTM F959.

2) Install bolts, with DTIs plus hardened washers as required, in holes of assembly and tighten until plies are in firm contact and fasteners are uniformly snug tight.

e. Final tightening bolts begin at most rigid part of bolted connection and progress toward free edges until final twist off of TC bolts or until DTIs have been compressed to an average gap equal to or less than shown in ASTM F959, Table 2.

2. Welded:

a. As specified in Section 05 05 23, Welding.

b. Groove and Butt Joint Welds: Complete penetration, unless otherwise indicated.

3.02 MISFITS

A. At Bolted Connections:

1. Immediately notify Engineer for approval of one of the following methods of correction:

a. Ream holes that must be enlarged to admit bolts and use oversized bolts.

b. Plug weld misaligned holes and redrill holes to admit standard size bolts.

c. Drill additional holes in connection, conforming to AISC for bolt spacing and end and edge distances, and add additional bolts.

d. Reject member containing misfit, incorrect sized, or misaligned holes and fabricate new member to ensure proper fit.

1) Do not enlarge incorrectly sized or misaligned holes in members by burning or by use of drift pins.

B. At Anchor Bolts:

1. Resolve misalignments between anchor bolts and bolt holes in steel members in accordance with approved Shop Drawing.

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2. Do not flame cut to enlarge holes without prior approval of Engineer.

C. Gas Cutting:

1. Do not use gas cutting torches in field for correcting fabrication errors in structural framing.
2. Secondary members not under stress and concealed in finished structure may be corrected by gas cutting torches, if approved by Engineer.

2. Finish flame-cut sections equivalent to sheared and punched appearance.

3.03 REPAIR AND CLEANING

A. Clean shop primer from field welds, bolted connections, and abraded areas immediately after erection.

B. Remove and grind smooth tack welds, fit-up-lugs, and weld runoff tabs.

C. Remove weld back-up bars and grind smooth where indicated on Drawings.

D. Apply touchup paint primer by brush or spray of same thickness and material as that used in shop application and as specified in Section 09 90 00, Painting and Coating.

E. [Hot-Dip Galvanized Coating Repair:

1. Conform to ASTM A780/A780M.
2. For minor repairs at abraded areas, use sprayed zinc conforming to ASTM A780/A780M.
3. For flame cut or welded areas, use zinc-based solder, or zinc sticks, conforming to ASTM A780/A780M.
4. Use magnetic gauge to determine thickness is equal to or greater than base galvanized coating.]

3.04 FIELD QUALITY CONTROL

A. High-Strength Bolted Connections:

1. An independent testing agency [will be retained by Owner] [shall be retained by Contractor and approved by Engineer] to perform the following inspection and testing in accordance with the RCSC Specification for Structural Joints Using ASTM A325 or ASTM A490 Bolts:
   a. Marking identification and conformance to ASTM standards.
   b. Alignment of bolt holes.

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c. Placement, type, and thickness of hardened washers.
d. Tightening of bolts.

B. Bearing-Type Connections Not Fully Tensioned (N, X): Snug tight condition with plies of joint in firm contact.

1. Fully Tensioned (FT) Bearing and Slip Critical (SC) Connections:
   a. Conduct preinstallation test.
   b. Monitor installation and tightening of DTIs or TC bolts.
   c. Monitor condition of faying surfaces for slip critical connections.
2. Preinstallation Test:
   a. Conduct test in accordance with Specification for Structural Joints Using ASTM A325 or ASTM A490 bolts prior to using bolt tension measuring device.
   b. Select representative sample of not less than three bolts of each diameter, length, and grade.
   c. Include DTIs and flat hardened washers as required to match actual connection assembly.
3. Nondestructive Testing (NDT): Inspect bolted connections and perform corrections as required to meet code acceptance criteria per RCSC Specification for Structural Joints Using ASTM A325 or ASTM A490 Bolts.
4. Defective Connections: Correct and reinspect defective and improperly tightened high-strength bolted connections. Retest fully tensioned bolts as necessary to demonstrate compliance of completed work.

C. Welded Connections:

1. Visually inspect field welds in accordance with AWS D1.1/D1.1M, Section 6 and Table 6.1, Visual Inspection Acceptance Criteria.
2. An independent testing agency [will be retained by Owner] [shall be retained by Contractor and approved by Engineer] to perform the following inspection and testing of field welds as specified in Section 05 05 23, Welding.
   a. Groove Welds:
      1) Radiographic (RT) or ultrasonic (UT) testing for [10] [_____] percent of randomly selected welds, unless otherwise indicated.
      2) Use RT only for butt joint groove welds.
   b. Fillet Welds Larger Than 5/16 Inch: Liquid penetrant (PT) or magnetic particle (MT) for 10 percent of randomly selected welds, unless otherwise indicated.

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c. All Welds: 100 percent visually inspected (VT).

3. Repair and retest defective welds as specified in Section 05 05 23, Welding.

D. [Special inspection will be provided by Owner as indicated on Drawings.]

E. [Welded Shear Studs: Inspect and test welded shear studs as specified in Section 05 50 00, Metal Fabrications.]

END OF SECTION

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SECTION 05 21 19
OPEN WEB STEEL JOIST FRAMING

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Institute of Steel Construction (AISC):
   a. Specification for Structural Steel Buildings-Allowable Stress Design and Plastic Design.
   b. Allowable Stress Design Specification for Structural Joints using ASTM A325 or A490 Bolts.
   c. Code of Standard Practice for Steel Buildings and Bridges.
2. American Welding Society (AWS): D1.1, Structural Welding Code - Steel.
3. Steel Joist Institute (SJI):
   a. Standard Specifications and Load Tables:
      1) Open-Web Steel Joists, K-Series.
      2) Long Span Steel Joists, LH-Series, and Deep Long Span Steel Joists, DLH-Series.
      3) Super Longspan Steel Joists, SLH-Series.
      4) Joist Girders.
   b. Recommended Code of Standard Practice for Steel Joists and Joist Girders.

1.02 SUBMITTALS

A. Action Submittals:

1. Plan view layout of joists and bridging.
2. Elevation view of each type of joist showing configuration, chord and web member sizes, panel point dimensions, and chord extensions.
3. Connection and bearing details.
4. Special joist reinforcing and connections for supported items, such as monorails and mechanical equipment.
5. Bridging member sizes and connection details.
6. Complete design, including stress and deflection calculations, for joists, joist members, and connections for design load and equipment weight as indicated, plus any construction loads applied by CONTRACTOR’s operations.

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7. Calculations shall include check of joist chord bending stresses for concentrated loads applied between panel points.
8. Registered Professional ENGINEER's stamp, valid in same state as Project, on structural calculations.
9. Procedure for handling, erection, and bracing of steel joists.

B. Informational Submittals:

1. Joist manufacturer's installation requirements.
2. Welding Procedures, Qualifications, and Inspection Report: As specified in Section 05 05 23, Welding.

1.03 QUALITY ASSURANCE

A. General: Design and fabricate steel joists and bridging to meet requirements of SJI Standard Specifications and Load Tables.

B. Certification: SJI Membership, with certification for joist types as indicated on Drawings.

C. Qualifications for Field Welding: As specified in Section 05 05 23, Welding.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Protect from corrosion, deformation, and other damage during delivery, storage, and handling.

B. Protect joist paint system from abrasion at steel bands and other joists.

C. Store joists and bridging off ground on wood sleepers.

D. Support joists so there is no danger of tipping, sliding, rolling, shifting or material damage.

PART 2 - PRODUCTS

2.01 STEEL JOISTS AND BRIDGING

A. Provide type of joist, chord configuration, and depth as indicated on Drawings.

B. Design and Manufacture:

1. In accordance with the applicable SJI Standard Specifications.
2. Chord Members: Rolled double angle sections only.

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3. Provide the following where indicated, in accordance with SJI Standard Specifications and Load Tables:
   a. Bottom chord bracing and end anchorage for uplift design criteria.
   b. Ceiling extension to within 1 inch of finished wall surface, unless otherwise indicated.
   c. Top chord extension, [S type,] [R type,] unless otherwise indicated.
   d. Bottom chord extension and stabilizer plates for joist girders.
   e. Full camber, unless otherwise indicated.

C. Joist Bridging:

1. In accordance with applicable SJI Standard Specifications for type of joist.
2. Furnish bridging of minimum size and type as indicated.
3. Provide anchorage connection to walls and girders at bridging lines as indicated.

2.02 SHOP PRIMER

A. [Surface Preparation and Primer: As specified in Section 09 90 00, Painting and Coating].

B. [Apply one shop coat of rust-inhibitive primer in accordance with SJI Standard Specifications.]

1. [Remove loose scale, rust, and slag from welds before painting.]
2. [Apply primer within 8 hours after surface preparation.]

PART 3 - EXECUTION

3.01 EXAMINATION

A. Examine supporting framing and field conditions for compliance with requirements for installation tolerances and other conditions affecting performance of steel joists.

3.02 INSTALLATION

A. Erection: SJI Standard Specifications and approved shop drawings.

B. Welded Connections: As specified in Section 05 05 23, Welding.

C. [High-Strength Bolted Connections: Install as specified in Section 05 12 00, Structural Steel Framing.]

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3.03 TOUCHUP PAINTING

A. Immediately following erection, remove debris from completed installation.

B. Clean field welds, bolted connections, rust spots, and abraded areas.

C. Repair damaged painted and galvanized surfaces as specified in Section 09 90 00, Painting and Coating.

3.04 FIELD QUALITY CONTROL

A. Welding:

1. [Visually inspect field welds in accordance with AWS D1.1, Section 6 and Table 6.1, Visual Inspection Acceptance Criteria.]
2. [An independent testing agency [will be retained by OWNER] [shall be retained by CONTRACTOR and approved by ENGINEER] to visually inspect field welded connections in accordance with AWS D1.1, Table 6.1, and as specified in Section 05 05 23, Welding.]
3. Repair defective welds as specified in Section 05 05 23, Welding.

B. [High-Strength Bolted Connections:

1. An independent testing agency [will be retained by OWNER] [shall be retained by CONTRACTOR and approved by ENGINEER] to perform inspection and testing in accordance with the AISC Specification for Structural Joints Using ASTM A325 or ASTM A490 Bolts.
2. Inspect and test as specified in Section 05 12 00, Structural Steel Framing.]

C. [Special inspection will be provided by OWNER where indicated on Drawings.]

END OF SECTION

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SECTION 05 31 00
STEEL DECKING

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Iron and Steel Institute (AISI): Specifications for the Design of Cold Formed Steel Structural Members.
2. American Welding Society (AWS): D1.3, Structural Welding Code - Sheet Steel.
3. ASTM International (ASTM):
   a. A611, Standard Specification for Structural Steel (SS), Sheet, Carbon, Cold-Rolled.
   b. A653, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.
   c. A780, Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings.
   d. A924, Standard Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process.
4. Steel Deck Institute (SDI):
   a. Design Manual for Composite Decks, Form Decks and Roof Decks.
   b. Diaphragm Design Manual.
5. Factory Mutual (FM):
   a. Factory Mutual Approval Guide.
   b. FM Research Corporation (FMRC): Approval Requirements for Steel Roof Deck Construction.
6. International Code Council Evaluation Service, Inc. (ICC-ES): Evaluation Reports for Deck Fasteners.
7. Underwriters Laboratories, Inc. (UL): Fire Resistance Directory.

1.02 SUBMITTALS

A. Action Submittals:

1. Plan view layout of decking showing type and section properties of deck panels, reinforcing channels, pans, special jointing, and accessories.
2. Location of openings, deck laps, and deck attachment details.

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3. [Location of temporary shoring for placement of concrete topping.]

B. Informational Submittals:

1. Decking manufacturer's installation requirements.
2. Welding Procedures, Qualifications, and Inspection Report: As specified in Section 05 05 23, Welding.
3. Operation manuals for mechanical fastener installation tools.
4. Manufacturer's Certificate of Compliance, in accordance with Section 01 33 00, Submittal Procedures.

1.03 QUALITY ASSURANCE

A. General: For metal decking section properties, meet requirements of AISI Specifications for Design of Cold-Formed Steel Structural Members.

B. FM Requirements:

1. Steel Roof Deck: Listed in Factory Mutual "Approval Guide" for Class 1 fire rating and [Class 1-90] [_____] wind uplift rating.
2. Mechanical Fasteners: Packing containers shall show name of manufacturer and product and FMRC approval mark.

C. Qualifications for Field Welding: As specified in Section 05 05 23, Welding.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Protect steel deck from corrosion, deformation, and other damage during delivery, storage, and handling.

B. Store deck bundles on platforms or pallets, with one end elevated to provide drainage.

C. Protect bundles against condensation with a ventilated waterproof covering.

D. Stack bundles so there is no danger of tipping, sliding, rolling, shifting or material damage.

E. [Architecturally exposed deck shall be appropriately packaged and protected to prevent damage during shipment.]

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PART 2 - PRODUCTS

2.01 METAL DECKING

A. Provide metal deck as shown in the following schedule:

Steel Deck Schedule								
Type	**Depth (in)**	**Panel Width (in)**	**Design Thickness (in)**	**Min. Yield Strength Fy (ksi)**	**Min. (+) S (in^3/ft)**	**Min. I (in^4/ft)**	**Minimum Diaphragm Shear Capacity (lbs/ft)**	**Finish**
Roof Deck	[1-1/2] [3]	[36] [24]	[0.0358] [_____]	[33] [_____]	[0.23] [0.48] [_____]	[0.21] [0.84] [_____]	[400] [_____]	[Galv, G-60] [Galv, G-90]
Composite Floor Deck	[3] [2]	[36] [24]	[0.0358] [_____]	[A:33] [_____]	[0.53] [0.36] [	[0.90] [0.42] [	[1,600] [_____]	[Galv, G-60] [
Non-composite Form	[1-5/16] [_____]	[36] [32]	[0.0358] [_____]	[A:80] [_____]	[0.19] [_____]	[0.14] [_____]	[N/A] [_____]	[Galv, G-60] [

B. Materials and Finishes:

1. Galvanized Deck:
   a. Sheet steel for galvanized deck and accessories shall conform to ASTM A653 Structural Quality Grade 33 or higher, as shown in Steel Deck Schedule.
   b. Galvanizing shall conform to ASTM A924 with coating class of G60 or G90 as defined in ASTM A653 and as shown in Steel Deck Schedule.
2. [Painted Deck:]
   a. [Sheet steel for primer painted roof deck and accessories shall conform to ASTM A611 with minimum yield strength of 33, or higher as indicated.]
   b. [Steel deck shall have a coat of manufacturer's standard rust-inhibitive primer.]
3. [Vented Form Deck:
   a. Use galvanized noncomposite form deck for use with insulating concrete fill, unless indicated otherwise.

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b. Manufacturer's standard vent slots shall provide 1-1/2-percent minimum open area.]

C. Manufacturers:

1. Vulcraft Division of Nucor Co., Brigham City, UT.
2. BHP Steel Building Products, USA, Inc., West Sacramento, CA.
3. Verco Manufacturing, Inc., Phoenix, AZ.
4. United Steel Deck, Inc., Summit, NJ.

2.02 [SHOP PRIMER]

A. [Clean and coat with shop paint primer where shown in Finish Schedule.]

B. [Surface Preparation and Primer: As specified in Section 09 90 00, Painting and Coating].

2.03 ACCESSORIES

A. Provide pour stops, column closures, end closures, cover plates, girder fillers, ridge and valley plates, finish strips, reinforcing channels, and other accessories as required for complete installation.

B. Accessories shall be minimum 22-gauge, except edge forms shall be sized as required by the deck manufacturer, unless shown otherwise on the Drawings.

2.04 MECHANICAL FASTENERS

A. Self-Drilling Screws:

1. Self-drilling, self-tapping screws with hexagonal washer head and corrosion-resistant finish.
2. Manufacturers and Products:
   a. ITW Buildex, Itasca, IL; ICH Traxx Self-Drilling Fasteners with Climaseal Coating and Autotraxx Standup Installation Tool.
   b. Hilti, Inc., Tulsa, OK; Kwik-Pro HWH Self-Drilling Screws with Kwik-Cote Treatment and Kwik-Tapper Screwdriver.

B. Powder Driven Fasteners:

1. Knurled shank, minimum 1/2-inch-diameter steel washer, corrosion-resistant coating.

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2. Pin diameter and length to suit deck type and flange thickness of steel support member.
3. Manufacturers and Products:
   a. ITW Buildex, Itasca, IL; Buildex BX14 pins with yellow dichromate galvanizing and BX900 Installation Tool.
   b. Hilti, Inc., Tulsa, OK; ENP-series fasteners with electroplated zinc coating and DX-750 Installation Tool.

2.05 [SHEAR CONNECTORS FOR COMPOSITE DECK

A. Welded Headed Anchor Studs: Size and spacing as indicated on Drawings and as specified in Section 05 50 00, Metal Fabrications.]

PART 3 - EXECUTION

3.01 EXAMINATION

A. Examine supporting framing and field conditions for compliance with requirements for installation tolerances and other conditions affecting performance of steel deck.

3.02 INSTALLATION

A. Locate deck bundles to prevent overloading of support framing members.

B. Install at right angles to supporting members in a three span minimum lay-up, unless shown otherwise, and in accordance with Specification and manufacturer's installation recommendation.

C. Bearing: 1-1/2 inches, minimum.

D. Endlaps: Minimum of 2 inches and located over supports.

E. Do not stretch sidelaps.

F. Closure Plates:

1. Install closure and cover plate accessories as recommended by the metal deck manufacturer, unless shown otherwise on the Drawings.
2. Floor Deck and Form Deck Closures:
   a. Fasten column closures, cell closures, and zee closures to deck to provide tight fitting closures at open ends of ribs and sides of decking.

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b. Fasten cell closures at changes of direction of deck units unless otherwise indicated.

G. Holes and Openings:

1. Cut and fit around roof openings and other work projecting through or adjacent to decking.
2. Locate holes and openings as shown to clear structural framing and bracing members.
3. Reinforcement Around Openings:
   a. Roof Deck: For hole sizes of at least 6 inches across, but not more than 12 inches across in roof deck, reinforce with 0.0474-inch design thickness steel plate, painted or galvanized to match deck coating. Extend plate at least 12 inches beyond opening in all directions and attach to top of roof deck with No. 10 self-drilling screws at 6-inch spacing and at all corners. For openings larger than 12 inches across, reinforce roof deck with framing as shown on Drawings.
   b. Composite Floor Deck and Form Deck: Reinforce openings as indicated on Drawings.

H. Protect deck areas from heavy concentrated loads or wheel traffic with planking or other approved means.

I. Install temporary shoring, if required, to meet strength and deflection limitations, before placing any concrete topping on deck panels.

J. Completed Deck: Free from buckles and irregularities, and in accordance with FM and UL requirements.

3.03 DECK ATTACHMENT

A. [Fasten panels as shown on Drawings.]

B. [Fasten panels as shown in the following schedule:]

Steel Deck Attachment Schedule

		At Perpendicular Supports		**At Parallel Supports**		**At Sidelaps**	
Type	Depth (in.)	Type	No. Per Sheet	Type	Spacing (in.)	Type	Spacing
Roof Deck	[1-1/2]	[5/8" dia. spot	[7]	[5/8" dia. spot	[A:12]	[1-1/2" seam	[12"]

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Steel Deck Attachment Schedule							
		At Perpendicular Supports		At Parallel Supports		At Sidelaps	
Type	Depth (in.)	Type	No. Per Sheet	Type	Spacing (in.)	Type	Spacing
	[3]	welds] [#12 Self-drilling screws] [Power driven fasteners]	[5] [4] [_____]	welds] [#12 Self-drilling screws] [Power driven fasteners]	[24]	weld] [#10 Self-drilling screws]	[24"] [_____]
Composite Floor Deck	[3] [2]	[5/8" dia. spot welds] [#12 Self-drilling screws] [Power driven fasteners]	[7] [5] [4] [_____]	[5/8" dia. spot welds] [#12 Self-drilling screws] [Power driven fasteners]	[A:12] [24].	[1-1/2" seam weld] [#10 Self-drilling screws] [Button-punch]	[36"] ["] [per span]
Non-composite Form Deck	[1-5/16] [_____]	[5/8" dia. spot welds] [#12 Self-drilling screws] [Power driven fasteners]	[7] [5] [4] [_____]	[5/8" dia. spot welds] [#12 Self-drilling screws] [Power driven fasteners]	[A:12] [24].	[1-1/2" seam weld] [#10 Self-drilling screws] [Button-punch]	[36"] ["] [per span]

C. Welded Connections: Weld deck sidelaps, attachments to framing, and accessories shall be in accordance with AWS D1.3 and as specified in Section 05 05 23, Welding.

D. Mechanical Fasteners:

1. Self-Drilling Screws:
   a. Install screws in accordance with manufacturer's written instructions and with special installation tool. Do not over-torque.
   b. Remove and redrive screws at sidelaps where upper sheet is not drawn tightly against lower sheet.

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2. Powder Driven Fasteners:
   a. Install fasteners in accordance with manufacturer's written instructions and with special installation tool.
   b. Minimum Sidelap Edge Distance: 3/8 inch.
   c. Minimum End/End Lap Distance: 1 inch.
   d. Head Projection: As specified by manufacturer for correct penetration into flange of steel support member.

3.04 TOUCHUP PAINTING

A. Immediately following erection, remove unused deck edge trimmings, screws, fasteners, welding washers, butt ends of welding rods, and debris from completed installation.

B. Clean field welds, bolted connections, rust spots, and abraded areas.

C. Repair damaged painted surfaces as specified in Section 09 90 00, Painting and Coating.

D. Repair damaged galvanized surfaces with zinc-rich spray paint in accordance with ASTM A780; color to match galvanized deck.

E. Use magnetic gauge to determine that thickness of repair is equal to or greater than base painted or galvanized coating.

3.05 FIELD QUALITY CONTROL

A. An independent testing agency [will be retained by OWNER] [shall be retained by Contractor and approved by ENGINEER] to perform following inspections.

1. Welded Connections: Visually inspect in accordance with AWS D1.3, Section 7, and as specified in Section 05 05 23, Welding.
2. Mechanical Fasteners: Visually inspect, in accordance with manufacturer's instructions, for each type of fastener.

B. Repair or replace defective welds and fasteners.

C. [Special inspection will be provided by OWNER where indicated on Drawings.]

D. [Welded Shear Studs: Inspect and test as specified in Section 05 50 00, Metal Fabrications.]

END OF SECTION

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SECTION 05 41 00
STRUCTURAL METAL STUD FRAMING

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Iron and Steel Institute (AISI):
   a. Specification for the Design of Cold-Formed Steel Structural Members.
   b. Cold-Formed Steel Design Manual.
   c. Design Guide for Cold-Formed Steel Trusses.
   d. Fasteners for Residential Steel Framing.
2. American Welding Society, Inc. (AWS):
   a. C1.1, Recommended Practices for Resistance Welding.
   b. C1.3, Recommended Practices for Resistance Welding Coated Low Carbon Steels.
   c. D1.3, Structural Welding Code-Sheet Steel.
3. ASTM International (ASTM):
   a. A370, Standard Test Methods and Definitions for Mechanical Testing of Steel Products.
   b. A500, Standard Specification for Cold-Formed Welded and Seamless Carbon Structural Tubing in Rounds and Shapes.
   c. A653/A653M, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.
   d. A780, Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings.
   e. C954, Standard Specification for Steel Drill Screws for the Application of Gypsum Panel Products or Metal Plaster Bases to Steel Studs from 0.033 in. (0.84 mm) to 0.112 in. (2.84 mm) in Thickness.
   f. C955, Standard Specification for Load-Bearing (Transverse and Axial) Steel Studs, Runners (Tracks), and Bracing or Bridging for Screw Application of Gypsum Panel Products and Metal Plaster Bases.
4. Center for Cold-Formed Steel Structures (CCFSS): Technical Bulletin, Vol. 2, No. 1, February 1993, Screw Connections.
5. International Code Council (ICC): Evaluation Reports for Cold-Formed Steel Framing and Fasteners.

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1.02 SUBMITTALS

A. Action Submittals:

1. Plan and elevation views of all metal framing systems, including location and framing of all openings.
2. Material specifications, member sizes, and properties.
3. Details of track, web stiffeners, stud bracing, blocking, bridging, and other members as required to provide a complete installation.
4. Details of connections including welding, mechanical fasteners, and accessory items.
5. [Light-Gauge Steel Trusses: Complete design calculations for member stresses, deflections, and connections, stamped by a registered professional engineer, valid in same state as Project. Include calculations for anchorage connections to resist wind uplift and lateral loads and for temporary handling and bracing requirements.]
6. Installation and erection instructions, including sequence of operations and requirements for temporary bracing and bridging.

B. Informational Submittals:

1. Manufacturer’s installation requirements.
2. Welding Procedures, Qualifications, and Inspection Report: As specified in Section 05 05 23, Welding.
3. Operation manuals for mechanical fastener installation tools.

1.03 QUALITY ASSURANCE

A. General: For member section properties, meet requirements of AISI, Specification for the Design of Cold-Formed Steel Structural Members.

B. Qualifications for Welding: As specified in Section 05 05 23, Welding.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Deliver to Site in bundles marked with name of manufacturer, section type, thickness, grade of material, and length.

B. Store bundles on wood blocking, flat and off ground, to keep clean and to prevent any damage or permanent distortion.

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PART 2 - PRODUCTS

A. GENERAL

B. Provide size and type of members as indicated on Drawings.

C. Sheet Steel: ASTM A653/A653M, with G-60 galvanized coating.

D. Cold-Formed Members and Accessories: ASTM C955.

E. Dimensions and Properties: Calculate section properties in accordance with AISI Cold-Formed Steel Design Manual.

2.02 STUDS AND JOISTS

A. Material:

1. ASTM A653/A653M, Structural Steel (SS) Grade 33, or High-Strength Low-Alloy Steel (HSLAS), Type A or B, Grade 50.
2. Section: Type, size, and thickness as indicated on Drawings.
3. Flanges: Stiffened with return lip.
4. Webs:
   a. Studs: Punched.
   b. Joists: Unpunched, unless indicated otherwise on Drawings.

B. Accessories:

1. Track: Size as required to fit over studs, same thickness as stud material, unpunched.
2. Blocking, Bridging, and Fire Stops: Same depth as studs or joists, 0.0566-inch minimum design thickness, unpunched.
3. Bracing Straps, Angle Bracing, Clip Angles: Size and thickness as indicated on Drawings.
4. Mounting Plates: 0.0566-inch minimum design thickness by 8 inches by 18 inches.
5. Accessories shall be from same manufacturer as studs and joists.

C. Manufacturers and Products:

1. AMS, Los Angeles, CA; Angeles Metal Systems.
2. Clark Steel, Middleton, OH; Steel Framing Systems.
3. Dale Industries; Dearborn, MI; Dale/Incor Steel Framing.
4. Dietrich Industries, Pittsburgh, PA; Lightgauge Metal Framing Products.

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5. Knorr Steel Framing Systems, Salem, OR; Light Gauge Steel Framing.
6. Marino/Ware, South Plainfield, NJ; Stud-Rite Lightweight Steel Framing Systems.
7. Unimast Incorporated, Schiller Park, IL; Steel Framing Systems.

2.03 [LIGHT-GAUGE STEEL TRUSSES

A. General: Provide type, chord configuration, span, and depth of trusses as indicated on Drawings.

B. Material:

1. Chord and Web Members:
   a. ASTM A653/A653M, Structural Steel (SS) Grade 33, High-Strength Low-Alloy Steel (HSLAS), Type A or B, Grade 50, or A500, Grade B, with G60 galvanized coating and minimum design thickness equal to 0.0346 inch.
   b. Section: Cold-formed rectangular tubing or C-sections with return lips and unpunched webs.
2. Accessories: Provide manufacturer's standard bracing, bridging, blocking, reinforcements, tie straps, holddowns, fasteners, and accessories as required for a complete light gauge steel truss system.

C. Design:

1. Load Criteria: Dead, live, wind, and seismic, as shown on Drawings.
2. Deflection Criteria:
   a. Roof Live Load: [1/240] [1/360] of span.
   b. Floor Live Load: 1/480 of span.
3. Design Standards:
   a. AISI, Specification for Design of Cold-Formed Steel Structural Members.
   b. AISI, Design Guide for Cold-Formed Steel Trusses.
   c. CCFSS, Technical Bulletin for screw connections.
   d. AWS C1.1, C1.3, and D1.3 for welded connections.

D. Manufacturers and Products:

1. Alpine Engineered Products, Inc., Pompano Beach, FL; TrusSteel.
2. MiTek Industries, Inc., St. Louis, MO; Ultra-Span.]

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2.04 MECHANICAL FASTENERS

A. Self-Drilling Screws:

1. Self-drilling, self-tapping screws with hexagonal washer head and corrosion-resistant finish.
2. Manufacturers and Products:
   a. ITW Buildex, Itasca, IL; ICH Traxx Self-Drilling Fasteners with Climaseal Coating and Autotraxx Standup Installation Tool.
   b. Hilti, Inc., Tulsa, OK; Kwik-Pro HWH Self-Drilling Screws with Kwik-Cote Treatment and Kwik-Tapper Screwdriver.

B. Powder-Driven Fasteners:

1. Knurled shank, minimum 1/2-inch-diameter steel washer, corrosion-resistant coating.
2. Pin diameter and length to suit deck type and flange thickness of steel support member.
3. Manufacturers and Products:
   a. ITW Buildex, Itasca, IL; Buildex BX14 pins with yellow dichromate galvanizing and BX900 Installation Tool.
   b. Hilti, Inc., Tulsa, OK; ENP-series fasteners with electroplated zinc coating and DX-750 Installation Tool.

2.05 CONCRETE ANCHORS

A. Drilled anchors, size and type as shown on Drawings and as specified in Section 05 50 00, Metal Fabrications.

2.06 PREFABRICATION

A. Structural wall framing panels may be prefabricated prior to erection.

B. [Light-gauge steel trusses shall be shop prefabricated.]

C. Prefabricated assemblies shall be not more than 1/8 inch out of square within length of assembly and shall be braced against racking. Use jig templates for layout and fabrication.

D. Protect prefabricated panels from damage during handling.

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2.07 SOURCE QUALITY CONTROL

A. [Special inspection of fabrication process and shop welding for light-gauge steel trusses will be provided by Owner as indicated on Drawings.]

PART 3 - EXECUTION

3.01 EXAMINATION

A. Inspect all prefabricated assemblies and repair any damage.

B. Examine bearing support surfaces for compliance with requirements for installation tolerances and other conditions affecting performance of metal framing systems.

C. Provide smooth level bearing surfaces for bottom track of load-bearing walls.

D. Clean all member and bearing surfaces that will be in contact after assembly.

3.02 INSTALLATION

A. General:

1. Install framing systems as indicated on Drawings, complete and in accordance with manufacturer's recommendations.
2. Provide temporary bracing for support of all construction loads until framing system is installed complete with sheathing or decking.
3. Install framing in true line, plumb, level, and in proper alignment.
4. Cut ends of framing members with saw or shear to bear uniformly against abutting members. Flame cutting is not permitted.
5. All structural framing members shall be full-length without splices, unless indicated otherwise.
6. Fasten members together in accordance with AISI, Cold-Formed Steel Design Manual, Part IV, Connections. Wire tying is not permitted.

B. Stud Bearing Walls:

1. Secure bottom track to floor slab with concrete anchors as indicated on Drawings.
2. Seat studs squarely and firmly within track before securing with fasteners. Gap between end of stud and track shall be less than 1/16 inch.
3. Install studs with spacing as shown and not more than 2 inches from abutting walls.

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4. Provide double studs at jambs of openings wider than stud spacing.
5. Provide triple studs at corners and at jambs of openings wider than 48 inches, unless indicated otherwise.
6. Track shall be continuous. Center splices between studs and splice with stud section full length between studs.
7. Frame wall penetrations for pipes and ducts larger than stud spacing to avoid cutting structural members.
8. Fire stop stud walls and partitions with unpunched blocking full width of stud at midpoint or where required for nailers, in conformance with applicable building code.
9. Provide blocking for support of mechanical items.
10. Do not remove the web knockouts within 10 inches of either end of load-bearing studs.
11. Provide bracing straps with gusset plates and anchor holddown assemblies where indicated on Drawings.
12. Tolerances:
    a. Stud Plumbness: 1/8 inch in 10 feet.
    b. Stud Spacing: Plus or minus 1/8 inch.

C. Joists:

1. Position joists directly over bearing studs and attach to track.
2. Joists shall be one-piece within a single span. For multiple spans, lap joists and splice as shown on Drawings.
3. Immediately install bridging and solid blocking to support joists. Maximum spacing of bridging shall be 5 feet.
4. Install web stiffeners where indicated
5. Web Penetrations:
    a. Drilled holes for other trades shall be limited to the middle 1/3 of the joist depth within the middle 1/3 of the span, unless indicated otherwise. Minimum spacing between drilled holes shall be 1-1/2 times the joist depth. Notching of joist flanges and flame cutting of holes are not permitted.
6. Tolerances:
    a. Joist Spacing: Plus or minus 1/8 inch.
    b. Joist Levelness: Plus or minus 1/8 inch in 10 feet.

D. [Light-Gauge Steel Trusses:

1. Follow truss fabricator’s instructions for proper handling, installation, and bracing of prefabricated trusses.

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2. Provide proper lifting equipment adequate for size of trusses. Use designated lift points to avoid bending truss in weak direction.
3. Position trusses directly over bearing studs and attach to bearing track with holddown anchors.
4. Immediately install temporary bracing as required at top and bottom chords to keep trusses plumb and true to line.
5. Use temporary diagonal bracing to support top chords as required.
6. Install solid blocking at bearing tracks and ridge and attach permanent bridging.
7. Do not apply load to trusses until all bracing and bridging have been installed complete.
8. Do not remove, cut, or otherwise alter truss members or connections.
9. Tolerances:
    a. Truss Length: Plus or minus 1/2 inch up to 30 feet in length, plus or minus 3/4 inch over 30 feet.
    b. Truss Height: Plus or minus 1/4 inch up to 5 feet in height, plus or minus 1/2 inch over 5 feet.
    c. Truss Spacing: Plus or minus 1/8 inch.
    d. Truss Levelness: Plus or minus 1/8 inch in 10 feet.]

3.03 FASTENERS

A. Self-Drilling Screws:

1. Install in accordance with manufacturer’s written instructions and with special installation tool.
2. Screw type, diameter, and length shall be in accordance with AISI, Fasteners for Residential Steel Framing, minimum two screws per connection unless indicated otherwise.
3. Use clamp to hold members together. Drive screw from lighter to heavier gauge, to allow plies to be pulled together without stripping metal. Do not over torque. A minimum of three exposed threads shall extend through steel.
4. Minimum screw spacing, end distance, and edge distance shall be 3 diameters.

B. Powder-Driven Fasteners:

1. Use only for connecting cold-formed steel to structural steel members, unless indicated otherwise.
2. Install in accordance with manufacturer’s written instructions and with special installation tool.

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C. Welded Connections:

1. Welding shall not be used for material thinner than 0.0451 inch.
2. Weld framing members and accessories in accordance with AWS D1.3.
3. Resistance welding for prefabricated framing shall be in accordance with AWS C1.1 and AWS C1.3.
4. Repair galvanized surfaces damaged by welding with zinc-rich spray paint in accordance with ASTM A780.

D. Concrete Anchors: Install in accordance with Section 05 50 00, Metal Fabrications.

3.04 FIELD QUALITY CONTROL

A. An independent testing agency [will be retained by Owner] [shall be retained by Contractor and approved by ENGINEER] to perform following inspections.

1. Welded Connections: Visually inspect in accordance with AWS D1.3, Section 7, and as specified in Section 05 05 23, Welding.
2. Mechanical Fasteners: Visually inspect, in accordance with manufacturer's instructions, for each type of fastener.

B. Repair or replace defective welds and fasteners.

C. [Special inspection will be provided by Owner where indicated on Drawings.]

END OF SECTION

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SECTION 05 50 00
METAL FABRICATIONS

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. The Aluminum Association, Inc. (AA): The Aluminum Design Manual.
2. American Galvanizers Association (AGA):
3. Inspection of Hot-Dip Galvanized Steel Products.
4. Quality Assurance Manual.
5. American Iron and Steel Institute (AISI): Stainless Steel Types.
6. American Ladder Institute (ALI): A14.3, Ladders - Fixed - Safety Requirements.
7. American National Standards Institute (ANSI).
8. American Society of Safety Engineers (ASSE): A10.11, Safety Requirements for Personnel and Debris Nets.
9. American Welding Society (AWS):
   a. D1.1/D1.1M, Structural Welding Code - Steel.
   b. D1.2/D1.2M, Structural Welding Code - Aluminum.
   c. D1.6/D1.6M, Structural Welding Code - Stainless Steel.
10. ASTM International (ASTM):
    a. A36/A36M, Standard Specification for Carbon Structural Steel.
    b. A48/A48M, Specification for Gray Iron Castings.
    c. A53/A53M, Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless.
    d. A108, Standard Specification for Steel Bar, Carbon and Alloy, Cold-Finished.
    e. A123/A123M, Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
    f. A143/A143M, Standard for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement.
    g. A153/A153M, Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.
    h. A193/A193M, Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications.

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i. A194/A194M, Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both.
j. A240/A240M, Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications.
k. A276, Standard Specification for Stainless Steel Bars and Shapes.
l. A283/A283M, Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates.
m. A307, Standard Specification for Carbon Steel Bolts and Studs, 60,000 PSI Tensile Strength.
n. A325, Standard Specification for Structural Bolts, Steel, Heat Treated 120/105 ksi Minimum Tensile Strength.
o. A380, Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems.
p. A384/A384M, Standard Practice for Safeguarding Against Warpage and Distortion During Hot-Dip Galvanizing of Steel Assemblies.
q. A385/A385M, Standard Practice for Providing High-Quality Zinc Coatings (Hot-Dip).
r. A489, Standard Specification for Carbon Steel Lifting Eyes.
s. A500/A500M, Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes.
t. A501, Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing.
u. A563, Standard Specification for Carbon and Alloy Steel Nuts.
v. A653/A653M, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.
w. A780/A780, Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings.
x. A786/A786M, Standard Specification for Hot-Rolled Carbon, Low-Alloy, High-Strength Low-Alloy, and Alloy Steel Floor Plates.
y. A793, Standard Specification for Rolled Floor Plate, Stainless Steel.
z. A967, Standard Specification for Chemical Passivation Treatments for Stainless Steel Parts.
aa. A992/A992M, Standard Specification for Structural Steel Shapes.
bb. B209, Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate.
cc. B308/B308M, Standard Specification for Aluminum-Alloy 6061-T6 Standard Structural Profiles.
dd. B429/B429M, Standard Specification for Aluminum-Alloy Extruded Structural Pipe and Tube.

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ee. B632/B632M, Standard Specification for Aluminum-Alloy Rolled Tread Plate.
ff. C881/C881M, Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete.
gg. D1056, Standard Specification for Flexible Cellular Materials - Sponge or Expanded Rubber.
hh. F436, Standard Specification for Hardened Steel Washers.
ii. F468, Standard Specification for Nonferrous Bolts, Hex Cap Screws, and Studs for General Use.
jj. F593, Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs.
kk. F594, Standard Specification for Stainless Steel Nuts.
ll. F844, Standard Specification for Washers, Steel, Plain (Flat), Unhardened for General Use.
mm. F1554, Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength.

11. International Code Council Evaluation Service (ICC-ES):
    a. AC01, Acceptance Criteria for Expansion Anchors in Masonry Elements.
    b. AC106, Acceptance Criteria for Predrilled Fasteners (Screw Anchors) in Masonry Elements.
    c. AC193, Acceptance Criteria for Mechanical Anchors in Concrete Elements.
    d. AC308, Acceptance Criteria for Post-Installed Adhesive Anchors in Concrete Elements.
    e. AC70, Acceptance Criteria for Fasteners Power-driven into Concrete, Steel and Masonry Elements.
12. NSF International (NSF): 61, Drinking Water System Components—Health Effects.
13. Occupational Safety and Health Administration (OSHA):
    a. 29 CFR 1910.27, Fixed Ladders.
    b. 29 CFR 1926.105, Safety Nets.
    c. 29 CFR 1926.502, Fall Protection Systems Criteria and Practices.
14. Specialty Steel Industry of North America (SSINA):
    a. Specifications for Stainless Steel.
    b. Design Guidelines for the Selection and Use of Stainless Steel.
    c. Stainless Steel Fabrication.
    d. Stainless Steel Fasteners.

1.02 DEFINITIONS

A. Anchor Bolt: Cast-in-place anchor; concrete or masonry.

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B. Concrete Anchor: Post-installed concrete anchors listed in this specification.

C. Corrosive Area: Containment area or area exposed to delivery, storage, transfer, or use of chemicals.

D. Exterior Area: Location not protected from weather by building or other enclosed structure.

E. Interior Dry Area: Location inside building or structure where floor is not subject to liquid spills or washdown, nor where wall or roof slab is common to a water-holding or earth-retaining structure.

F. Interior Wet Area: Location inside building or structure where floor is sloped to floor drains or gutters and is subject to liquid spills or washdown, or where wall, floor, or roof slab is common to a water-holding or earth-retaining structure.

G. Masonry Anchor: Post-installed masonry anchors listed in this specification.

H. Submerged: Location at or below top of wall of open water-holding structure, such as basin or channel, or wall, ceiling or floor surface inside a covered water-holding structure, or exterior belowgrade wall or roof surface of water-holding structure, open or covered.

1.03 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. Metal fabrications, including welding and fastener information.
   b. Specific instructions for concrete anchor installation, including drilled hole size, preparation, placement, procedures, and instructions for safe handling of anchoring systems.
2. Samples: Color samples of abrasive stair nosings.

B. Informational Submittals:

1. Concrete and Masonry Post-Installed Anchors:
   a. Manufacturer’s product description and printed installation instructions.
   b. Current ICC-ES Report for each type of post-installed anchor to be used.
   c. Adhesive Anchor Installer Certification.
2. U-Channel Concrete Inserts:
   a. Manufacturer’s product description.
   b. Allowable load tables.

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3. Ladders: Letter of certification that ladder meets OSHA 29 CFR 1910.27 requirements.
4. Passivation method for stainless steel members.
5. [Hot-Dip Galvanizing: Certificate of compliance signed by galvanizer, with description of material processed and ASTM standard used for coating.]

1.04 QUALITY ASSURANCE

A. Qualifications:

1. Adhesive Anchor Installer: Trained to install adhesive anchors in accordance with manufacturer's printed installation instructions.
2. Galvanized Coating Applicator: Company specializing in hot-dip galvanizing after fabrication and following procedures of Quality Assurance Manual of the American Galvanizers Association.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Insofar as practical, factory assemble specified items. Assemblies, because of necessity, have to be shipped unassembled shall be packaged and tagged in manner that will protect materials from damage and will facilitate identification and field assembly.

B. Package stainless steel items in a manner to provide protection from carbon impregnation.

C. Protect painted coatings and hot-dip galvanized finishes from damage as a result of metal banding and rough handling. Use padded slings and straps.

D. Store fabricated items in dry area, not in direct contact with ground.

E. Store adhesives anchors at service temperature ranges recommended by manufacturer.

1.06 SPECIAL GUARANTEE

A. Manufacturer's extended guarantee or warranty, with Owner named as beneficiary, in writing, as special guarantee. Special guarantee shall provide for correction, or at option of Owner, removal and replacement of [sidewalk doors] [and] [floor hatches] found defective during a period of 5 years after date of Substantial Completion. Duties and obligations for correction or removal and replacement of defective Work as specified in General Conditions.

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1.07 EXTRA MATERIALS

A. Furnish, tag, and box for shipment and storage the following extra materials:

Item	**Quantity**
[Neoprene Gasket]	[Two] [_____] for each location requiring neoprene gaskets.
[4 inches wide by 50 feet long Neoprene Gasket Material]	[One] [_____] roll for each location requiring neoprene gaskets.
[Neoprene Gasket Adhesive]	[One] [_____] (manufacturer's recommended) for each location requiring neoprene gaskets.
[_____]	[One] [_____] complete set.

B. Delivery: [In accordance with Section 01 61 00, Common Product Requirements.]

PART 2 - PRODUCTS

2.01 GENERAL

A. [For hot-dip galvanized steel that is exposed to view and does not receive paint, limit the combined phosphorus and silicon content to 0.04 percent. For steels that require a minimum of 0.15 percent silicon (such as plates over 1.5 inches thick for ASTM A36/A36M steel), limit maximum silicon content to 0.21 percent and phosphorous content to 0.03 percent.]

B. Unless otherwise indicated, meet the following requirements:

Item	**ASTM Reference**
Steel Wide Flange Shapes	A992/992M
Other Steel Shapes and Plates	A36/A36M
Steel Pipe	A501 or A53/A53M, Type E or S, Grade B
Hollow Structural Sections (HSS)	A500/A500M, Grade B
Stainless Steel:	
Bars and Angles	A276, AISI Type 316 (316L for welded connections)

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Item	ASTM Reference
Shapes	A276, AISI Type 304 (304L for welded connections)
Steel Plate, Sheet, and Strip	A240/A240M, AISI Type 316 (316L for welded connections)
Bolts, Threaded Rods, Anchor Bolts, and Anchor Studs	F593, AISI Type 316, Condition CW
Nuts	F594, AISI Type 316, Condition CW
Steel Bolts and Nuts:	
Carbon Steel	A307 bolts, with A563 nuts
High-Strength	A325, Type 1 bolts, with A563 nuts
Anchor Bolts and Rods	F1554, Grade [36] [55], with weldability supplement S1.
Eyebolts	A489
Threaded Rods	A36/A36M
Flat Washers (Unhardened)	F844
Flat and Beveled Washers (Hardened)	F436
Thrust Ties for Steel Pipe:	
Threaded Rods	A193/A193M, Grade B7
Nuts	A194/A194M, Grade 2H
Plate	A283/A283M, Grade D
Welded Anchor Studs	A108, Grades C-1010 through C-1020
Aluminum Plates and Structural Shapes	B209 and B308/B308M, Alloy 6061-T6
Aluminum Bolts and Nuts	F468, Alloy 2024-T4
Cast Iron	A48/A48M, Class 35

C. Bolts, Washers, and Nuts: Use stainless steel, hot-dip galvanized steel, zinc-plated steel, and aluminum material types as indicated in Fastener Schedule at end of this section.

2.02 ANCHOR BOLTS AND ANCHOR BOLT SLEEVES

A. Cast-In-Place Anchor Bolts:

1. Headed type, unless otherwise shown on Drawings.

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2. Material type and protective coating as shown in Fastener Schedule at end of this section.

B. Anchor Bolt Sleeves:

1. Plastic:
   a. Single unit construction with corrugated sleeve.
   b. Top of sleeve shall be self-threading to provide adjustment of threaded anchor bolt projection.
   c. Material: High-density polyethylene.
   d. Manufacturer: Sinco Products, Inc., Middletown, CT, (800) 243-6753.

2. Fabricated Steel: ASTM A36/A36M.

2.03 POST-INSTALLED CONCRETE ANCHORS

A. General:

1. AISI Type 316 stainless, hot-dip galvanized, or zinc-plated steel, as shown in Fastener Schedule at end of this section.
2. Current ICC-ES Report indicating acceptance per IBC 2006 and IBC 2009 for anchors at structural applications in cracked concrete.
3. Anchors shall be suitable for long-term loads, as well as for wind and seismic loads.
4. Acceptable for use in potable water structures by EPA and local health agencies or NSF 61.
5. Torque-Controlled Expansion Anchors (Wedge Anchors):
   a. Wedge anchors used in sustained tension applications (such as overhead or cantilevered applications) shall have current ICC-ES Report that demonstrates compliance with ICC-ES AC193 for cracked concrete.
   b. Manufacturers and Products:
      1) ITW Ramset/Red Head, Addison, IL; Trubolt+ Wedge Anchor (ESR-2427).
      2) Hilti, Inc., Tulsa, OK; Kwik-Bolt–TZ (KB-TZ) Anchors (ESR-1917).
      3) Powers Fasteners, Brewster , NY; Power-Stud +SD2 or +SD1 Anchors (ESR-2502 and ESR-2818).
      4) Simpson Strong-Tie Co., Inc., Pleasanton, CA; Strong-Bolt Anchors (ESR-1771).
      5) Wej-It Corp., Tulsa, OK; ANKRtite CCAT Wedge Anchor (ESR-2777).
6. Displacement-Controlled Expansion Anchors (Drop-in Anchors):
   a. Self-drilling anchors, snap-off or flush type, zinc-plated.

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b. Nondrilling Anchors: Flush type for use with zinc-plated or stainless steel bolt, or stud type with projecting threaded stud.
c. Manufacturers and Products:
1) ITW Ramset/Red Head, Addison, IL; Multi-Set II Drop-In and Self Drill Anchor.
2) Hilti, Inc., Tulsa, OK; Hilti HDI Drop-In Anchor.
3) Powers Fasteners, Brewster, NY; Steel Drop-In Anchor.
4) Simpson Strong-Tie Co., Inc., Pleasanton, CA; Drop-In Anchor.

7. [Undercut Anchors:
a. When used in sustained tension applications (such as overhead or cantilevered applications) shall have current ICC-ES Report that demonstrates compliance with ICC-ES AC193 for cracked concrete.
b. Manufacturers and Products:
1) USP Structural Connectors, Burnsville, MN; DUC Undercut Anchor (ESR-1970).
2) Hilti, Inc., Tulsa, OK; HDA Undercut Anchor (ESR-1546).
3) Powers Fasteners, Brewster, NY; Atomic+ Undercut (ESR-3067).
4) Simpson Strong-Tie Co., Inc., Pleasanton, CA; Torq-Cut (ESR pending).]

8. [Self-Tapping Concrete Screw Anchors:
a. When used in sustained tension applications (such as overhead or cantilevered applications) shall have current ICC-ES Report that demonstrates compliance with ICC-ES AC193 for cracked concrete.
b. Manufacturers and Products:
1) Powers Fasteners, Brewster, NY; Wedge-Bolt+ (ESR-2526).
2) Powers Fasteners, Brewster, NY; Vertigo+ Rod Hanger Screw Anchor (ESR-2989).
3) Powers Fasteners, Brewster, NY; Snake+ Flush Mount Screw Anchor (ESR-2272).
4) Hilti, Inc., Tulsa, OK; HUS-EZ Screw Anchor (ESR-3027).
5) Simpson Strong-Tie Co., Inc., Pleasanton, CA; Titen HD Screw Anchor (ESR-2713).]

9. Light-Duty Torque Controlled Expansion Anchors (Sleeve Anchors):
a. Manufacturers and Products:
1) ITW Ramset/Red Head, Addison, IL; Dynabolt Hex Nut Sleeve Anchor.
2) Powers Fasteners, Brewster, NY; Lok-Bolt AS.
3) Simpson Strong-Tie Co., Inc., Pleasanton, CA; Sleeve-All Hex Head Anchor.
4) Wej-It Corp., Tulsa, OK; Wej-It Sleeve Anchor.
b. Heavy-Duty Torque Controlled Expansion Anchors (Sleeve Anchors):

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c. Manufacturers and Products:
   1) Powers Fasteners, Brewster, NY; Power-Bolt+ Anchor.
   2) Hilti, Inc., Tulsa, OK; HSL-3 Heavy Duty Sleeve Anchor.

B. Adhesive Anchors (Epoxy Anchors):

1. If approved by ENGINEER, adhesive anchors used in sustained tension applications (such as overhead or cantilevered applications) shall have current ICC-ES Report that demonstrates compliance with ICC-ES AC308 for cracked concrete.
2. Threaded Rod:
   a. ASTM F593 stainless steel threaded rod, diameter as shown on Drawings.
   b. Length as required, to provide minimum depth of embedment.
   c. Clean and free of grease, oil, or other deleterious material.
   d. For hollow-unit masonry, provide galvanized or stainless steel wire cloth screen tube to fit threaded rod.
3. Adhesive:
   a. Two-component, insensitive to moisture, designed to be used in adverse freeze/thaw environments.
   b. Cure Temperature, Pot Life, and Workability: Compatible for intended use and anticipated environmental conditions.
   c. Mixed Adhesive: Nonsag light paste consistency with ability to remain in 1-inch diameter overhead drilled hole without runout.
   d. Meet requirements of ASTM C881/C881M.
4. Packaging and Storage:
   a. Disposable, self-contained cartridge system capable of dispensing both components in proper mixing ratio and fitting into manually or pneumatically operated caulking gun.
   b. Store adhesive cartridges [and adhesive components] on pallets or shelving in covered storage area.
   c. Container Markings: Include manufacturer’s name, product name, batch number, [mix ratio by volume], product expiration date, ANSI hazard classification, and appropriate ANSI handling precautions.
   d. Dispose of when:
      1) Shelf life has expired.
      2) Stored other than in accordance with manufacturer’s instructions.
5. Manufacturers and Products:
   a. Hilti, Inc., Tulsa, OK; HIT Doweling Anchor System, HIT RE 500 SD (ESR-2322).
   b. Simpson Strong-Tie Co., Inc., Pleasanton, CA; SET-XP Epoxy Adhesive Anchors(ESR-2508).

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c. Powers Fasteners, Brewster NY, PE1000+ Adhesive anchoring system (ESR-2583).

C. Adhesive Threaded Inserts:

1. Stainless steel, internally threaded inserts.
2. Manufacturer and Product: Hilti, Inc., Tulsa, OK; HIS-RN Insert with HIT-RE 500-SD adhesive.

2.04 POST-INSTALLED MASONRY ANCHORS

A. General: AISI Type 316 stainless, hot-dip galvanized, or zinc-plated steel, as shown in Fastener Schedule at end of this section.

B. Current ICC Evaluation Report indicating acceptance per IBC 2006 for anchors at structural applications in masonry.

C. Manufacturers and Products:

1. Hilti, Inc., Tulsa, OK;Kwik-Bolt-3 (KB-3) (ESR-1385), for grout-filled masonry.
2. Powers Fasteners, Brewster NY, T308+ Epoxy Adhesive Anchoring System in Unreinforced Masonry (ESR-3149), Power-Stud+ SD1 (ESR-2966) for grout-filled masonry, Wedgebolt+ (ESR-1678) for grout-filled masonry.

2.05 STUD SHEAR CONNECTORS

A. Headed anchor studs (HAS), or threaded anchor studs (TAS),or stud shear connectors, as indicated on Drawings.

1. Carbon Steel: ASTM A108, Standard Quality Grades 1010 through 1020, inclusive either semikilled or killed aluminum or silicon dioxidation, unless indicated otherwise.
2. Stainless Steel: ASTM F593, AISI Type 316, Condition CW, where indicated.

B. Manufacturers:

1. Nelson Stud Welding, FabriSteel Co., Elyria, OH.
2. Stud Welding Associates, Inc., Elyria, OH.

2.06 PIPE SLEEVES

A. [As specified in Section 40 27 01, Process Piping Specialties.]

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B. [ASTM A53/A53M, Schedule 40 steel pipe sleeves with continuously welded 3/16-inch-thick seep ring with outside diameter 3 inches greater than sleeve outside diameter. Hot-dip galvanize in accordance with ASTM A123/A123M.]

2.07 STEEL LINTELS AND SHELF ANGLES

A. ASTM A36/A36M, hot-dip galvanize after fabrication in accordance with ASTM A123/A123M.

2.08 EMBEDDED STEEL SUPPORT FRAMES FOR FLOOR PLATE AND GRATING

A. Steel angle support frames to be embedded in concrete shall be stainless steel, ASTM A276, AISI Type 316, unless indicated otherwise.

B. Welded anchors for stainless steel support frames shall also be stainless steel.

2.09 U-CHANNEL CONCRETE INSERTS

A. Rolled ASTM A240/A240M, AISI Type 316 stainless steel, 0.105-inch-thick, 1-5/8 inches wide by 1-3/8 inches deep, with stainless steel anchors at 10-inch maximum spacing, styrofoam fillers, and end caps.

B. Nut and Bolt Hardware: Type 316 stainless steel, 5/8-inch minimum diameter, unless indicated otherwise. Manufacturer’s standard to match insert.

C. Manufacturers and Products:

1. Power-Strut, Wayne, MI; PS 349 Series.
2. B-Line Systems, Inc., Highland, IL; B32 Series.
3. Halfen Anchoring Systems, Converse, TX; Channel Type 4141HTA.

2.10 ABRASIVE NOSING FOR STAIRS

A. Unless otherwise shown on Drawings, furnish flush type abrasive nosings on stairs.

B. Nosing Components:

1. Homogeneous epoxy abrasive, with minimum 50 percent aluminum oxide content, formed and cured upon an extruded aluminum base.
2. Epoxy abrasive shall extend over and form curved front edge of nosing.
3. Base of Nosing: Extruded aluminum alloy, 6063-T5, heat-treated.

C. Anchoring System: Double-set anchors consisting of two rows of integrally extruded anchors.

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D. Size: 3 inches wide by 1/4 inch to 3/8 inch thick by length as shown.

E. Color: Selected by ENGINEER from manufacturer's standard color range.

F. Manufacturers and Products:

1. Wooster Products, Inc., Wooster, OH; [Spectra Type WP3J] [and] [Spectra Type WP3C] [_____].
2. American Safety Tread Co., Inc., Helena, AL; [Type BF-311D] [and] [Type FA-311D] [_____].

2.11 FLOOR PLATE

A. Material:

1. Galvanized Steel: Carbon steel, ASTM A786/A786M, commercial grade, hot-dip galvanized after fabrication in accordance with ASTM A123/A123M.
2. Stainless Steel: ASTM A793, AISI Type 304.
3. Aluminum: ASTM B632/B632M, Alloy 6061-T6.

B. Minimum Thickness:

1. Steel: 1/4 inch, unless shown otherwise on Drawings.
2. Aluminum: 3/8 inch, unless shown otherwise on Drawings.

C. Surface shall be raised-lug pattern or diamond tread, unless shown otherwise on Drawings.

D. Slip-Resistant Surface:

1. Provide where indicated on Drawings.
2. Manufacturers and Products:
   a. IKG/Borden, Clark, NJ; MEBAC 2.
   b. W.S. Molnar Co., Detroit, MI; SLIPNOT Grade 2–Medium.

2.12 EXTRUDED FLOOR PLATE

A. Extruded Deck Plate:

1. Minimum Section Height: As shown on Drawings.
2. Minimum Section Width: 12 inches.
3. Accessories: [Dovetail interlock strips.] [Anchor clamp fixtures.] [Toeboard, 1-inch raised lip.]

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4. Manufacturer and Product: Alcoa Building Products, Inc., Sidney, OH; Standard Diamondback.

B. Extruded Tread Plate:

1. Minimum Section Height: 0.360 inch, plus serrations.
2. Section Width: 12 inches.
3. Accessories: Edgebands, tongue-and-groove attachment.
4. Manufacturer and Product: Alcoa Building Products, Inc., Sidney, OH; Standard Diamondback.

2.13 SIDEWALK DOORS

A. Load Capacity: 300 psf with maximum deflection of 1/150th of span. [Provide H-20 wheel loading capacity where indicated on Drawings.]

B. Component Fabrication:

1. Access Door Leaf(s): 1/4-inch aluminum diamond pattern plate. [Provide stainless steel safety chain and attachments for end of double-leaf door assembly when open.]
2. Channel Frame: 1/4-inch-thick extruded aluminum trough frame with continuous anchor flange around perimeter. Weld 1-1/2-inch diameter drain coupling, and drain pipe, to frame trough at front right corner, unless indicated otherwise on Drawings.
3. [Safety Grate: Aluminum grating with 300 psf live load capacity, 5-inch by 5-inch grate openings, permanent hinging system that locks grate in 90-degree position, and opening arm with vinyl grip handle and locking device.]

C. Door Hardware:

1. Hinges: Heavy-duty brass or stainless steel with stainless steel pins through-bolted to cover plate with tamper-proof stainless steel bolts flush with top of cover and to outside leg of channel frame with stainless steel bolts and locknuts.
2. Lifting Mechanism: Stainless steel compression lift springs enclosed in telescoping vertical housing or stainless steel torsion lift springs.
3. Hold-Open Arm:
   a. Locks automatically in open position.
   b. Disengages with slight pull on vinyl grip with one hand.
   c. Door can be easily closed with one hand by pulling forward and down on vinyl grip.
4. Snap Lock:

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a. Stainless steel snap lock mounted on bottom of door leaf with removable topside key wrench and inside fixed lever handle.
b. Threaded plug for flush outside surface with key wrench removed.

D. Aluminum shall be mill finished with protective coating applied to surfaces to be in contact with concrete, as specified in Section 09 90 00, Painting and Coating.

E. Manufacturers and Products:

1. Bilco Co., New Haven, CT; J Series.
2. Nystrom Products Co., Minneapolis, MN; FG Series.
3. U.S.F. Fabrication, Hialeah, FL; T Series.
4. ITT Flygt Corporation, Trumbull, CT; FDRN Series.
5. Thompson Fabricating Co., Birmingham, AL; TE Series.
6. Halliday Products, Orlando, FL; WS Series.

2.14 FLOOR HATCHES

A. Load Capacity: [150] [300] psf with maximum deflection of 1/150th of span.

B. Component Fabrication:

1. Access Door Leaf(s): 1/4-inch-thick aluminum diamond pattern plate. [Provide stainless steel safety chain and attachments for end of double-leaf door assembly when open.]
2. Angle Frame: 1/4-inch thick extruded aluminum angle frame with concrete anchors and integral neoprene gasket strip.

C. Door Hardware:

1. Hinges: Heavy-duty brass or stainless steel with stainless steel pins, through-bolted to cover plate with tamper-proof stainless steel bolts flush with top of cover and to outside leg of channel frame with stainless steel bolts and locknuts.
2. Lifting Mechanism: Stainless steel compression lift springs enclosed in telescoping vertical housing or stainless steel torsion lift springs.
3. Hold-Open Arm:
   a. Locks automatically in open position.
   b. Disengages with slight pull on vinyl grip with one hand.
   c. Door can be easily closed with one hand by pulling forward and down on vinyl grip.
4. Snap Lock:

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a. Stainless steel snap lock mounted on bottom of door leaf with removable topside key wrench and inside fixed lever handle.
b. Threaded plug for flush outside surface with key wrench removed.

D. Aluminum shall be mill finished with protective coating applied to surfaces to be in contact with concrete, as specified in Section 09 90 00, Painting and Coating.

E. Manufacturers and Products:

1. Bilco Co., New Haven, CT; K Series.
2. Nystrom Products Co., Minneapolis, MN; FH Series.
3. U.S.F. Fabrication, Hialeah, FL; A Series.
4. ITT Flygt Corporation, Trumbull, CT; FLE Series.
5. Thompson Fabricating Co., Birmingham, AL; TI Series.
6. Halliday Products, Orlando, FL; SS Series.

2.15 HATCH SAFETY NET

A. General:

1. Conforms to ASSE A10.11 and OSHA CFR Part 1926.105.
2. Size to fit hatch opening where indicated.

B. Components and Accessories:

1. Rails and Slide Rings: Aluminum 6061-T6 extruded rails and aluminum-alloy 713.0 slide rings.
2. Corner Hooks and Eyebolts: AISI Type 316 stainless steel.
3. Netting: Polyester, 5-inch by 5-inch net openings; 5,000 pounds minimum breaking strength.
4. Bolts, Nuts, and Concrete Anchors: AISI Type 316 stainless steel.

C. Manufacturer and Product: Safe Approach Inc., Auburn, ME; Hatch Net 121.

2.16 HINGED MANHOLE COVERS

A. Slab type rectangular manhole frame and cover with flush, waterproof lift handles, and stainless steel butt hinges.

B. ASTM A48/A48M, Class 35, cast iron, unpainted.

C. Furnish as shown in table:

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Hinged Manhole Covers			
Mark	**Duty**	**Size (inches)**	**Weight (pounds)**
HMC-1	Light	24 x 36	275
HMC-2	Light	30 x 30	290
HMC-3	Light	30 x 36	335
HMC-4	Light	30 x 48	450
HMC-5	Heavy	30 x 36	525
HMC-6	Heavy	36 x 36	700

D. Manufacturers:

1. Neenah Foundry Co., Neenah, WI.
2. Flockhart Foundry Co., Newark, NJ.

2.17 LADDERS

A. Fabricate ladders with rails, rungs, landings, and cages to meet applicable requirements of OSHA, CFR Part 1910.27, and ALI A14.3.

1. Concentrated load of 200 pounds loads imposed by persons occupying ladder shall be considered to be concentrated at such points as will cause maximum stress in structural member being considered.
2. Weight of ladder and attached appurtenances together with live load shall be considered in design of rails and fastenings.
3. Self-closing gates at landings.

B. Flat Bar Ladder:

1. Punch rails, pass rungs through rails, and weld on outside.
2. Weld brackets to ladder for fastening ladder to wall.
3. [Hot-dip galvanize steel after fabrication in accordance with ASTM A123/A123M and ASTM A385/A385M.]

C. Aluminum Pre-engineered Pipe Ladder:

1. Rungs:
   a. Aluminum extrusions of Alloy 6063-T6.
   b. [Nonslip grip surface, 1-inch wide flat top, and semicircular bottom with mill finish.]

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c. [Diamondback, finish to match rails, as manufactured by Alcoa Building Products, Inc., Sidney, OH.]

2. Side Rails: ASTM B429/B429M, Alloy 6063-T6, 1-1/2 inches, Schedule 40 pipe with anodized finish, AA M32-C22-A41.
3. Ladder Attachments and Cage Assembly Fasteners: Stainless steel.
4. Welded, pop riveted, or glued construction is not acceptable.
5. Fabricate to longest length as practical but not to exceed 24 feet.
6. Furnish support attachments to side rails at 6 feet maximum spacing.
7. Manufacturer: Thompson Fabricating Co. Inc., Tarrant, AL.

D. Ladder Safety Post:

1. Telescoping tubular, spring balanced and automatically locking in raised position, with release lever for unlocking.
2. Post: [Hot-dip galvanized steel in accordance with ASTM A123/A123M.] [Stainless steel, AISI Type 316.] [Aluminum.]
3. Spring Mechanism: Stainless steel.
4. Furnish dissimilar metal protective coatings at connections.
5. Manufacturer and Product: Bilco Co., New Haven, CT; "Ladder Up" to fit ladder rungs.

2.18 SAFETY CLIMB DEVICE

A. General:

1. Conforms to ALI A14.3 and OSHA CFR Part 1910.27.
2. Belt and harness shall withstand minimum drop test of 250 pounds in 6-foot free fall.
3. Fall Prevention System Material: [Aluminum 6061-T6.] [Hot-dip galvanized steel in accordance with ASTM A123/A123M.] [Stainless steel, AISI Type 316.]

B. Components and Accessories:

1. Main Components: Sleeve or trolley, safety harness, and carrier or climbing rail.
2. Ladder rung clamps with [aluminum] [hot-dip galvanized steel] [stainless steel, AISI Type 316,] mounting brackets and hardware.
3. Removable extension kit with tiedown rod or trolley gate, mandrel, and carrier rail for ladders under manholes and hatches.

C. Manufacturers and Products:

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1. Miller Equipment, Franklin, PA; Sure Track Rail System.
2. TS Products, St. Charles, IL; TS Safety Rail System.

2.19 LADDER CLIMB PREVENTION SHIELD

A. Eight feet long with angled sides to within 2 inches of wall when closed.

B. Furnish dissimilar metals protective coatings at bolted connections.

C. Manufacturer and Product: North Safety Products, Specialty Products Division, Toronto, Ontario, Canada; Ladder Gate 770-000-001.

2.20 FALL ARREST ANCHORS

A. General:

1. Conforms to OSHA CFR Part 1926.502.
2. Minimum Breaking Strength: 5,000 pounds.
3. Material: [Hot-dip galvanized steel in accordance with ASTM A123/A123M.] [Stainless steel, AISI Type 304.]

B. Components and Accessories:

1. Forged combination eye and base assembly with [headed anchor bolt, backer plate,] [hooked anchor bolt,] lock washer, and nut.
2. Suitable for embedment in concrete wall or slab.

C. Manufacturers and Products:

1. Thaler Metal Industries, Buffalo, NY; FARA Wall Anchor.
2. Rose Manufacturing Company, Pittsburgh, PA; Anchorage Connector.

2.21 SPIRAL STAIR

A. Design: Aluminum, open-riser design, [54] [_____]-inch diameter, 30-degree cast aluminum treads or 12 treads per circle with abrasive surface on treads and platforms with risers of equal height.

B. Meet applicable standards in Federal Register Volume 36, No. 105, Part II, Department of Labor Occupational Safety and Health Administration, and state and municipal codes.

C. Fabrication:

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1. Landing(s): Similar material to treads.
2. Center Aluminum Column: 3-1/2-inch minimum OD with top capped and 10-inch minimum baseplate.
3. Furnish adequate bracing to wall at each circle of height.
4. Furnish manufacturer's standard aluminum handrail satisfying OSHA strength requirements with balusters at each tread.
5. Fasteners: Stainless steel.
6. Furnish minimum 10-minute etch on aluminum, and satin finish on rails.

D. Manufacturers and Products:

1. Duvinage Corp., Hagerstown, MD; Series 320.
2. Woodbridge Ornamental Iron Co., Chicago, IL.

2.22 ALTERNATING STAIR TREADS

A. Material:

1. Landings, Treads, and Foot Castings: Cast aluminum alloy F356F.
2. Handrails: Aluminum alloy 6063-T4, 1-1/2-inch by 1/8-inch tube.
3. Central Stringer: Aluminum alloy 6063-T52, 1-3/4-inch by 4-inch by 1/8-inch tube with rubber bumper strip.

B. Treads: Skid-resistant with upturned integrally cast skid barriers.

C. Risers: Equally spaced to within 3/16 inch for adjacent risers and to within 3/8 inch for nonadjacent risers.

D. Handrails: Contoured for body guidance and underarm support, with supports positioned to allow free sliding of hands along rails.

E. Foot Divider: Cast aluminum integral part of landing, which provides support for rubber bumper strip attached to central stringer.

F. Stair Angle: 68 degrees from horizontal.

G. Vertical Drop: As shown on Drawings.

H. Finish: Natural aluminum finish.

I. Manufacturer and Product: Lapeyre Stair, Inc., Harahan, LA; 68-Degree Alternating Tread Aluminum Stair.

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2.23 FABRICATED UNITS

A. Mooring Cable Anchors for Floating Aerators: [5/8-inch diameter by _____ long galvanized steel, as manufactured by Chance; Catalog No. 617 with triple eye.]

B. Chlorine Cylinder Trunnions: [_____]-ton, as manufactured by Chlorine Specialties, Inc., San Francisco, CA; Model C-256.

C. Chlorine Cylinder Lift Beam:

1. Maximum 13 inches from top of cylinder to hook hole.
2. Hot-dip galvanize after fabrication.
3. Manufacturers and Products:
   a. Mansaver Industries, Inc., New Haven, CT; Style 1118.
   b. Allied Steel Co., Inc., Los Angeles, CA.

D. Decant Arm:

1. Fabricate from welded steel pipe.
2. Coat interior with coal-tar enamel as specified in Section 09 90 00, Painting and Coating.
3. Paint exterior as specified in Section 09 90 00, Painting and Coating.

E. Pressure Type Manhole Hatches:

1. Aluminum cover suitable for 15 psi with steel weld neck and cam locks.
2. Hot-dip galvanize manhole and extension sleeve in accordance with ASTM A123/A123M after welding.
3. Furnish cam handle, bar, and six extra gaskets.
4. Manufacturer and Product: West Coast Engineered Products, Huntington Park, CA; West Coast No. 1520.

F. Digester Wall Manholes:

1. Fabricate of steel.
2. Shop coat as specified in Section 09 90 00, Painting and Coating.
3. Weld joints continuously and make watertight.
4. Furnish neoprene gasket of type that is satisfactory for use in contact with sewage to cover full bearing surface.

G. Shell Manhole:

1. Flanged and bolted type with confined rubber gasket.

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2. Manhole Unit: Capable of withstanding pressure of full tank of water with no leakage.
3. Minimum clear opening of 24 inches.
4. Cover: Hinged to tank.
5. Grind welds and sheared edges smooth.

H. Weir or Staff Gauge: Porcelain enameled, [_____] long, graduated in [_____] and marked at every [_____] and every [_____] as manufactured by Stevens Water Monitoring Equipment, Beaverton, OR; Style C.

I. Filter Screens: Steel, expanded metal, 3/4 inch, galvanized, as manufactured by Diamond Expanded Metals Co., Gardena, CA; Style No. 9.

J. Overflow Pipe and Accessories:

1. Use steel pipe and fabricate flared section at top of overflow of steel plate, weld seams, and grind smooth.
2. Flange at Base:
   a. Standard 125-pound steel ring flange drilled 125-pound ANSI Standard.
   b. Flange: Parallel to upper edge of fitting so lip can be installed in horizontal plane with pipe vertical.
   c. Grind upper lip smooth.
3. Fabricate supporting brackets of structural shapes and flat bar stock, as shown.
4. Bolts: Hot-dip galvanized steel machine bolts with hexagon nuts in accordance with ASTM A153/A153M.
5. Hot-dip galvanize assembly after fabrication in accordance with ASTM A123/A123M.
6. Coat interior with coal-tar enamel as specified in Section 09 90 00, Painting and Coating.

K. Float Pipe:

1. Standard weight steel pipe.
2. Furnish flanges of 1/2-inch steel plate for mid-height connection.
3. Furnish steel angle braces and all accessories.
4. Hot-dip galvanize float pipe after fabrication in accordance with ASTM A123/A123M.

L. Vortex Breaker: Use aluminum shapes and plate.

1. Plate Pattern: Approved nonslip pattern.
2. Supporting Frame: Aluminum, furnished with anchors for embedment in concrete.

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3. Make connections with welds, bolts, or machine screws.
4. Grind smooth sheared edges of structural shapes and plates.
5. Hardware: Aluminum.
6. Apply protective coating of bituminous paint to aluminum surfaces in contact with concrete.

M. T-Handled Operating Wrenches: Galvanized operating wrenches, [4] [_____]-foot total length, No. A-2461 as manufactured by Mueller.

N. Valve Operator Access Box: Cast iron, 8 inches by 4 inches, as manufactured by Zurn; No. ZN-1930-K.

O. Sampling Hatch Covers for [_____]: 6 inches in diameter, as manufactured by Vapor Recovery Systems, Varec No. 42-81.

P. Nonsparking Manhole Covers for [_____]: 24 inches, with galvanized steel roof insert frame and 1/4-inch neoprene gasket for each, as manufactured by Vapor Recovery Systems; Varec No. 220-82.

Q. Wire Mesh Screen:

1. Fabricate frame of aluminum shapes and flat bar stock.
2. Wire Mesh: Woven of 14-gauge aluminum wire, three openings per inch, stretched taut over frame before bolts are tightened down.

R. Weir and Baffle Plates: Fabricate plates and associated framing of [stainless steel, AISI Type 316] [aluminum alloy 6061-T6 using welding filler wire as manufactured by Alcoa, No. 4043], unless indicated otherwise on Drawings.

S. Stop Gates and Guide Frames: Aluminum plate with aluminum channel or angle sections as stiffeners.

1. Guides, Rests, and Fasteners: AISI Type 316 stainless steel.
2. Identification Plate:
   a. 16-gauge aluminum or stainless steel securely mounted on each gate.
   b. Text: 1-inch die-stamped word “WATERSIDE” and corresponding gate number [as shown in Gate Schedule].
   c. Mount plate on side opposite gate stiffeners.
3. Extruded Aluminum Guide Manufacturer: Washington Aluminum Co., Baltimore, MD.

2.24 DUMPING EQUIPMENT AND GRIT DRUMS

A. Dumping Equipment:

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1. Girdle: Suitable for use with 55-gallon standard steel drums, complete with locking toggle and handwheel adjustment for variations in drum size.
2. Dumping Frame:
   a. Suitable for use with grit washer hoist.
   b. Suitable for dumping open-end drums, 1,000-pound capacity.
3. Manufacturers and Products:
   a. Girdle: Star Machinery Co., Portland, OR; Cecor Model 95.

a. Dumping Frame: Star Machinery Co., Portland, OR; Cecor Model 1095.

B. Grit Drums:

1. Furnish [four] [_____] 55-gallon standard steel drums.
2. Finish: Commercial blast clean and paint in accordance with Section 09 90 00, Painting and Coating.

2.25 CASTINGS

A. Frame and Cover for [_____]: Olympic Foundry; No. [_____]

B. Meter Box Manhole: Nonslip surface and handle, as manufactured by Olympic Foundry Co.; 5823B.

C. Floor Boxes:

1. Cast iron, except as otherwise shown.
2. Depth: Equal to slab thickness where installed.
3. Diameter: As shown.
4. Manufacturers and Products:
   a. Neenah Foundry, Neenah, WI; R 7506.
   b. Mueller, Decatur, IL; No. A-27010.
   c. Olympic Foundry Co., Seattle, WA; No. 5680.

2.26 ACCESSORIES

A. Antiseizing Lubricant for Stainless Steel Threaded Connections:

1. Suitable for potable water supply.
2. Resists washout.
3. Manufacturers and Products:
   a. Bostik, Middleton, MA; Neverseez.
   b. Saf-T-Eze Div., STL Corp., Lombard, IL; Anti-Seize.

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B. Neoprene Gasket:

1. ASTM D1056, 2C1, soft, closed-cell neoprene gasket material, suitable for exposure to sewage and sewage gases, unless otherwise shown on Drawings.
2. Thickness: Minimum 1/4 inch.
3. Furnish without skin coat.
4. Manufacturer and Product: Monmouth Rubber and Plastics Corporation, Long Branch, NJ; Durafoam DK1111LD.

2.27 FABRICATION

A. General:

1. Finish exposed surfaces smooth, sharp, and to well-defined lines.
2. Furnish necessary rabbets, lugs, and brackets so work can be assembled in neat, substantial manner.
3. Conceal fastenings where practical; where exposed, flush countersink.
4. Drill metalwork and countersink holes as required for attaching hardware or other materials.
5. Grind cut edges smooth and straight. Round sharp edges to small uniform radius. Grind burrs, jagged edges, and surface defects smooth.
6. Fit and assemble in largest practical sections for delivery to Site.

B. Materials:

1. Use steel shapes, unless otherwise noted.
2. Steel to be hot-dip galvanized: Limit silicon content to less than 0.04 percent or to between 0.15 and 0.25 percent.
3. Fabricate aluminum in accordance with AA Specifications for Aluminum Structures–Allowable Stress Design.

C. Welding:

1. Weld connections and grind exposed welds smooth. When required to be watertight, make welds continuous.
2. Welded fabrications shall be free from twisting or distortion caused by improper welding techniques.
3. Steel: Meet fabrication requirements of AWS D1.1/D1.1M, Section 5.
4. Aluminum: Meet requirements of AWS D1.2/D1.2M.
5. Stainless Steel: Meet requirements of AWS D1.6/D1.6M.
6. Welded Anchor Studs: Prepare surface to be welded and weld with stud welding gun in accordance with AWS D1.1/D1.1M, Section 7, and manufacturer’s instructions.

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7. Complete welding before applying finish.

D. Painting:

1. Shop prime with rust-inhibitive primer as specified in Section 09 90 00, Painting and Coating, unless otherwise indicated.
2. Coat surfaces of galvanized steel and aluminum fabricated items to be in direct contact with concrete, grout, masonry, or dissimilar metals, as specified in Section 09 90 00, Painting and Coating, unless indicated otherwise.
3. Do not apply protective coating to galvanized steel anchor bolts or galvanized steel welded anchor studs, unless indicated otherwise.

E. Galvanizing:

1. Fabricate steel to be galvanized in accordance with ASTM A143/A143M, ASTM A384/A384M, and ASTM A385/A385M. Avoid fabrication techniques that could cause distortion or embrittlement of the steel.
2. Provide venting and drain holes for tubular members and fabricated assemblies in accordance with ASTM A385/A385M.
3. Remove welding slag, splatter, burrs, grease, oil, paint, lacquer, and other deleterious material prior to delivery for galvanizing.
4. Remove by blast cleaning or other methods surface contaminants and coatings not removable by normal chemical cleaning process in the galvanizing operation.
5. Hot-dip galvanize steel members, fabrications, and assemblies after fabrication in accordance with ASTM A123/A123M.
6. Hot-dip galvanize bolts, nuts, washers, and hardware components in accordance with ASTM A153/A153M. Oversize holes to allow for zinc alloy growth. Shop assemble bolts and nuts.
7. Galvanized steel sheets in accordance with ASTM A653/A653M.
8. Galvanize components of bolted assemblies separately before assembly. Galvanizing of tapped holes is not required.

F. Electrolytic Protection: Coat surfaces of galvanized steel and aluminum fabricated items to be in direct contact with concrete, grout, masonry, or dissimilar metals, as specified in Section 09 90 00, Painting and Coating, unless indicated otherwise.

G. Watertight Seal: Where required or shown, furnish neoprene gasket of a type that is satisfactory for use in [contact with sewage] [_____]. Cover full bearing surfaces.

H. Fitting: Where movement of fabrications is required or shown, cut, fit, and align items for smooth operation. Make corners square and opposite sides parallel.

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I. Accessories: Furnish as required for a complete installation. Fasten by welding or with stainless steel bolts or screws.

2.28 SOURCE QUALITY CONTROL

A. Visually inspect all fabrication welds and correct deficiencies.

1. Steel: AWS D1.1/D1.1M, Section 6 and Table 6.1, Visual Inspection Acceptance Criteria.
2. Aluminum: AWS D1.2/D1.2M.
3. Stainless Steel: AWS D1.6/D1.6M.

B. [Hot-Dip Galvanizing:]

1. [An independent testing agency [, will be retained by Owner] [, shall be retained by Contractor and approved by ENGINEER] to inspect and test hot-dip galvanized fabricated items [, except _____] in accordance with ASTM A123/A123M and ASTM A153/A153M.]
2. [Visually inspect and test for thickness and adhesion of zinc coating for minimum of three test samples from each lot in accordance with ASTM A123/A123M and ASTM A153/A153M.]
3. [Reject and retest nonconforming articles in accordance with ASTM A123/A123M and ASTM A153/A153M.]

PART 3 - EXECUTION

3.01 INSTALLATION OF METAL FABRICATIONS

A. General:

1. Install metal fabrications plumb and level, accurately fitted, free from distortion or defects.
2. Install rigid, substantial, and neat in appearance.
3. Install manufactured products in accordance with manufacturer’s recommendations.
4. Obtain ENGINEER approval prior to field cutting steel members or making adjustments not scheduled.

B. Aluminum:

1. Do not remove mill markings from concealed surfaces.
2. Remove inked or painted identification marks on exposed surfaces not otherwise coated after installed material has been inspected and approved.

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3. Fabrication, mechanical connections, and welded construction shall be in accordance with the AA Aluminum Design Manual.

C. Pipe Sleeves:

1. Provide where pipes pass through concrete or masonry.
2. Holes drilled with a rotary drill may be provided in lieu of sleeves in existing walls.
3. Provide center flange for water stoppage on sleeves in exterior or water-bearing walls.
4. Provide rubber caulking sealant or a modular mechanical unit to form watertight seal in annular space between pipes and sleeves.

D. Steel Lintels and Shelf Angles: Provide as required for support of masonry and other construction not attached to structural steel framing, unless otherwise shown on Drawings.

3.02 CAST-IN-PLACE ANCHOR BOLTS

A. Locate and hold anchor bolts in place with templates at time concrete is placed.

B. Use anchor bolt sleeves for location adjustment and provide two nuts and one washer per bolt of same material as bolt.

C. Minimum Bolt Size: 1/2-inch diameter by 12 inches long, unless otherwise shown.

3.03 CONCRETE AND MASONRY POST-INSTALLED ANCHORS

A. Begin installation only after concrete or masonry to receive anchors has attained design strength.

B. Install in accordance with manufacturer's instructions.

C. Provide minimum embedment, edge distance, and spacing as follows, unless indicated otherwise by anchor manufacturer's instructions or shown otherwise on Drawings:

Anchor Type	Minimum Embedment (Bolt Diameters)	Minimum Edge Distance (Bolt Diameters)	Minimum Spacing (Bolt Diameters)
Expansion	9	6	12

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Anchor Type	Minimum Embedment (Bolt Diameters)	Minimum Edge Distance (Bolt Diameters)	Minimum Spacing (Bolt Diameters)
Undercut	9	12	16
Adhesive	9	9	13.5

D. Use only drill type and bit type and diameter recommended by anchor manufacturer. Clean hole of debris and dust with brush and compressed air per manufacturer's printed installation instructions.

E. For undercut anchors, use special undercutting drill bit and rotary hammer drill and apply final torque as recommended by anchor manufacturer.

F. When embedded steel or rebar is encountered in drill path, slant drill to clear obstruction. If drill must be slanted more than 10 degrees to clear obstruction, notify ENGINEER for direction on how to proceed.

G. Adhesive Anchors:

1. Do not install adhesive anchors when temperature of concrete is below 40 degrees F or above 100 degrees F, unless cold temperature adhesives, compliant with ACI 308 are used. Refer to the respective ICC-ES report and manufacturer's printed installation instructions.
2. Remove water from hole with oil-free compressed air. Damp or water filled holes may be allowed only if approved in manufacturer's printed installation instructions and ICC-ES report.
3. For hollow-unit masonry, install screen tube in accordance with manufacturer's printed installation instructions.
4. Do not disturb anchor during recommended curing time.
5. Do not exceed maximum torque as specified in manufacturer's printed installation instructions.

H. Prestressed Concrete: Do not use post-installed anchors in prestressed or post-tensioned concrete members without ENGINEER's prior approval, unless specifically shown on Drawings. If ENGINEER approves anchor installation all prestressed tendons in vicinity of anchors must be located prior to drilling.

3.04 U-CHANNEL CONCRETE INSERTS

A. Provide as indicated for pipe supports and where otherwise shown on Drawings.

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B. Except for interior dry areas, use plastic clips or similar dielectric material to isolate channel anchors from concrete reinforcing steel.

3.05 ABRASIVE NOSINGS

A. Provide abrasive nosings on concrete steps not being supplied or coated with another type of nosing or nonskid material.

3.06 ACCESS COVERS

A. Install access covers, including sidewalk doors, floor hatches, and hinged manhole covers in accordance with manufacturer's instructions.

B. Accurately position prior to placing concrete, such that covers are flush with floor surface.

C. Protect from damage resulting from concrete placement. Thoroughly clean exposed surfaces of concrete spillage to obtain a clean, uniform appearance.

B. [Route drain pipe to exterior face of concrete or as shown on Drawings].

3.07 SAFETY CLIMB DEVICE SYSTEM

A. Provide for each ladder where unbroken height between levels exceeds 20 feet, or at lesser height where indicated on Drawings.

B. Install in accordance with manufacturer's instructions.

C. Furnish additional accessories required to complete system for each ladder.

D. Furnish one harness for each ladder equipped with safety climb device.

E. Furnish pivot section at platforms, landings, and roofs.

F. When installed to required height, fall prevention system shall be rigid and an integral part of the structure.

3.08 ELECTROLYTIC PROTECTION

A. Aluminum and Galvanized Steel:

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1. Coat surfaces of galvanized steel and aluminum fabricated items to be in direct contact with concrete, grout, masonry, or dissimilar metals, as specified in Section 09 90 00, Painting and Coating, unless indicated otherwise.
2. Do not apply protective coating to galvanized steel anchor bolts or galvanized steel welded anchor studs, unless indicated otherwise.
3. Allow coating to dry before installation of the material.
4. Protect coated surfaces during installation.
5. Should coating become marred, prepare and touch up in accordance with paint manufacturer's written instructions.

B. Titanium: Where titanium equipment is in contact with concrete or dissimilar metal, provide full-face neoprene insulation gasket, 3/32-inch minimum thickness and 70-durometer hardness.

C. Stainless Steel:

1. During handling and installation, take necessary precautions to prevent carbon impregnation of stainless steel members.
2. After installation, visually inspect stainless steel surfaces for evidence of iron rust, oil, paint, and other forms of contamination.
3. Remove contamination using cleaning and passivation methods in accordance with requirements of ASTM A380 and ASTM A967.
4. Brushes used to remove foreign substances shall utilize only stainless steel or nonmetallic bristles.
5. After treatment, visually inspect surfaces for compliance.

3.09 PAINTING

A. Painted Galvanized Surfaces: Prepare as specified in Section 09 90 00, Painting and Coating.

B. Repair of Damaged Hot-Dip Galvanized Coating:

1. Conform to ASTM A780/A780M.
2. For minor repairs at abraded areas, use sprayed zinc conforming to ASTM A780/A780M.
3. For flame cut or welded areas, use zinc-based solder, or zinc sticks, conforming to ASTM A780/A780M.
4. Use magnetic gauge to determine thickness is equal to or greater than base galvanized coating.

C. [Field Painting of Shop Primed Surfaces: Prepare surfaces and field finish in accordance with Section 09 90 00, Painting and Coating.]

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3.10 FIELD QUALITY CONTROL

A. Owner-Furnished Quality Assurance:

1. In accordance with IBC Chapter 17 requirements, is provided in the Statement of Special Inspections Plan on Drawings.
2. Contractor responsibilities and related information on special inspection [, observation,] and testing are included in Section 01 45 33, Special Inspection [, Observation,] and Testing.

B. Contractor-Furnished Quality Control:

1. Inspection and testing required in Section 01 45 16.13, Contractor Quality Control.
2. Certificate of Compliance per Section 01 43 33, Manufacturer's Field Services, for test results, or calculations, or drawings that ensure material and equipment design and design criteria meet requirements of Section 01 61 00, Common Product Requirements [and Section 01 88 15, Anchorage and Bracing].

C. [Stud Shear Connectors:

1. At start of each production period, conduct the following test to determine proper generator, control unit, and stud welding gun settings, in accordance with AWS D1.1/D1.1M, Chapter 7:
   a. Weld two test studs and visually inspect for full 360-degree flash.
   b. Bend test studs 30 degrees from vertical for headed anchor studs (HAS). Torque test threaded anchor studs (TAS) studs per AWS D1.1/D1.1M, Section 7.6.6.2.
   c. Test studs will be acceptable if there is no failure of welds.
   d. If weld fails, repeat test until two consecutive test studs test to be satisfactory.
2. During production, if visual inspection reveals weld does not exhibit full 360-degree flash or that stud has been repaired by welding, conduct the following test in accordance with AWS D1.1/D1.1M, Chapter 7:
   a. Bend HAS studs or stud shear connectors approximately 15 degrees from vertical, away from missing portion of flash. For TAS studs, torque test per AWS D1.1/D1.1M, Section 7.6.6.2.
   b. Studs meeting this test without exhibiting cracks in weld will be considered acceptable and left in bent position.
   c. Replace studs failing test.]
3. [Special inspection shall be provided by Owner where indicated on Drawings.]

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D. [Concrete and Masonry Drilled Anchors: Special inspection and testing will be provided by Owner where indicated on Drawings.]

3.11 [MANUFACTURER'S SERVICES

A. Anchor Installation: Conduct site training of installation personnel for proper installation, handling, and storage of mechanical and adhesive anchor systems. Notify ENGINEER of time and place for sessions.]

3.12 FASTENER SCHEDULE

A. Unless indicated otherwise on Drawings, provide fasteners as follows:

Service Use and Location	Product	Remarks
1. Anchor Bolts Cast Into Concrete for Structural Steel, Metal Fabrications and Castings		
Interior Dry Areas	[Plain uncoated] [Hot-dip galvanized] steel headed anchor bolts, unless indicated otherwise	
Exterior and Interior Wet Areas	[Hot-dip galvanized] [Stainless] steel headed anchor bolts	
Submerged and Corrosive Areas	Stainless steel headed anchor bolts with fusion bonded coating	See Section 09 90 00, Painting and Coating
2. Anchor Bolts Cast Into Concrete for Equipment Bases		
Interior Dry Areas	Stainless steel headed anchor bolts, unless otherwise specified with equipment	
Submerged, Exterior, Interior Wet, and Corrosive Areas	Stainless steel headed anchor bolts with fusion bonded coating, unless otherwise specified with equipment	See Section 09 90 00, Painting and Coating

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Service Use and Location	Product	Remarks
3. Drilled Anchors for Metal Components to Cast-in-Place Concrete (e.g., Ladders, Handrail Posts, Electrical Panels, and Equipment)		
Interior Dry Areas	Zinc-plated or stainless steel wedge or expansion anchors	[Use zinc-plated undercut anchors for overhead and ceiling installations.] [Use zinc-plated wedge anchors approved for use in cracked concrete for overhead and ceiling installations.]
Submerged, Exterior, Interior Wet, and Corrosive Areas	Adhesive stainless steel anchors	[Use stainless steel undercut anchors for overhead and ceiling installations.] [Use stainless steel wedge anchors approved for use in cracked concrete for overhead and ceiling installations.]
4. Anchors in Grout-Filled Concrete Masonry Units		
Exterior and Interior Wet and Dry Areas	Hot-dip galvanized steel headed anchor bolts, zinc-plated or stainless steel sleeve anchors, or stainless steel adhesive anchors	
5. Anchors in Hollow Concrete Masonry Units		
Exterior and Interior Wet and Dry Areas	Zinc-plated or stainless steel sleeve anchors, or stainless steel adhesive anchors with screen tube	
6. Connections for Structural Steel Framing		
Exterior and Interior Wet and Dry Areas	High-strength steel bolted connections	Use hot-dipped galvanized high-strength bolted connections for galvanized steel framing members.
7. Connections for Steel Fabrications and Wood Components		

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Service Use and Location	Product	Remarks
Exterior and Interior Wet and Dry Areas	[Hot-dip galvanized carbon] [Stainless] steel bolted connections	
8. Connections of Aluminum Components		
Submerged, Exterior and Interior Wet and Dry Areas	Stainless steel bolted connections, unless otherwise specified with equipment	
9. All Others		
Exterior and Interior Wet and Dry Areas	Stainless steel fasteners	

B. Antiseizing Lubricant: Use on stainless steel threads.

C. Do not use adhesive anchors to support fire-resistive construction or where ambient temperature will exceed 120 degrees F.

END OF SECTION

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SECTION 05 52 00
METAL RAILINGS

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. Aluminum Association, Incorporated (AA): DAF45, Designation System for Aluminum Finishes.
2. American Iron and Steel Institute (AISI).
3. ASTM International (ASTM):
   a. A36/A36M, Standard Specification for Carbon Structural Steel.
   b. A53/A53M, Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless.
   c. A123/A123M, Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
   d. A167, Standard Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip.
   e. A193/A193M, Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications.
   f. A194/A194M, Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both.
   g. A501, Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing.
   h. A554, Standard Specification for Welded Stainless Steel Mechanical Tubing.
   i. E985, Standard Specification for Permanent Metal Railing Systems and Rails for Buildings.
4. International Code Council (ICC): International Building Code (IBC).
5. Occupational Safety and Health Act (OSHA): 29 CFR 1910, Code of Federal Regulations.

1.02 DEFINITIONS

A. Handrails: Synonymous with terms; i.e., guardrail system, railing system, ramp-rail system, and stair-rail system. Handrails are comprised of a framework of

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vertical, horizontal, or inclined members, grillwork or panels, accessories, or combination thereof.

B. ICC Evaluation Services Report for concrete anchor manufacturers.

C. Special Inspection: As governed by the ICC IBC.

D. Toeboards: Vertical barrier at floor level usually erected on handrails along exposed edges of floor or wall openings, platforms, ramps, or stairs to prevent miscellaneous items from falling through.

1.03 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. Indicate handrail profiles, sizes, connections, anchorage, size and type of fasteners, and accessories. Project-specific scale plans and elevations of handrails.
   b. Manufacturer's literature and catalog data of handrail and components.
   c. Design Data: Calculations or test data using design performance loads and include the following:
      1) Bending stress in, and deflection of, posts in accordance with ASTM E985.
      2) Stress in post base connection.
      3) Calculation of anchorage forces and comparison of these forces to ICC IBC recommendations regarding safe allowable design loads of anchorages.
      4) For concrete anchor spacings less than 12 anchor diameters and edge distances less than six anchor diameters, make reduction in allowable pullout and shear values. Provide independent laboratory inspection service for ICC Evaluation Services Report values with Special Inspection.
2. Samples:
   a. Railing sections, 6 inches long showing different connections and proposed finish.
   b. Each fitting including wall brackets, castings, toeboard fittings, and rail expansion joints.

B. Informational Submittals:

1. Manufacturer's assembly and installation instructions.

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2. Special Inspection:
   a. Manufacturer's instructions for Special Inspection of concrete anchors.
   b. Special Inspection report in accordance with Article Tests and Inspections.

C. Manufacturer's Certificate of Proper Installation in accordance with Section 01 43 33, Manufacturers' Field Services.

1. Manufacturer's written recommendations describing procedures for maintaining handrails including cleaning materials, application methods, and precautions to be taken in the use of cleaning materials.
2. Test Reports: Test data may supplement load calculations providing data covers the complete handrail system, including anchorage:
   a. Test data for handrail and components showing load and deflection due to load, in enough detail to prove handrail is strong enough and satisfies national, state, local standards, regulations, code requirements, and OSHA 29 CFR 1910, using design loads specified. Include test data for the following:
      1) Railing and post connections.
      2) Railing wall connections.
      3) Post and base connections.
      4) Railing expansion joint connections.
      5) Railing gate assembly, including latch and gate stop. Both gate latch and stop to support required loads applied, independent of each other.
      6) Railing gate hinges.
      7) [Railing picket panel clamps and connections.]
   b. Deflection Criteria: In accordance with ASTM E985 and design loads specified.
   c. Aluminum Rail Piping: Test data showing yield strength of pipe as-delivered equals or exceeds values specified in this section.
   d. Concrete Anchors: Calculations and test data for review prior to use, on anchors other than those specified.

1.04 QUALITY ASSURANCE

A. Qualifications: Calculations required for design data stamped by a registered civil or structural engineer licensed in the state where the Project will be constructed.

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1.2 DELIVERY, STORAGE, AND HANDLING

A. Handrails adequately packaged and wrapped to prevent scratching and denting during shipment, storage, and installation. Maintain protective wrapping until railing is completely installed.

A. Aluminum Handrails:

1. Shop assemble into practical modules of lengths not exceeding 24 feet for shipment.
2. Deliver toeboards loose for field assembly.
3. Deliver clear anodized handrail pipe and posts with protective plastic wrap.

1.05 ENVIRONMENTAL REQUIREMENTS

A. Thermal Movements: Allow for thermal movement resulting from the following maximum range in ambient temperature in design, fabrication, and installation of handrails to prevent buckling, opening up of joints, over stressing of components, connections and other detrimental effects. Base design calculation on actual surface temperatures of materials due to both solar heat gain and night time sky heat loss. Temperature change is difference between high or low temperature and installation temperature.

1. Temperature Change Range: [70] [_____] degrees F, ambient; [100] [_____] degrees F, material surfaces.

PART 2 - PRODUCTS

2.01 DESIGN PERFORMANCE

A. Structural Performance of Handrails: Design, test, fabricate, and install handrails to withstand the following structural loads without exceeding allowable design working stress or allowable deflection. Apply each load to produce maximum stress and deflection in each of the respective components comprising handrails.

1. Top Rail of Handrails: Capable of withstanding the following load cases applied:
   a. Concentrated load of 200 pounds applied at any point and in any direction in accordance with ICC IBC.
   b. [Uniform load of 50 pounds per linear foot applied in any direction in accordance with ICC IBC.]
   c. Concentrated load need not be assumed to act concurrently with uniform loads in accordance with ICC IBC.

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2. In-Fill Area of Railing Systems:
   a. Capable of withstanding a horizontally applied normal load of 50 pounds applied to 1 square foot at any point in the system including panels, intermediate rails, balusters, and openings and space between railings.
   b. Horizontal concentrated load need not be assumed to act concurrently with loads on top rails of handrails.
3. Mid-rails with corner returns to withstand a 300-pound concentrated vertical load applied at any point or direction without damage and loosening of pipe, fittings, or attachment hardware.
4. Concrete Anchors for Handrail Wall Brackets: Anchors with a strength required by calculations with concrete strength assumed at 4,000 psi and in conformance with ICC IBC.
5. Concrete Anchors: In accordance with ICC IBC for size, length, embedment, spacing, and edge distance to match required loads shown in calculations.

2.02 ALUMINUM HANDRAILS

A. General:

1. Furnish pre-engineered and prefabricated [two] [three] picket handrails.
2. Pop rivets and glued railing construction not permitted.

B. Manufacturers:

1. Thompson Fabricating Co., Birmingham, AL.
2. Moultrie Manufacturing, Moultrie, GA; Wesrail II.
3. [No “or-equal” or substitute products will be considered.]

C. Rails, Posts, and Formed Elbows: Extruded Alloy 6105-T5 or 6061-T6, minimum tensile strength of 38,000 psi and minimum yield strength of 35,000 psi.

1. Miscellaneous Aluminum Parts: 6063-T6 or 6061-T6 extruded aluminum of adequate strength for all loads.
2. Post and Railing: Nominal 1-1/2 inch diameter.
   a. Rails: 1.900-inch outside diameter by 0.145-inch wall thickness, Schedule 40.
   b. Posts: 1.900-inch outside diameter by 0.200-inch wall thickness, Schedule 80.
   c. Solid dowel interconnectors of 6105-T5 or 6061-T6 aluminum.

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D. Fittings:

1. Handrail and Post Fittings: Extruded, machined bar stock, permanent mold castings, or die castings of sufficient strength to meet load requirements. Fittings shall match color of pipe in handrails. Sand cast parts not permitted.
2. Concrete Top Mount Post Base:
   a. Four holes in base for concrete anchors. For narrow walls or curbs, furnish two holes in base for concrete anchors with required edge distance.
   b. Manufacturers and Products:
      1) Thompson Fabricating Co.; Part No. TBF-3.4 and Part No. TBF-3.2 for narrow walls and curbs.
      2) Moultrie Manufacturing Co.; Part No. WII4HB and WII2HB for narrow walls and curbs.
3. Concrete Side Mounted Handrail Bracket: Extruded aluminum, Alloy 6063-T6 with four holes for bolts or concrete anchors.
   a. Manufacturers and Products:
      1) Thompson Fabricating Co.; Part No. TSM-1.5.
      2) Moultrie Manufacturing Co.; Part No. WIISMB.
4. Concrete Anchors for Securing Bases and Brackets to Concrete: Type 304 or Type 316 stainless steel 1/2-inch concrete anchors.
5. Handrail Connections for Metal Stairway Stringers:
   a. Extruded aluminum bracket, Alloy 6063-T6.
   b. Brackets bolts 1/2-inch diameter Type 304 or Type 316 stainless steel bolts.
   c. Offset Adjustable Stair Fitting:
      1) Thompson Fabricating Co.; Part No. ASF of cast Al-mag.
      2) Moultrie Manufacturing Co.; Standard and custom elbow angles, Part No. W51XXX (numbers vary based on angle).
   d. Additional Offset Adjustable Fitting for Picket Railing System: Thompson Fabricating Co.; Part No. APF of cast Al-mag.
   e. Base Connection:
      1) Manufacturers and Products:
         a) Thompson Fabricating Co.; Part Nos. SMB-2 or SMB-3, ASF, APF.
         b) Moultrie Manufacturing Co.; Part No. WIISMBEXT.
6. Handrail Connections for Metal Beams:
   a. Extruded aluminum bracket, Alloy 6063-T6.
   b. Bracket bolts 1/2-inch diameter Type 304 stainless steel bolts.
   c. Manufacturers and Products:
      1) Thompson Fabricating Co.; Part Nos. SMB-2 or SMB-3. Use Part No. TSM-1.5 if bracket is attached to flat side of channel.

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2) Moultrie Manufacturing Co.; Part No. WIISMBEXT. Use Part No. WIISMB if bracket is attached to flat side of channel.

7. Handrail Wall Brackets: Adjustable wall fitting, with provision for three 3/8-inch Type 304 stainless steel bolts or concrete anchors.
   a. Manufacturers and Products:
      1) Thompson Fabricating Co.; Part No. AWF cast Al-mag aluminum bracket.
      2) Moultrie Manufacturing Co.; Part No. W41100.
8. Miscellaneous Rail to Post Fittings:
   a. Aluminum Tee Fittings:
      1) Manufacturers and Products:
         a) Thompson Fabricating Co.; Part Nos. TF-1 and TX-1.
         b) Moultrie Manufacturing Co.; Part Nos. WIIT40, WIIT40/05, WIIT80, and WIIT80/05.
   b. Aluminum Ell Fittings:
         a) Manufacturers and Products:
         b) Thompson Fabricating Co.; Part Nos. TE-1, TE-2, and TE-3.
         c) Moultrie Manufacturing Co.; Part No. 51900.
   c. Aluminum Splice Lock:
      1) Manufacturers and Products:
         a) Thompson Fabricating Co.; Part No. SL-1.
         b) Moultrie Manufacturing Co.; Part No. WIIS40.
   d. Aluminum Expansion Joint Splice:
      1) Manufacturers and Products:
         a) Thompson Fabricating Co.; Part No. ES-1.
         b) Moultrie Manufacturing Co.; Part No. WII40, omit set screws on one side.
   e. Formed Aluminum Wall Flange:
      1) Manufacturers and Products:
         a) Thompson Fabricating Co.; Part No. CF-2.
         b) Moultrie Manufacturing Co.; Part No. 41250.
9. Handrail Gate: 6063-T6, 6105-T5, or 6061-T6 extruded aluminum.
   a. Hardware Manufacturers and Products:
      1) Julius Blum & Co., Inc., Carlstadt, NJ; No. 782/3 gate hinges with springs, and No. 784 gate latch and stop.
      2) CraneVeyor Corp., South El Monte, CA; No. C4370b gate hinges with spring, No. C4369 gate latch, and No. C4368 gate stop.
      3) Thompson Fabricating Co., Birmingham, AL.
      4) Moultrie Manufacturing Co., Moultrie, GA; Part No. W60006.

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10. In-Fill Area Picket and Attachments:
    a. 1/2-inch Schedule 40 aluminum pipe (picket). Alloy 6105, 6063, or 6061.
    b. Extruded aluminum 1-1/2-inch by 7/8-inch by 1/8-inch channel. Alloy 6105, 6063, or 6061.
    c. Fittings for Offset Stair Railings:
        1) Cast Al-mag Adjustable Picket Fitting Manufacturer and Product: Thompson Fabricating Co.; Part No. APF.
        2) Cast Al-mag Adjustable Stair Fitting Manufacturer and Product: Thompson Fabricating Co.; Part No. ASF.
    d. Furnish neoprene plug for each end of the picket.
11. Toeboards and Accessories:
    a. Material: Molded or extruded 6063 or 6061 aluminum.
        1) Manufacturers:
        2) Thompson Fabricating Co.
        3) Moultrie Manufacturing Co.; Part No. WIIKP20.
    b. Castings for Handrails:
        1) Cast Al-mag with sufficient strength to meet load and test requirements.
        2) Anodizable grade finish with excellent resistance to corrosion when subject to exposure of sodium chloride solution intermittent spray and immersion.

E. Concrete Embedded Metal Anchorages: In accordance with Section [05 50 00, Metal Fabrications] [_____].

F. Finishes:

1. Handrail Pipe and Post: In accordance with AA DAF45, designation AA-M32-C22-A41.
2. Cast Fittings and Toeboards: In accordance with AA DAF45, designation AA-M10-C22-A41.

2.03 GALVANIZED STEEL HANDRAILS

A. Pipe: Hot-dip galvanized carbon steel, ASTM A53/A53M, Type E or S, Grade B; or ASTM A501, 1-1/2-inch NPS with 1.900-inch outside diameter and a minimum 0.145-inch wall thickness for rails and a minimum of 0.200-inch wall thickness for posts.

B. Fittings:

1. Anchor Bolts and Fasteners: Stainless steel.

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2. Handrail Post Bolted Baseplate Connector: Baseplate, carbon steel ASTM A36/A36M.
    a. Insert: Minimum wall thickness of 0.200 inch or from solid rod in accordance with ASTM A36/A36M.
3. Handrail Wall Brackets: Malleable iron, round top, and galvanized.
    a. Manufacturers and Products:
        1) R & B Wagner; No. 1765.
        2) Julius Blum; No. 1382.
4. Handrail Gate: As specified for galvanized steel piping.
    a. Gate Hardware Manufacturers and Products: Type 304 stainless steel:
        1) Julius Blum & Co., Inc., Carlstadt, NJ; Connectorail System, No. 782/3 gate hinges with spring, and No. 784 gate latch and stop.
        2) Craneveyor Corp., South El Monte, CA; No. C4370b gate hinges with spring, No. C4369 gate latch, and No. C4368 gate stop.
5. Handrail Picket Panels and Clamps:
    a. Solid bar steel meeting minimum requirements specified for piping.
    b. Fasteners: Stainless steel.
6. Toeboards and Accessories:
    a. ASTM A36/A36M steel.
    b. Fasteners: Stainless steel.

C. Concrete Embedded Metal Anchorages: In accordance with Section [05 50 00, Metal Fabrications] [_____].

D. Fasteners: Stainless steel.

2.04 ANCHOR BOLTS, FASTENERS, AND CONCRETE ANCHORS

A. Locknuts, Washers, and Screws:

1. Elastic Locknuts, Steel Flat Washers, RHMS Round Head Machine Screws: Type A 304 or Type A 316 stainless steel.
2. Flat Washers: Molded nylon.
3. Manufacturer: McMaster-Carr Supply Co., Los Angeles, CA.

B. Bolts and Nuts for Bolting Handrail to Metal Beams: ASTM A193/A193M and ASTM A194/A194M, Type A 316 stainless steel with minimum yield strength for bolts of 95,000 psi, unless otherwise shown.

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C. Concrete Anchors:

1. Stainless steel Type 304 or Type 316.
2. Use ICC IBC approved values for size, length, embedment, spacing, and edge distance to match required loads shown in calculations.

D. Epoxy Anchors: Heavy-duty 1/2-inch diameter, for exterior use only in accordance with Section 05 50 00, Metal Fabrications, as an alternative to mechanical concrete anchors. Design and provide the number required. Do not use where fire or elevated temperatures above 110 degrees F exist.

2.05 FABRICATION OF ALUMINUM HANDRAILS

A. Shop Assembly:

1. Post Spacing: Maximum [6-foot] [_____] horizontal spacing.
2. Railing Posts Bolted to Metal or Concrete:
   a. In lieu of field cutting, provide approved fitting with sufficient post overlap, containing provisions for vertical adjustment.
   b. Field fit-up is required.
3. Free of burrs, nicks, and sharp edges when fabrication is complete.
4. Welding is not permitted.

B. Shop/Factory Finishing:

1. Use same alloy for uniform appearance throughout fabrication for railings.
2. Handrail and Post Fittings: Match fittings with color of pipe in handrail.
3. Sand cast parts not permitted.

C. Tolerances:

1. Shop assemble rails, posts, and formed elbows with a close tolerance for tight fit.
2. Fit dowels tightly inside posts.

2.06 FABRICATION OF GALVANIZED STEEL HANDRAILS

A. Shop Assembly:

1. Alternate Post to Baseplate Connection:
   a. Field measure elevation of concrete at each post location and determine exact post length so baseplate is on concrete surface

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without shims or grout. Rails shall be in straight alignment when all rails to posts and posts to baseplates are welded.

b. Grind welds prior to hot-dip galvanizing of railing sections.

2. Handrail Post Bolted to Metal or Concrete:
   a. Field fit-up is required.
   b. Field measure and weld post to baseplate as an alternative to field cutting.
3. Remove burrs from cut edges.
4. Form elbow bends and wall returns to uniform radius, free from buckles and twists, with finished surfaces smooth.
5. Cover exposed ends of steel pipe by welding 3/16-inch thick steel plate in place or use prefabricated fittings.
6. Welding:
   a. Thoroughly fuse without undercutting or overlap.
   b. Remove splatter, grind exposed welds to blend, and contour surfaces to match those adjacent.
7. Furnish explosion prevention holes at closed ends of pipes.
8. Form and assemble joints exposed to weather to prevent water and moisture from penetrating.

B. Shop/Factory Finishing: Hot-dip galvanize all components in accordance with ASTM A123/A123M after fabrication.

C. Tolerances:

1. Cut pipe square within 2 degrees and to lengths within 1/8 inch.
2. Welding: Miter and cope intersections of posts and rails within 2 degrees, fit to within 0.020 inch, and perform continuous welds around joints.
3. Repair of Defective Work: Remove stains and replace defective Work.

PART 3 - EXECUTION

3.01 GENERAL

A. Provide railing posts longer than needed and field cut to exact dimensions required in order to satisfy vertical variations on the actual structure. Install railing with a base that provides plus or minus 1/4-inch vertical adjustment inside the base fitting. If adjustment is required in the field and exceeds plus or minus 1/4-inch, reduce post length not to exceed beyond bottom of lowest set-screw or bolt in base fitting.

B. Field fabrication of aluminum railing systems not permitted.

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C. Modification to structure not permitted where handrail is attached.

D. [Mount handrails only on completed walls. Do not support handrails temporarily by means not satisfying structural performance requirements.] [Mount handrails only on gypsum board assemblies reinforced to receive anchors and where the location of concealed anchor plates has been clearly marked for benefit of installer.]

3.02 HANDRAIL INSTALLATION

A. Assembly and Installation: Perform in accordance with manufacturer's written recommendations for installation.

B. Protection from Entrapped Water:

1. Make provisions in exterior and interior installations subject to high humidity to drain water from railing system.
2. Posts mounted in concrete, bends and elbows occurring at low points, drill weep holes of 1/4-inch diameter at lowest possible elevations, one hole per post or rail. Drill hole in the plane of the rail.

C. Expansion Joints:

1. Maximum intervals of 54 feet on center and at structural joints.
2. Slip joint with internal sleeve extending 2 inches beyond each side of joint. Provide 1/2-inch slip joint gap to allow for expansion.
3. Fasten to one side using 3/8-inch diameter set-screw. Place set-screw at bottom of pipe.
4. Locate joints within 12 inches of posts. Locate expansion joints in rails that span expansion joints in structural walls and floors supporting the posts.

D. Setting Posts:

1. Embedded:
   a. Clean dust and foreign matter from sleeves or blockouts.
   b. Moisten interior of hole and surrounding surface with clean water. Fill hole with nonshrink grout prior to installing post.
   c. Brace railing until grout sets.
   d. Posts installed outside and exposed to freezing temperatures, drill weep hole through post approximately 1/2 inch above level of grout inside post and in plane of rail to prevent entrapment and freezing of water inside post.
2. Surface Mounted:

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a. Bolt post baseplate connectors firmly in place.
b. Shims, wedges, grout, and similar devices for handrail post alignment not permitted.

E. Posts and Rails:

1. Set posts plumb and aligned to within 1/8 inch in 12 feet.
2. Set rails horizontal or parallel to slope of steps to within 1/8 inch in 12 feet.
3. Install posts and rails in same plane. Remove projections or irregularities and provide a smooth surface for sliding hands continuously along top rail. Use offset rail for use on stairs and platforms if post is attached to web of stringers or structural platform supports.
4. Support 1-1/2-inch rails directly above stairway stringers with offset fittings.

F. Handrail Wall Brackets:

1. Support wall rails on brackets spaced maximum 6 feet on centers for steel and 5 feet for aluminum as measured on the horizontal projection.
2. Install wall anchor backplates on solid blocking in stud walls.

G. Toeboard:

1. Provide at all handrails except where 4-inch or higher concrete curbs are installed or at gates.
2. Accurately measure in field for correct length, after handrail post installation, cut and secure to posts.
3. Dimension between bottom of toeboard and walking surface not to exceed 1/4 inch.
4. Aluminum Toeboards: Provide expansion and contraction connections between each post.
5. Steel Toeboards: Between each post cut toeboard and provide slotted holes for expansion and contraction.

H. Railing Gate: Install in accordance with manufacturer’s installation instructions.

3.03 FIELD FINISHING

A. Corrosion Protection: Prevent galvanic action and other forms of corrosion caused from direct contact with concrete and dissimilar metals by coating metal surfaces as specified in Section 09 90 00, Painting and Coating.

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1. Treatment of Field Welds for Galvanized Steel Railings: Touch up welds by application of two coats high-zinc dust content paint to dry film thickness of 2 mils.

3.04 TESTS AND INSPECTIONS

A. Perform Special Inspection for anchors where ICC Evaluation Services Reports require them for anchor strength value used.

B. Provide an independent test laboratory to perform Special Inspection.

3.05 CLEANING

A. Wash railing system thoroughly using clean water and soap. Rinse with clean water.

B. Do not use acid solution, steel wool, or other harsh abrasive.

C. If stain remains after washing, restore in accordance with manufacturer's recommendations, or replace stained handrails.

END OF SECTION

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SUPPLEMENTAL PARAGRAPH

PART 1 - GENERAL

1.01 SUBMITTALS

A. Information Submittals:

1. Test Reports:
   a. Stainless Steel Rail Piping: Test data showing yield strength of pipe as-delivered and insert equals or exceeds 50,000 psi.

PART 2 - PRODUCTS

2.01 STAINLESS STEEL HANDRAILS

A. Manufacturer: KDI Paragon, Inc., Pleasantville, NY.

B. Pipe:

1. Welded stainless steel, Type 304, ornamental grade, ASTM A554 with minimum yield strength of 50,000 psi.
2. Outside diameter for rails, posts, and fittings 1.900 inches.
3. Wall thickness for horizontal railing tubular materials, 0.109 inch minimum.
4. Wall thickness for posts, 0.145 inch minimum.

C. Fittings: Tubular railing components, flanges, wall brackets, and anchor plates and similar accessories, Type 304 stainless steel with physical strength properties equivalent to piping materials.

1. Anchor Bolts: Type 316 stainless steel.
2. Handrail Post Bolted Baseplate Connector:
   a. Baseplate: ASTM A167, Type 304 stainless steel with minimum yield strength of 30,000 psi.
   b. Insert: Pipe ASTM A584 with minimum yield strength of 50,000 psi and minimum wall thickness of 0.230 inch or from solid rod ASTM A36/A36M.

D. Handrail Wall Brackets: Stainless steel with round top, with stain finish.

1. Manufacturers and Products:
   a. R & B Wagner; No. 1768.

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b. Julius Blum; No. 275.

E. Handrail Gate: Type 304 stainless steel.

1. Gate Hardware Manufacturers and Products:
   a. Julius Blum & Co., Inc., Carlstadt, NJ; Connectorail System, No. 782/3 gate hinges with spring, and No. 784 gate latch and stop.
   b. Craneveyor Corp., South El Monte, CA; No. C4370b gate hinges with spring, No. C4369 gate latch, and No. C4368 gate stop.

F. Picket Panels:

1. Handrail Picket Panels and Clamps: Solid bar Type 304 stainless steel.
   a. Fasteners: Stainless steel.
2. Toeboards and Accessories:
   a. Type 304 stainless steel.
   b. Fasteners: Stainless steel.
   c. Furnish expansion connections between each post.

G. Concrete Embedded Metal Anchorages: In accordance with Section [05 50 00, Metal Fabrications] [_____].

H. Exposed Stainless Steel Surface Finish: [AISI SS306, No. 4, satin.] [Mechanical rubbed, 180 grit.] [Circumferentially polished to 320 grit finish.]

2.02 FABRICATION OF STAINLESS STEEL HANDRAILS

A. Shop Assembly:

1. Handrail Post Bolted to Metal or Concrete: Field fit-up is required.
2. Joints Between Rails and Posts: Grind for 100 percent contact between the two parts and fully weld using a gas shielded arc. After welding, clean, smooth, and blend joints to the finish of tubular material.

B. Shop/Factory Finishing: Apply finish after fabrication and welding.

END OF SUPPLEMENTAL PARAGRAPHS

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SECTION 05 53 00
METAL GRATINGS

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Association of State Highway and Transportation Officials (AASHTO): Standard Specifications for Highway Bridges.
2. ASTM International (ASTM):
   a. A36/A36M, Standard Specification for Carbon Structural Steel.
   b. A510, Standard Specification for General Requirements for Wire Rods and Coarse Round Wire, Carbon Steel.
   c. A666, Standard Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar.
   d. A1011/A1011M, Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength.
   e. B221, Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes.
3. National Association of Architectural Metal Manufacturers (NAAMM):
   a. MBG 531, Metal Bar Grating Manual.
   b. MBG 532, Heavy-Duty Metal Bar Grating Manual.

1.02 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. Grating: Show dimensions, weight, size, and location of connections to adjacent grating, supports, and other Work.
   b. Grating Anchorage: Show details of anchorage to supports to prevent displacement from traffic impact.
   c. Product data for grating, grating clips, anchors, accessories, and other manufactured products specified herein.
   d. Manufacturer’s specifications, including coatings, surface treatment, and finishes.
      1) [Samples: Two Samples of [_____] grating approximately 4 inches by 8 inches, showing at least four crossbars each and

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four bearing bars each. One Sample will be retained at Site to be used as a basis for acceptance or rejection of grating installed.]

B. Informational Submittals:

1. Special handling and storage requirements.
1. Installation instructions.

1.03 DELIVERY, STORAGE, AND HANDLING

A. Insofar as is practical, factory assemble items.

B. Package and clearly tag parts and assemblies that are, due to necessity, shipped unassembled.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Materials, equipment, and accessories specified in this section shall be products of:

1. Alabama Metal Industries Corporation (AMICO), Birmingham, AL.
2. IKG Industries, Houston, TX.
3. Ohio Gratings, Inc., Canton, OH.
2. Seidelhuber Metal Products, Inc., South San Francisco, CA.

2.02 GRATING MATERIALS

A. [Aluminum: Provide alloy and temper as designated below.

1. Bearing Bars and Banding: ASTM B221 alloy 6061-T6 or 6063-T6.
2. Swaged Crossbar Rods: ASTM B221 alloy 6061 or 6063, or ASTM B210 alloy 3003.
3. Finish: Mill.]

B. [Carbon Steel:

1. Bearing Bars, Banding, and Rectangular Cross Bars: ASTM A1011/A1011M commercial steel Type II for hot rolled carbon steel sheet and strip, or ASTM A36/A36M.
2. Cross Bars made from Wire Rods: Not Permitted.
3. Finish: Galvanized after fabrication.]

C. [Stainless Steel:

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1. Bearing Bars, Banding and Cross Bars: ASTM A666, Type [304L] [316L].
2. Finish: Mill.]

2.03 METAL BAR GRATING

A. General Requirements:

1. Maximum Service Load:
   a. Light Duty (Type A): [100 psf] [_____] uniformly distributed load.
   b. Medium Duty (Type B): [500 psf] [_____] uniformly distributed load.
2. Maximum Deflection: [Span/240 or 1/4 inch, whichever is less] [_____].
3. Bearing Bar Spacing:
   a. Light Duty: [1-3/16 inch] [_____] maximum, center-to-center.
   b. Medium Duty: [15/16 inch] [_____] maximum, center-to-center.
4. Cross Bar Spacing: [4] [2] inches maximum, center-to-center. [For aluminum I-bar grating with depths greater than 2 inches, provide cross bars at 2 inches maximum, center-to-center.]
5. Bearing Bars, Cross Bars and Banding: Minimum thickness as specified in NAAMM MBG 531 or as shown on Drawings.

B. Grating Materials:

1. [Aluminum, pressure-locked [I-bar grating fabricated by swaging crossbars between extruded I-shaped bearing bars] [rectangular bar grating fabricated by pressing crossbars between rectangular bearing bars].]
2. [Galvanized steel [welded, rectangular bar grating fabricated by electro-forging cross bars to bearing bars] [pressure-locked rectangular bar grating fabricated by pressing rectangular crossbars into slots in rectangular bearing bars] [pressure-locked rectangular bar grating fabricated by swaging crossbars between rectangular bearing bars].]
3. [Stainless steel [pressure-locked rectangular bar grating fabricated by swaging crossbars between rectangular bearing bars] [pressure-locked rectangular bar grating fabricated by pressing rectangular crossbars into slots in rectangular bearing bars] [welded, rectangular bar grating fabricated by welding cross bars to bearing bars].]

C. Surface:

1. [Plain.] [Serrated.] [Slip resistant, consisting of an applied abrasive finish of aluminum-oxide aggregate.] [Striated.]

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2. [When surface of bars is serrated provide 1/4-inch deeper bearing bars than shown on Drawings to maintain specified load carrying capacity of grating.]

D. Stair Treads:

1. Material and Type: Same as grating material and grating type as furnished for connecting walkway or work surface.
2. Nosings: Integral ribbing and serrated edge on one long axis of tread, or nonslip abrasive on each tread along one long edge.
3. Carrier Plate or Angle: Furnish at each end for connection to stair stringers.

2.04 HEAVY-DUTY METAL BAR GRATING (TYPE C)

A. General Requirements:

1. Maximum Service Load: AASHTO H-20.
2. Maximum Deflection: [Span/240] [_____].
3. Bearing Bar Spacing: [1-7/8 inch] [_____] maximum center-to-center.
4. Cross Bar Spacing: 4 inches maximum center-to-center.
5. Bearing Bars, Cross Bars and Banding: Minimum thickness as specified in NAAMM MBG 532 or as shown on Drawings.
6. Grating Type: Galvanized steel, heavy-duty, rectangular bar grating fabricated by [welding crossbars between rectangular bearing bars] [pressing deep rectangular crossbars into slots in rectangular bearing bars].

2.05 ACCESSORIES

A. Embedded Frames:

1. As indicated on Drawings and as specified in Section 05 50 00, Metal Fabrications.
2. [Extruded aluminum frames as manufactured by:
   a. Ohio Gratings, Inc., Canton, OH.
   b. Thompson Fabricating, LLC, Tarrant, AL.]

B. Grating Clamps:

1. Use at flanged beam and bolted angle frame supports.
2. Removable from above grating walkway surface.
3. Provide hat bracket, recessed bolt, and bottom clamp of same material as grating.
4. Manufacturers and Products:
   a. Direct Metals Company, LLC, Kennesaw, GA; Grating Clamp.
   b. Grating Fasteners, Inc., Harvey, LA; G-Clip.

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C. Anchor Stud and Saddle Clip:

1. Use at embedded angle frame supports with stud anchor and nut recessed below top of grating surface.
2. Removable from above grating walkway surface.
3. Provide Type 316 stainless steel welded threaded stud anchor, nut, washer, and saddle clip.
4. Manufacturers and Products:
   a. Welded Stud Anchor:
      1) Nelson Stud Welding, Inc., Elyria, OH.
      2) Stud Welding Associates, Inc. Elyria, OH.
   b. Saddle Clip:
      3) Direct Metals Company, LLC, Kennesaw, GA; Saddle Clip.
      4) Grating Fasteners, Inc., Harvey, LA; Saddle Clip.
      5) Struct-Fast, Inc., Baltimore, MD; Gratefast.
5. [At Embedded Extruded Aluminum:
   a. Provide aluminum clip, bolt, nut, and washer, with clip engaging bottom flange of I-bar.
   b. Manufacturers and Products:
6. Direct Metals Company, LLC, Kennesaw, GA; Plank Clip.
7. Thompson Fabricating Company, Inc., Birmingham, AL; TFCO Standard Hold Down Clip.]

2.06 [PLANK STYLE GRATING

A. Material: [Aluminum] [Galvanized Steel] [Stainless Steel].

B. Style: [_____].

C. Openings: [_____].

D. Manufacturers and Products:

1. [_____].
2. [_____].]

2.07 FABRICATION

A. General:

1. In accordance with NAAMM MBG 531 or NAAMM MBG 532.
2. Do not weld aluminum grating.
3. Conceal fastenings where practical.

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4. Drill metalwork and countersink holes as required for attaching hardware or other materials.
5. Cutouts:
   a. Fabricate in grating sections for penetrations indicated.
   b. Arrange to permit grating removal without disturbing items penetrating grating.
   c. Edge band openings in grating that interrupt four or more bearing bars with bars of same size and material as bearing bars.
6. Do not notch bearing bars at supports to maintain elevation.
7. Field measure areas to receive grating. Verify dimensions of new fabricated supports, and fabricate to dimension required for specified clearances.
8. Section Length: Sufficient to prevent section from falling through clear opening when oriented in the span direction and one end is touching either the concrete or the vertical leg of grating support.
9. Minimum Bearing: 1 inch for grating depth up to 2-1/4 inches and 2 inches for grating depth greater than 2-1/4 inches.
10. Banding and Toe Plates: Same material as grating and welded to bearing bars in accordance with requirements of NAAMM MBG 531 and NAAMM MBG 532.

B. Metal Bar Grating: A single grating section shall be not less than 1.5 feet or greater than 3 feet in width, or weigh more than 150 pounds.

C. Heavy Duty Metal Bar Grating: Minimum width of grating sections shall be 2 feet regardless of length and weight.

D. Supports:

1. Same material as grating, except that supports which are to be embedded in concrete shall be Type 316 stainless steel, unless part of an extruded aluminum system.
2. Coordinate dimensions and fabrication with grating to be supported.
3. [Coordinate dimensions with increased depth due to serrations.]

PART 3 - EXECUTION

3.01 PREPARATION

A. Electrolytic Protection:

1. Protect aluminum surfaces in contact with dissimilar metals, or embedded or in contact with masonry, grout, or concrete as specified in [Section 09 90 00, Painting and Coating] [_____].
2. Allow paint to dry before installation of material.

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3.02 INSTALLATION

A. Until grating sections are securely fastened in place, area shall be appropriately barricaded or flagged to alert people working in the area of potential fall hazard.

B. Install manufactured products in accordance with manufacturer's recommendations.

C. Install supports such that grating sections have a solid bearing on both ends, and that grating sections will not rock or wobble under design loads.

D. Install grating supports plumb and level as applicable.

E. Install sections of welded frames with anchors to straight plane without offsets.

F. Field locate and install fasteners to fit grating layout.

G. Anchor grating securely to supports using minimum of four fastener clips and bolts per grating section.

H. Each grating or plank section shall be easily removable and replaceable.

I. Completed installation shall be rigid and neat in appearance.

J. Protect painted and galvanized surfaces during installation.

K. Repair damaged coatings as specified in [Section 09 90 00, Painting and Coating] [_____].

END OF SECTION

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SECTION 07 14 00
FLUID-APPLIED WATERPROOFING

PART 1 - GENERAL

1.01 SUMMARY

A. Section includes fluid applied elastomeric membrane waterproofing; and protective covering.

B. Related Sections:

1. Section 07 21 13, Board Insulation: Perimeter protective cover.
2. Section 07 62 00, Sheet Metal Flashing and Trim.
3. Section 31 23 23, Fill.
4. Section 33 46 00, Subdrainage.

1.02 REFERENCES

A. ASTM International:

1. ASTM C836, Standard Specification for High Solids Content, Cold Liquid-Applied Elastomeric Waterproofing Membrane for Use with Separate Wearing Course.
2. ASTM D412, Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers-Tension.
3. ASTM D429, Standard Test Method for Rubber Property, Adhesion to Rigid Substrates.
4. ASTM D471, Standard Test Method for Rubber Property - Effect of Liquids.
5. ASTM D624, Standard Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers.
6. ASTM D746, Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact.
7. ASTM D822, Standard Practice for Filtered Open-Flame Carbon-Arc Exposures of Paint and Related Coatings.
8. ASTM D1004, Standard Test Method for Tear Resistance (Graves Tear) of Plastic Film and Sheeting.
9. ASTM D2240, Standard Test Method for Rubber Property-Durometer Hardness.
10. ASTM D3468, Standard Specification for Liquid-Applied Neoprene and Chlorosulfonated Polyethylene Used in Roofing and Waterproofing.
11. ASTM E96/E96M, Standard Test Methods for Water Vapor Transmission of Materials.

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B. National Roofing Contractors Association: NRCA, The NRCA Waterproofing and Damp proofing Manual.

1.03 SYSTEM DESCRIPTION

A. Waterproofing System: Fluid applied material to prevent moisture migration to interior.

1.04 PERFORMANCE REQUIREMENTS

A. Waterproofing System: Capable of resisting water head of [_____] feet and preventing moisture migration to interior.

1.05 SUBMITTALS

A. Section 01 33 00, Submittal Procedures: Submittal procedures.

B. Shop Drawings: Indicate special joint or termination conditions and conditions of interface with other materials.

C. Product Data: Submit data for [surface conditioner], flexible flashings, joint cover sheet, and joint and crack sealants, with temperature range for application of waterproofing membrane.

D. Manufacturer's Installation Instructions: Submit special procedures and perimeter conditions requiring special attention.

E. Manufacturer's Certificate: Certify products meet or exceed specified requirements.

F. Warranty: Submit manufacturer warranty and ensure forms have been completed in Owner's name and registered with manufacturer.

1.06 QUALITY ASSURANCE

A. Perform Work in accordance with NRCA Waterproofing Manual.

B. Perform Work in accordance with local jurisdiction requirements.

C. Maintain one copy of each document on site.

1.07 QUALIFICATIONS

A. Waterproofing Material Manufacturer: Company specializing in waterproofing membrane with minimum three years documented experience.

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B. Applicator: Company specializing in performing the work of this section and approved by manufacturer.

1.08 MOCKUP

A. Section 01 40 00, Quality Requirements: Requirements for mockup.

B. Construct Mockup, 100 sq ft of waterproofed panel; to represent finished work including internal and external corners, jointing, attachment method, flashings, drainage panel, base flashings,, protective cover.

C. Locate where indicated on Drawings.

D. Incorporate accepted mockup as part of Work.

1.09 PRE-INSTALLATION MEETINGS

A. Section 01 30 00, Administrative Requirements: Pre-installation meeting.

B. Convene minimum one week prior to commencing work of this section.

1.10 ENVIRONMENTAL REQUIREMENTS

A. Section 01 60 00, Product Requirements.

B. Maintain ambient temperatures above 40 degrees F for 24 hours before and during application and until liquid or mastic accessories have cured. Follow manufacturer's requirements.

1.11 WARRANTY

A. Section 01 70 00, Execution and Closeout Requirements: Product warranties and product bonds.

B. Furnish five year manufacturer warranty for waterproofing failing to resist penetration of water.

C. For warranty repair work, remove and replace materials concealing waterproofing.

PART 2 - PRODUCTS

2.01 FLUID APPLIED WATERPROOFING

A. Manufacturers:

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1. [American Hydrotech, Inc.] Model [_____].
2. [Barrett Co.] Model [_____].
3. [Carlisle Coatings & Waterproofing] Model [_____].
4. [Tremco Sealants & Waterproofing.] Model [_____].
5. [_____] Model [_____].

B. COMPONENTS

C. Waterproofing Membrane: ASTM C836; two component elastomeric compound; quick setting.

D. Cured Membrane Characteristics:

Properties	**Test**	**Results**
Tensile Strength	ASTM D412	[_____]
Elongation	ASTM D412	[_____]
Hardness - Shore A	ASTM D2240	[_____]
Tear Strength	ASTM [D624] [D1004]	[_____]
Water Absorption	ASTM [D471]	[_____]
Water Vapor Permeance (perms)	ASTM E96/E96M [desiccant method] [water method]	[_____]
Exposure	ASTM D822	[_____]
Brittleness	ASTM D746	[_____]
Adhesion	ASTM D429	[_____]

2.02 ACCESSORIES

A. Surface Primer: compatible with membrane compound; as recommended by membrane manufacturer.

B. Elastic Flashings: [0.047] [_____] inch thick, [butyl] [neoprene] [EPDM] [_____], as recommended by membrane manufacturer.

C. Joint Cover Sheet: [_____] inch thick elastic sheet material designated for and compatible with membrane.

D. Cant Strips: Premolded composition material Approved by membrane manufacturer.

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E. Drainage Panel: 3/8 inch thick formed plastic, or as approved by membrane manufacturer.

F. Joint and Crack Sealant: As recommended by membrane manufacturer.

G. Back-up Material: [PVC membrane] [Butyl rod] [_____].

H. Counterflashings: [_____] as specified in Section [07 62 00.] [_____.]

****** [OR] ******

I. Counterflashings: [Galvanized steel] [_____] type, [_____] inch thick.

J. Tack-free Surfacing: [Type 1 Portland cement.] [Stone dust.]

K. Separation Sheet: Sheet [polyethylene] [_____], [6] [_____] mil thick.

L. Protection Board: Rigid insulation specified in Section 07 21 13.<<part of package?>>

PART 3 - EXECUTION

3.01 EXAMINATION

A. Section 01 30 00, Administrative Requirements: Coordination and project conditions.

B. Verify substrate surfaces are free of frozen matter, dampness, loose particles, cracks, pits, projections, penetrations, or foreign matter detrimental to adhesion or application of waterproofing system.

C. Verify substrate surfaces are smooth, free of honeycomb or pitting, and not detrimental to full contact bond of waterproofing materials.

D. Verify items penetrating surfaces to receive waterproofing are securely installed.

E. Verify substrate surface slopes to drain for horizontal waterproofing applications.

3.02 PREPARATION

A. Protect adjacent surfaces not designated to receive waterproofing.

B. Clean and prepare surfaces to receive waterproofing. [Vacuum substrate clean.]

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C. Do not apply waterproofing to surfaces unacceptable to [manufacturer] [or] [applicator].

D. Seal cracks and joints with sealant materials using depth to width ratio as recommended by sealant manufacturer.

3.03 INSTALLATION

A. Apply surface conditioner at rate recommended by manufacturer. Protect conditioner from rain or frost until dry.

B. Apply 12 inch wide strip of joint cover sheet over cracks, non-working joints , and expansion joints over 1/16 inch but not exceeding 1/2 inch in width.

C. At expansion joints from 1/2 to 1 inch in width, loop cover sheet down into joint between 1-1/4 and 1-3/4 inch. Extend sheet 6 inches on both sides of expansion joint.

D. Center cover sheet over crack or joints. Roll sheet into 1/8 inch coating of waterproofing material. Apply second coat over sheet extending minimum of 6 inches beyond sheet edges. Apply this procedure to expansion joints between horizontal and vertical surfaces.

E. Apply waterproofing material.

F. Extend membrane over cants and up intersecting surfaces at membrane perimeter minimum 6 inches above horizontal surface.

G. Install cant strips at inside corners.

H. Apply extra thickness of waterproofing material at corners, intersections, angles, and over joints as recommended by manufacturer.

I. Seal items protruding to or penetrating through membrane and install Counterflashing membrane material.

J. Install membrane flashings and seal into waterproofing material.

K. Place drainage panel directly against membrane, butt joints, place to encourage drainage downward.

L. Place protection panel directly against drainage panel membrane; butt joints.

M. Adhere drainage panel to substrate. Scribe and cut boards around projections, penetrations, and interruptions.

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3.04 FIELD QUALITY CONTROL

A. Section 01 40 00, Quality Requirements 01 70 00,Execution and Closeout Requirements: Field inspecting, testing, adjusting, and balancing.

3.05 PROTECTION OF INSTALLED CONSTRUCTION

A. Section 01 70 00, Execution and Closeout Requirements: Protecting installed construction.

B. Do not permit traffic over unprotected or uncovered membrane.

C. Immediately after curing, protect membrane per manufacturer's requirements.

3.06 SCHEDULE

A. Foundation Wall: 0.020 inch thick waterproofing; 0.030 inch thick at inside and external corners; asphalt impregnated board protective cover.

B. Subgrade Tunnel: 0.045 inch thick waterproofing on walls and roof of tunnel; 0.060 inch thick at external corners; 2 inch thick rigid insulation protective cover.

END OF SECTION

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SECTION 07 21 00
THERMAL INSULATION

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM):
2. C272, Standard Test Method for Water Absorption of Core Materials for Structural Sandwich Constructions.
3. C303, Standard Test Method for Dimensions and Density of Preformed Block and Board-Type Thermal Insulation.
4. C549, Standard Specification for Perlite Loose Fill Insulation.
5. C578, Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation.
6. C665, Standard Specification for Mineral-Fiber Blanket Thermal Insulation for Light Frame Construction and Manufactured Housing.
7. D4397, Standard Specification for Polyethylene Sheeting for Construction, Industrial, and Agricultural Applications.
8. E84, Standard Test Method for Surface Burning Characteristics of Building Materials.
9. E96/E96M, Standard Test Methods for Water Vapor Transmission of Materials.

1.02 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. Manufacturer’s product literature identifying products proposed for use.
   b. Drawings or letter indicating proposed locations of holes for injection of foam-in-place insulation in exposed, unpainted walls.

1.03 DELIVERY, STORAGE, AND HANDLING

A. On packaging clearly identify manufacturer, contents, brand name, applicable standard, and R-value.

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B. Store materials off ground and keep them dry. Protect against weather, condensation, and damage.

PART 2 - PRODUCTS

2.01 BATT INSULATION AND FASTENERS

A. Fiberglass or Mineral Wool Batts:

1. ASTM C665, III, Class A, with 0.10 or less perm rating, reinforced reflective aluminum foil vapor retarder membrane laminated to one side with R-values as indicated on Drawings.
2. Manufacturers:
   a. CertainTeed Corp.
   b. Owens-Corning Insulating Systems.
   c. Johns Manville.

B. Fasteners: As recommended by insulation manufacturer.

C. Tape: As recommended by insulation manufacturer.

2.02 VAPOR RETARDER

A. Plastic Sheeting: ASTM D4397, minimum thickness of [6] [10] mils.

B. Sealant and Tape: As recommended by vapor retarder manufacturer.

2.03 MASONRY INSERT INSULATION

A. Molded Expanded Polystyrene Inserts:

1. ASTM C578, Type I.
2. Fabricate to fit standard two-core concrete masonry units of 6-inch, 8-inch, 10-inch, and 12-inch width, as applicable.
3. Minimum Density: 1 pound per cubic foot when tested in accordance with ASTM C303.
4. R-Value at 1 inch Thickness:
   a. At 40 degrees F: 4.17.
   b. At 75 degrees F: 3.92.
5. Moisture Resistance:
   a. Water Vapor Transmission: 0.80 to 2.80 perm inches when tested in accordance with ASTM E96/E96M.

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b. Absorption: Less than 2 percent by volume when tested in accordance with ASTM C272.

6. Flame Spread: Less than 5 when tested in accordance with ASTM E84.
7. Pre-install at concrete masonry unit plant in accordance with manufacturer's instructions prior to delivery to Site.
8. Manufacturer and Product: Concrete Block Insulating Systems, Inc.; Korfil Standard U-Shaped Insulation Inserts.

2.04 RIGID INSULATION

A. Extruded Polystyrene Foam:

1. ASTM C578, Type IV.
2. Flame Spread: Less than 25 when tested in accordance with ASTM E84.
3. Thickness: As shown.
4. Manufacturers and Products:
   a. Dow Chemical Co.; Styrofoam Square Edge.
   b. UC Industries; Foamular.

B. Adhesives and Fasteners: As recommended by insulation manufacturer.

PART 3 - EXECUTION

3.01 BATT INSULATION

A. Install in accordance with manufacturer's instructions and as specified below:

1. Install in widths required by framing spacing with vapor retarder facing warm side.
2. Fit tightly to ensure continuous seal. Tape overlapping flanges of vapor retarder when necessary, using tape as recommended by insulation manufacturer.
3. Where electrical outlets, ducts, pipes, vents, or other utility items occur, place insulation on cold weather side of obstruction.
4. Protect installed insulation from tears and other damage until covered with finish material.
5. Remove and replace damaged material.

3.02 VAPOR RETARDER

A. Install in accordance with the following:

1. Apply to wall and ceiling framing in sheets as large as possible.

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2. Lap joints 6 inches.
3. Seal joints with sealant and tape as recommended by vapor retarder manufacturer.
4. Fit tightly and seal around penetrations.
5. Repair minor tears or holes with tape.
6. Replace sheets with tears or holes, which require more than 6-inch length of tape to repair.

3.03 RIGID INSULATION

A. Install in accordance with the following:

1. Install boards in location and in [thickness] [R-value] as [specified] [shown].
2. Cut insulation with saw, knife, or other sharp tool to fit tightly around obstructions.
3. Butt insulation boards together tightly at joints.
4. Where thickness required exceeds 1-1/2 inches, install two layers of boards.
5. [Apply to masonry or concrete with adhesive recommended by insulation manufacturer:
   a. Adhere first layer to substratum, then adhere second layer to first, staggering joints.
   b. Follow manufacturer's recommendations for preparing surfaces and applying adhesive.]
6. [Apply to masonry or concrete with fasteners recommended by insulation manufacturer.]

3.04 INSULATING SHEATHING

A. Install in accordance with the following:

1. Apply with long dimension perpendicular to supports.
2. Abut ends of sheathing at centers of supports.
3. Stagger end joints where applicable.
4. Attach sheathing to studding with fasteners as recommended by sheathing manufacturer.

END OF SECTION

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SECTION 07 26 00
VAPOR RETARDERS

PART 1 - GENERAL

1.01 SUMMARY

A. Section includes sheet materials for controlling vapor diffusion.

B. Related Sections:

1. Section 07 27 00 Air Barriers.
2. Section 07 90 00 Joint Protection.

1.02 REFERENCES

A. Abbreviations and Acronyms:

1. American Society of Testing and Materials (ASTM)
2. Ethylene Propylene Diene Monomer (EPDM)
3. Green Seal (GS)
4. South Coast Air Quality Management District (SCAQMD)
5. Sealant, Waterproofing and Restoration Institute (SWRI)

B. References Standards:

1. American Society of Testing and Materials (ASTM) C920, Standard Specification for Elastomeric Joint Sealants.
2. ASTM E96, Standard Test Methods for Water Vapor Transmission of Materials.
3. Green Seal (GS) 36, Aerosol Adhesives.
4. Sealant, Waterproofing and Restoration Institute (SWRI), Sealant and Caulking Guide Specification.
5. South Coast Air Quality Management District (SCAQMD) Rule 1168, Adhesive and Sealant Applications.

1.03 PERFORMANCE REQUIREMENTS

A. Vapor Retarder Permeance: Maximum [1 perm] [[_____] perms] ([57][_____] ng/Pa/s/sq m) when tested in accordance with ASTM E96, Procedure A.

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1.04 SUBMITTALS

A. Refer to the Submittal Schedule at the end of PART 3 for a list of submittal requirements for this Section.

1.05 QUALITY ASSURANCE

A. Perform Work in accordance with SWRI, Sealant and Caulking Guide Specification requirements for materials and installation.

B. Maintain one copy of each document on site.

1.06 SEQUENCING

A. Sequence Work to permit installation of materials in conjunction with other retardant materials and seals , and air barrier assemblies specified in Section 07 27 00 Air Barriers.

B. Do not install vapor retarder until items penetrating vapor retarder are in place.

PART 2 - PRODUCTS

2.01 VAPOR RETARDERS

A. Manufacturers:

1. Alumiseal Corp.
2. Fiberweb Corp.
3. Griffolyn, Reef Industries
4. Raven Industries

2.02 COMPONENTS

A. Sheet Retarder [Type [1][_____]]: [Black] [Clear] [_____] polyethylene film for above grade application, [10][20][_____]-mil ([0.25][0.50][_____]-mm) thick.

B. Sheet Retarder [Type [2][_____]]: [Black] [_____] polyethylene film reinforced with glass fiber square mesh, [_____]-mil ([_____]mm) thick.

C. Sheet Retarder [Type [3][_____]]: [Butyl] [Neoprene] [Ethylene Propylene Diene Monomer (EPDM)] [_____], black color, [45][_____]-mil ([1.2][_____]-mm) thick.

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D. [Butyl] Sealant [Type [A][_____]]: [ASTM C920, Grade [_____], Class [_____], Use [_____];] butyl rubber base, single component, solvent release, non-skinning, [black][_____] color.

1. Elongation Capability: [5][_____] percent.
2. Service Temperature Range: [-40 to 180][_____] degrees F ([-40 to 82][_____] degrees C).
3. Shore A Hardness Range: [10 to 30] [_____].
4. [Interior] Sealants and Sealant Primers: Maximum volatile organic compound content in accordance with SCAQMD Rule 1168.

E. Polysulfide Sealant [Type [B][_____]]: [ASTM C920, Grade [_____], Class [_____], Use [_____];] single component, chemical curing, capable of continuous water immersion, non-sagging type; [black][_____] color.

1. Elongation Capability: [25][_____] percent.
2. Service Temperature Range: [-40 to 180][_____] degrees F ([-40 to 82][_____] degrees C).
3. Shore A Hardness Range: [20 to 35][_____].
4. [Interior] Sealants and Sealant Primers: Maximum volatile organic compound content in accordance with SCAQMD Rule 1168.

F. [Polyurethane] Sealant [Type [C][_____]]: [ASTM C920, Grade [_____], Class [_____], Use [_____];] single component, chemical curing, non-sagging; [black] [_____] color.

1. Elongation Capability: [25][_____] percent.
2. Service Temperature Range: [-40 to 180][_____] degrees F ([-40 to 82][_____] degrees C).
3. Shore A Hardness Range: [20 to 35][_____].
4. [Interior] Sealants and Sealant Primers: Maximum volatile organic compound content in accordance with SCAQMD Rule 1168.

G. Sealant: [_____] Type specified in Section 07 90 00 Joint Protection.

H. Primer and Backer Rods: Recommended by sealant manufacturer to suit application.

1. [Interior] Sealants and Sealant Primers: Maximum volatile organic compound content in accordance with SCAQMD Rule 1168.

I. Cleaner: Non-corrosive type; recommended by sealant manufacturer; compatible with adjacent materials.

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J. Mastic Adhesive [Type [1][_____]]: Asphalt type, compatible with sheet retarder and substrate, thick mastic of uniform consistency.

1. [Interior] Adhesives: Maximum volatile organic compound content in accordance with SCAQMD Rule 1168.
2. [Interior] Aerosol Adhesives: Maximum volatile organic compound content in accordance with GS 36.

K. Adhesive [Type [2][_____]]: Compatible with sheet retarder and substrate, permanently non-curing.

1. [Interior] Adhesives: Maximum volatile organic compound content in accordance with SCAQMD Rule 1168.
2. [Interior] Aerosol Adhesives: Maximum volatile organic compound content in accordance with GS 36.

L. ACCESSORIES

M. Thinner and Cleaner for [Butyl] [Neoprene] [_____] Sheet: As recommended by sheet material manufacturer.

N. Tape: [Bright aluminum] [Polyethylene] [Polyester] self-adhering type, [mesh reinforced], [2][_____]-inch ([50][_____]-mm) wide, compatible with sheet material.

O. Attachments: [Galvanized steel] [_____] bars and anchors.

PART 3 - EXECUTION

3.01 PREPARATION

A. Remove loose or foreign matter capable of impairing adhesion.

B. Clean and prime substrate surfaces to receive adhesive and sealants.

3.02 EXISTING WORK

A. Clean and repair existing construction to provide positive and continuous seal for vapor retarders.

3.03 INSTALLATION

A. Vapor Retarder For Solid Substrate: Secure sheet retarder [Type [_____]] to solid construction with [adhesive] [tape] [continuous metal bar with anchors]. Lap

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edges and ends [6][_____] inches ([150][_____] mm) and [adhesive seal] [caulk with [Type [_____]] sealant] to ensure complete and continuous seal.

B. Vapor Retarder For Stud Framed Walls: Secure sheet retarder [Type [_____]] to stud faces with [adhesive] [_____]. Lap edges over stud faces, lap ends onto adjacent construction; caulk ends with [Type [_____]] sealant to ensure complete seal.

C. Vapor Retarder For Wall/Roof Junction: Lap sheet retarder [Type [_____]] from wall retarder onto roof vapor retarder continuously. Seal edges and ends with [sealant] [adhesive]. Caulk with [Type [_____]] sealant to ensure complete seal. [Position laps over firm bearing.]

D. Vapor Retarder Seal For Openings: Install sheet retarder [Type [_____]] between [window] [and] [door] frames and adjacent vapor retarder and seal with [sealant] [adhesive]. Caulk with [Type [_____]] sealant to ensure complete seal. [Position laps over firm bearing.]

E. Apply sealant within recommended application temperature ranges. Consult manufacturer when sealant cannot be applied within these temperature ranges or where compatibility with adjacent materials may be in doubt.

F. Install Work in accordance with applicable [State] [Municipality] of [_____] [Highways] [Public Works] standards.

3.04 SCHEDULES

A. Window Frame Perimeter: Lap sheet retarder Type 4 from wall vapor retarder (with 3 inches (75 mm) of contact over firm bearing) to window frame (with 1 inch (25 mm) of contact). Seal with sealant Type A.

B. Wall and Roof Junction: Lap sheet retarder Type 2 from wall vapor retarder (with 6 inches (150 mm) of contact over firm bearing) to roof vapor retarder (with 4 inches (100 mm) of contact). Seal with sealant Type A.

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3.05 SUBMITTAL SCHEDULE.

ITEM NO.	SUBMITTAL REQUIREMENT	WITH BID	AS INDICATED
07 26 00-01	Product Data: Submit data indicating material characteristics, performance criteria, limitations.	[ ]	Prior to delivery
07 26 00-02	Manufacturer's Installation Instructions: Submit preparation and installation requirements and techniques.	[ ]	Per construction schedule.
SUSTAINABLE DESIGN SUBMITTALS			
07 26 00-03	Manufacturer's Certificate: Certify products meet or exceed specified sustainable design requirements. Materials Resources Certificates: 1. Certify recycled material content for recycled content products. 2. Certify source for local and regional materials and distance from Project site. a. Indoor Air Quality Certificates. b. Certify volatile organic compound content for each interior adhesive and sealant and related primer.	[ ]	Per construction schedule.
CLOSEOUT SUBMITTALS			

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ITEM NO.	SUBMITTAL REQUIREMENT	WITH BID	AS INDICATED
07 26 00-01	Product Data: Submit data indicating material characteristics, performance criteria, limitations.	[ ]	Prior to delivery
07 26 00-05	Project Record Documents: Accurately record actual locations of capped utilities, concealed utilities discovered during demolition, subsurface obstructions.	[ ]	With record documents.
07 26 00-06	Maintenance Data: Submit description of system, cleaning requirements and methods, inspection data, and parts lists.	[ ]	With record documents.

END OF SECTION

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SECTION 07 92 00
JOINT SEALANTS

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM):
   a. C661, Standard Test Method for Indentation Hardness of Elastomeric Type Sealants by Means of a Durometer.
   b. C834, Standard Specification for Latex Sealants.
   c. C920, Standard Specification for Elastomeric Joint Sealants.
   d. C1193, Standard Guide for Use of Joint Sealants.

1.02 SUBMITTALS

A. Action Submittals:

1. Shop Drawings: Surface preparation instructions. Indicate where each product is proposed to be used.
2. Samples: Material proposed for use showing color [range available] [selected].

1.03 INFORMATIONAL SUBMITTALS:

1. Installation instructions.
2. Documentation showing applicator qualifications.
3. Manufacturer's Certificate of Compliance, in accordance with Section 01 43 33, Manufacturers' Field Services.
4. Special guarantee.

1.04 QUALITY ASSURANCE

A. Applicator Qualifications: Minimum of 5 years' experience installing sealants in projects of similar scope.

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1.05 ENVIRONMENTAL REQUIREMENTS

A. Ambient Temperature: Between 40 degrees F and 80 degrees F (4 degrees C and 27 degrees C) when sealant is applied. Consult manufacturer when sealant cannot be applied within these temperature ranges.

1.06 SPECIAL GUARANTEE

A. Product: Furnish manufacturer's extended guarantee or warranty, with Owner named as beneficiary, in writing, as special guarantee. Special guarantee shall provide for correction or, at the option of the Owner, removal and replacement of Work specified in this section found defective during a period of 5 years after the date of Substantial Completion. Duties and obligations for correction or removal and replacement of defective Work shall be as specified in the General Conditions.

B. Conditions: No adhesive or cohesive failure of sealant.

C. Sealed Joints: Watertight and weathertight with normal usage.

PART 2 - PRODUCTS

2.01 SEALANT MATERIALS

A. Characteristics:

1. Uniform, homogeneous.
2. Free from lumps, skins, and coarse particles when mixed.
3. Nonstaining, nonbleeding.
4. Hardness of 15 minimum and 50 maximum, measured by ASTM C661 method.
5. Immersible may be substituted for nonimmersible.

B. Color: [Unless specifically noted, match color of the principal wall material adjoining area of application.] [As selected by Engineer.] [As indicated in Joint Sealant Schedule in this section.]

C. Type 1—Silicone, Nonsag, Nonimmersible:

1. Silicone base, single-component, moisture curing; ASTM C920, Type S, Grade NS, Class 25.
2. Capable of withstanding movement up to 50 percent of joint width.
3. Manufacturers and Products:

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a. Dow Corning Corp.; No. 790.
b. General Electric; Silpruf.
c. BASF; Sonneborn, Omniseal-50.

D. Type 2—Multipart Polyurethane, Self-leveling, Immersible:

1. Polyurethane base, multicomponent, chemical curing; ASTM C920, Type M, Grade P, Class 25.
2. Capable of being continuously immersed in water.
3. Manufacturers and Products:
   a. BASF; Sonneborn, SL-2.
   b. Pecora Corp.; Urexspan NR-200.
   c. Tremco; THC-900/901.
   d. Sika Chemical Corp.; Sikaflex 2c SL.

E. Type 3—Multipart Polyurethane, Nonsag, Immersible:

1. Polyurethane base, multicomponent, chemical curing; ASTM C920, Type M, Grade NS, Class 25.
2. Capable of being continuously immersed in water.
3. Manufacturers and Products:
   a. Pecora; DynaTrol II.
   b. Tremco; Dymeric 240.
   c. BASF; Sonneborn NP-2.
   d. Sika Chemical Corp.; Sikaflex 2c NS.

F. Type 4—Multipart Polyurethane, Nonsag, Nonimmersible:

1. Polyurethane base, multicomponent, chemical curing; ASTM C920, Type M, Grade NS, Class 25.
2. Manufacturers and Products:
   a. BASF; Sonneborn NP-2.
   b. Pecora Corp.; Dynatrol II.
   c. Tremco; Dymeric 240.
   d. Sika Chemical Corp.; Sikaflex 2c NS.

G. Type 5—One-part Polyurethane, Immersible:

1. Polyurethane base, single-component, moisture curing; ASTM C920, Type S, Grade NS or P, Class 25.
2. Capable of being continuously immersed in water.
3. Manufacturers and Products for Nonsag:
   a. Sika Chemical Corp.; Sikaflex-1a.

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b. Tremco; Vulkem 116.

4. Manufacturers and Products for Self-leveling:
   a. BASF; Sonneborn, SL-1.
   b. Tremco; Vulkem 45.
   c. Sika Chemical Corp.; Sikaflex 1c SL.

H. Type 6—One-Part Polyurethane, Nonimmersible:

1. Polyurethane base, single-component, moisture curing; ASTM C920, Type S, Grade NS, Class 25.
2. Manufacturers and Products:
   a. Pecora Corp.; Dynatrol 1 XL.
   b. Tremco; Dymonic.
   c. BASF; Sonneborn, NP-I.

I. Type 7—Multipart Polysulfide, Immersible:

1. Polysulfide base, two-component, chemical curing; ASTM C920, Type M, Grade P or NS, Class 25.
2. Capable of being continuously immersed in water.
3. Manufacturers and Products:
   a. W. R. Meadows; Deck-O-Seal Gun Grade, two-part.
   b. BASF; Sonolastic, two-part Polysulfde.

J. Type 8—One-Part Polysulfide, Nonsag, Nonimmersible:

1. Polysulfide base, single-component, moisture curing; ASTM C920, Type S, Grade NS, Class 12 1/2.
2. Capable of withstanding movement up to 20 percent of joint width.
3. Manufacturer and Product: W. R. Meadows; Deck-O-Seal, one-part.

K. Type 9—One-Part Acrylic Terpolymer, Nonsag, Nonimmersible:

1. Acrylic base, single-component, solvent curing; ASTM C834 nonsag.
2. Capable of withstanding movement up to 7.5 percent of joint width; Shore “A” hardness of 55 maximum.
3. Manufacturer and Product: Tremco; Mono 555.

L. Type 10—Sanitary Sealant:

1. Silicone sealant similar to Type 1, above, formulated to resist mold growth and repeated exposure to high humidity while retaining adhesion, flexibility, and color.

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2. Manufacturers and Products:
   a. Dow Corning; 786.
   b. General Electric; Sanitary Sealant SCS1700.

M. Type 11—Fire Penetration Seal:

1. Manufacturers and Products:
   a. 3M Corp.; Fire Barrier Caulk CP25 and Putty 303.
   b. General Electric; Pensil Sealant or Foam.
   c. Unifrax Corporation; Fyre Putty.
   d. Hilti USA; CP 604.

N. Type 12—One-Part Polycarbonate, Immersible:

1. Polycarbonate base, single-component, moisture curing; ASTM C920, Type S, Grade NS, Class 25.
2. Capable of being continuously immersed in water.
3. Manufacturer and Product: Pro-Seal Products, Inc.; Pro-Seal 34.

O. Type 13—Tape Sealant:

1. Compressible polyurethane foam impregnated with polybutylene or polymer-modified asphalt.
2. Color: Black.
3. Size: 3/4 inch wide by length required by expanded thickness recommended by manufacturer for particular application.
4. Manufacturers and Products:
   a. Emseal Joint Systems, Ltd.; AST—High Acrylic.
   b. Dayton Superior; Polytite Standard.
   c. PARR Technologies; PARR Sealant EP-7212-T.

2.02 BACKUP MATERIAL

A. Nongassing, extruded, closed-cell round polyurethane foam or polyethylene foam rod, compatible with sealant used, and as recommended by sealant manufacturer.

B. Size: As shown or as recommended by sealant material manufacturer. Provide for joints greater than 3/16 inch wide.

C. Manufacturers and Products:

1. Sonneborn; Sonolastic Closed-cell Backing Rod.
2. Tremco; Closed-cell Backing Rod.

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3. Pecora Corporation; Green Rod.

2.03 ANCILLARY MATERIALS

A. Bond Breaker: Pressure sensitive tape as recommended by sealant manufacturer to suit application.

B. Joint Cleaner: Noncorrosive and nonstaining type, recommended by sealant manufacturer; compatible with joint forming materials.

C. Primer: Nonstaining type recommended by sealant manufacturer to suit application.

2.04 PREFORMED SEALS

A. Preformed Compressible Joint Seals:

1. Widths Up to 5 Inches:
   a. BASF, Watson Bowman Acme Div.; Wabo Weatherseal II.
   b. Emseal Joint Systems Limited; Colorseal.
   c. LymTal International; Iso-flex Joint System.
2. Other Widths: Series or model recommended by seal manufacturer.

PART 3 - EXECUTION

3.01 GENERAL

A. Use of more than one material for the same joint is not allowed unless approved by sealant manufacturer.

B. Install joint sealants in accordance with ASTM C1193.

C. Horizontal and Sloping Joints up to 1 Percent Maximum Slope: Use self-leveling (Grade P) joint sealant.

D. Steeper Sloped Joints, Vertical Joints, and Overhead Joints: Use nonsag (Grade NS) joint sealant.

E. Use joint sealant as required for the applicable application and as follows:

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Joint Size	Sealant Type
Less than 1"	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or 12
Less than 2"	1, 2, 3, 4, or 7
Over 2"	Follow manufacturer’s recommendation

3.02 PREPARATION

A. Verify that joint dimensions, and physical and environmental conditions, are acceptable to receive sealant.

B. Surfaces to be sealed shall be clean, dry, sound, and free of dust, loose mortar, oil, and other foreign materials.

1. Mask adjacent surfaces where necessary to maintain neat edge.
2. Starting of work will be construed as acceptance of subsurfaces.
3. Apply primer to dry surfaces as recommended by sealant manufacturer.

C. Verify joint shaping materials and release tapes are compatible with sealant.

D. Examine joint dimensions and size materials to achieve required width/depth ratios.

E. Follow manufacturer’s instructions for mixing multi-component products.

3.03 INSTALLATION

A. Use joint filler to achieve required joint depths, to allow sealants to perform intended function.

1. Install backup material as recommended by sealant manufacturer.
2. Where possible, provide full length sections without splices; minimize number of splices.
3. Tape sealant may be used as joint filler if approved by sealant manufacturer.

B. Use bond breaker where recommended by sealant manufacturer.

C. Seal joints around window, door and louver frames, expansion joints, control joints, and elsewhere as indicated.

D. Joint Sealant Materials: Follow manufacturer’s recommendation and instructions, filling joint completely from back to top, without voids.

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E. Joints: Tool slightly concave after sealant is installed.

1. When tooling white or light color sealant, use a water-wet tool.
2. Finish joints free of air pockets, foreign embedded matter, ridges, and sags.

F. Tape Sealant: Compress to 50 percent of expanded thickness and install in accordance with manufacturer's instructions.

3.04 PREFORMED SEALS

A. Prepare joint surfaces clean and dry, free from oil, rust, laitance, and other foreign material.

B. Construct joints straight and parallel to each other and at proper width and depth.

C. Apply joint sealant manufacturer's approved primer and adhesive in accordance with manufacturer's instructions.

D. Install seal in accordance with manufacturer's instructions.

3.05 CLEANING

A. Clean surfaces next to the sealed joints of smears or other soiling resultant of sealing application.

B. Replace damaged surfaces resulting from joint sealing or cleaning activities.

3.06 JOINT SEALANT SCHEDULE

A. This schedule lists the sealant types acceptable for each joint location. Use as few different sealant types as possible to meet the requirements of Project.

Joint Locations	Sealant Type(s)
Expansion/Contraction and Control Joints At:	
Concrete Walls (except water-holding and belowgrade portions of structures)	1, 3, 4, 5, 6, 7, 12
Concrete Floor Slabs (except for water-holding Structures)	2, 5
Slabs Subject to Vehicle and Pedestrian Traffic	2, 5
Masonry Walls	1, 3, 4, 5, 6, 7, 12, 13

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Joint Locations	Sealant Type(s)
Exterior Insulation and Finish System	4
Ceramic Tile Floors	1, 2, 5, 10
Ceramic Tile Walls	1, 3, 5, 10
Precast Concrete Wall Panels	3, 4, 5, 12, 13
Material Joints At:	
Metal Door, Window, and Louver Frames (Exterior)	1, 5, 6, 8, 12
Metal Door, Window, and Louver Frames (Interior)	1, 5, 6, 8, 9
Wall Penetrations (Exterior)	1, 5, 6, 8, 12
Wall Penetrations (Interior)	1, 5, 6, 8
Floor Penetrations	5, 6, 7
Ceiling Penetrations	1, 3, 4, 5, 6, 7
Roof Penetrations	5
Sheet Metal Flashings	5, 13
Sheet Metal Roofing and Siding	5, 13
Precast Concrete Wall Panels	1, 3, 4, 5, 6, 7, 12, 13
Glazed Concrete Masonry Unit Joints	1
Precast/Prestressed Floor Panels (Interior)	2, 7
Precast/Prestressed Floor and Roof Panels (Exterior)	3, 7
Other Joints:	
Threshold Sealant Bed	5
Between Counter Tops and Backsplashes	10
Around Plumbing Fixtures	10
Openings Around Pipes, Conduits, and Ducts Through Fire-Rated Construction	11
Concrete Form Snap-Tie Holes	1, 4, 5

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B. [Use sealant Type [4] [5] [6] [1] [12] [_____] for building joints and elsewhere as indicated.]

C. [Use sealant Type 10 for joints between counter tops and backsplashes and around plumbing fixtures where they fit against walls and floors.]

D. [Use sealant Type 11 to seal voids and holes around penetrations through fire-rated elements.]

END OF SECTION

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SECTION 08 11 00
METAL DOORS AND FRAMES

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American National Standards Institute (ANSI):
   a. A250.6, Hardware on Standard Steel Doors (Reinforcement - Application).
   b. A250.8, Recommended Specification for Standard Steel Doors and Frames.
   c. A250.11, Recommended Erection Instructions for Steel Frames.
2. ASTM International (ASTM):
   a. A167, Standard Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip.
   b. A480/A480M, Standard Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip.
   c. A653/A653M, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.
   d. A1008/A1008M, Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Solution Hardened, and Bake Hardenable.
   e. E90, Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements.
3. Builders Hardware Manufacturers Association (BHMA): A156.115, Hardware Preparations in Standard Steel Doors and Frames.
4. National Fire Protection Association (NFPA): 80, Standard for Fire Doors and Other Opening Protectives.
5. Underwriters Laboratories, Inc. (UL): Building Materials Directory.

1.02 SUBMITTALS

A. Action Submittals: Applicable information for each type of door and frame, including:

1. Frame conditions and complete anchorage details, supplemented by suitable schedules covering doors and frames.

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2. Glass and louver opening sizes and locations in doors.
3. Connections of door frames to structural steel framing concealed in frames.
4. Location and field splice joints for frames too large to ship in one piece; indicate complete instructions for making field splices.
5. Joints required to accommodate expansion joint movement.
6. Relate to door numbers used in Contract Drawings.

1.03 DELIVERY, STORAGE, AND HANDLING

A. Properly identify each item with number used in Contract Drawings.

B. Store doors upright, in protected dry area, at least 1 inch off ground or floor and at least 1/4 inch between individual pieces.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Materials, equipment, and accessories specified in this section shall be products of:

1. Curries Manufacturing.
2. The Ceco Corp.
3. Fenestra Division, Marmon Group.
4. Mesker Industries, Inc.
5. Monarch Steelcraft, Ltd.
6. Overly Manufacturing Co.
7. Pioneer Industries.
8. Precision Metals, Inc.
9. Republic Steel Corp.
10. Steelcraft Manufacturing Co.
11. Trussbilt, Inc.
12. Williamsburg Steel Products Co.
13. Stiles Custom Metal, Inc.

2.02 MATERIALS

A. Basic Metal Material:

1. ASTM A1008/A1008M; sheet steel, cold-rolled, stretcher level.
2. ASTM A167, Type 316 stainless steel.

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B. Hollow Metal Frames:

1. Products of hollow metal door manufacturer.
2. ANSI 250.8, except as modified herein.
3. Frames for Doors [and Windows:] 16 gauge for interior and 14 gauge [, with thermal break,] for exterior, [knockdown or] welded type, of cross-section shown.
4. Prepare floor and wall anchors, reinforcement, and cutouts for hardware to meet requirements of BHMA A156.115 and ANSI A250.6.
5. Finished size, shape, and profile of frame members as shown.
6. Concealed fasteners or welding are preferred to through-the-face fasteners.
7. Identification: Stamp opening number, as shown on Drawings, on center hinge reinforcement of each frame.

C. Hollow Metal Doors: ANSI A250.8, except as modified herein. BHMA A156.115 and ANSI A250.6 to receive hardware specified in Door and Hardware Schedule.

1. Interior:
   a. Flush Panel Doors: [18 gauge, Level 2, Model 1.] [18 gauge, Level 2, Model 2.] [_____]
   b. Stile and Rail Doors: 16 gauge, Level 3, Model 3.
   c. Flush end closure at top of doors.
2. Exterior:
   a. Flush Panel Doors: [16 gauge, Level 3, Model 1.] [16 gauge, Level 3, Model 2.] [_____]
   b. Stile and Rail Doors: 16 gauge, Level 3, Model 3.
   c. Double Doors: Overlapping astragals for active leaf, except as noted or detailed otherwise.
   d. Flush end closure at top of doors.
   e. R-Value: [_____]

D. Labeled Fire Doors and Frames:

1. Conform to listing requirements of Underwriters Laboratories, Inc. (UL).
2. Label each door and frame for class of rating required.
3. Overlapping astragal on active leaf of double doors.
4. Label requirements, dimensions, and type of door are indicated [in Door and Hardware Schedule.] [on Drawings.]
   a. Modify drawing details if required to secure label.
   b. Clearly identify modifications on Shop Drawings.
   c. Maximum temperature rise of 450 degrees F for stairway enclosures.

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E. Glazing:

2. Doors: Furnish with formed flush-type glazing strips with butt corner joints to permit selection of secure side in field.
3. Glazing Arrangements: Accommodate glass of type and thickness indicated and as specified in Section 08 80 00, Glazing.

1.2 MISCELLANEOUS ITEMS

A. Filler or Transom Panels: Furnish of same construction and finish as door to include fire-resistive label and sound-retardant construction.

B. Furnish manufacturer's standard core filler, anchors, fasteners, and other ancillary items.

1.3 FACTORY FINISHING REQUIREMENTS

A. Galvanized with A60 zinc coating in accordance with ASTM A653/A653M.

B. Phosphate treat metal for paint adhesion.

C. One shop coat of baked-on rust-inhibiting prime coating compatible with finish coating [as shown and] as specified in Section 09 90 00, Painting and Coating.

D. Stainless Steel: ASTM A480, No. 3 or No. 4.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Frames:

1. Follow ANSI A250.11 and manufacturer's instructions.
   a. Maintain scheduled dimensions, hold head level, and maintain jambs plumb and square.
   b. Secure anchorages and connections to adjacent construction.
   c. Wherever possible, leave frame spreader bars intact until frames are set perfectly square and plumb and anchors are securely attached.

B. Doors:

1. Hollow Metal Doors: ANSI A250.8.
2. Hardware: In accordance with manufacturer's templates and instructions.
   a. Adjust operable parts for correct function.

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b. Remove hardware, with exception of prime coated items, tag, box, and reinstall after finish paint work is completed.

3. Labeled Doors: NFPA Pamphlet No. 80.

3.02 FIELD PAINTING

A. Where prime coat has been damaged, sand smooth and touch up with same primer as applied at shop.

1. Remove rust before painting.
2. Touch Up: Not obvious.
3. Perform immediately after door and frame installation.

3.03 PROTECTION

A. Protect installed doors and frames against damage from other construction work.

3.04 SCHEDULES

A. For tabulation of door and frame characteristics, such as size, type, detail, and finish hardware requirements see Section 08 06 01, Door and Hardware Schedule on Drawings.

END OF SECTION

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SECTION 08 33 23
OVERHEAD COILING DOORS

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM):
   a. A653/A653M, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.
   b. A666, Standard Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar.
   c. A924/A924M, Standard Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process.
   d. B221, Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes.
   e. E84, Standard Test Method for Surface Burning Characteristics of Building Materials.
2. Intertek Testing Services (Warnock Hersey Listed) (WH): Certification Listings.
3. National Association of Metal Manufacturers (NAAMM).
4. National Electrical Manufacturers Association (NEMA): 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
5. ICS 2, Industrial Control and Systems: Controllers, Contactors, and Overload Relays Rated 600 Volts.
6. MG 1, Motors and Generators.
7. National Fire Protection Association (NFPA):
   a. 80, Standard for Fire Doors and Other Opening Protectives.
   b. 252, Standard Methods of Fire Tests of Door Assemblies.
8. Underwriters Laboratories Inc. (UL):
   a. Building Materials Directory.
   b. 10B, Standard Safety for Fire Tests of Door Assemblies.
   c. 325, Standard Safety for Door, Drapery, Gate, Louver, and Window Operators and Systems.

1.02 SUBMITTALS

A. Action Submittals:

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1. Shop Drawings: Indicate pertinent dimensioning, anchorage methods, hardware locations, and installation details.
2. Product Data: General construction, component connections and details [, wiring diagram and electrical equipment].
3. Samples: Submit two shutter slats, 12 by 12 inch in size illustrating shape, color and finish texture.

B. Informational Submittals:

1. Third party testing documentation or manufacturer’s literature qualifying door model as meeting required developed wind pressures [and impact testing for small or large missile]. Miami-Dade Notice of Approval (NOA) documentation is acceptable as third party evidence of certification.
2. Manufacturer's Instructions: Indicate installation sequence and procedures, and adjustment and alignment procedures.
3. Operation and Maintenance Data as specified in Section 01 78 23, Operation and Maintenance Data, include lubrication requirements and frequency, and periodic adjustments required.
4. Seismic Anchorage and Bracing:
   a. Drawings and product data as required by Section 01 88 15, Seismic Anchorage and Bracing.
   b. Calculations as required by Section 01 88 15, Seismic Anchorage and Bracing.
   c. Installer’s factory authorization.

1.03 QUALITY ASSURANCE

A. Qualifications:
1. Manufacturer: Company specializing in manufacturing products specified in this section with minimum 3 years documented experience.
2. Installer: Company specializing in performing work of this section approved by manufacturer.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Materials, equipment, and accessories specified in this section shall be products of:

1. [Cookson Co.] Model [_____].
2. [Cornell Iron Works, Inc.] Model [_____].

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3. [Dynaflair Corp.] Model [_____].
4. [Metro Door] Model [_____].
5. [Raynor Garage Door] Model [_____].
6. [Trac-Rite Door] Model [_____].
7. [Overhead Door Co. Model [_____].

2.02 GENERAL

A. Wind Loads: Design door assembly to withstand wind/suction load of [_____ psf (_____ Pa)] with a maximum deflection of 1/120 without damage to [door] [shutter] or assembly components.

B. Operation: Design door assembly , including operator, to operate for not less than 10,000 cycles and 10 cycles per day.

C. Fire Rated Door Construction: Conform to one of the following:

1. NFPA 252.
2. UL 10B.

D. Fire Rated Assemblies: Fire rated [door] [shutter] fusible link [fire alarm system] activated with automatically governed closing speed.

1. Design release mechanism for easy resetting by facility maintenance personnel.
2. Provide units allowing manual lifting for emergency exit after automatic closing, with curtain closing when released.

E. Products Requiring Electrical Connection: Listed and classified by UL or another testing firm acceptable to authority having jurisdiction.

F. Surface Burning Characteristics, Foam Insulation: Maximum 75/450 flame spread/smoke developed index when tested in accordance with ASTM E84.

2.03 COMPONENTS

A. Curtain: Conform to following:

1. Stainless Steel Slats:
   a. Interlocking, minimum 24 gauge thick of stainless steel conforming to ASTM A666 Type 304 rollable temper.
   b. Type: Single thickness perforated S-configuration slat.
2. Nominal Slat Size: 3 inches wide by required length.

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3. Slat Ends: Each slat fitted with end locks to act as wearing surface in guides and to prevent lateral movement.
4. Curtain Bottom: Fitted with angles, channels, or tubes to provide reinforcement and positive contact withfloor in closed position.

B. Guides:

1. Minimum 3/16 inch thick; galvanized steel conforming to ASTM A653/A653M, minimum galvanized coating designation G90 in accordance with ASTM A924/A924M stainless steel conforming to ASTM A666 Type 304 rollable temper.
2. Furnish continuous angles of profile to retain door in place; mounting brackets of same metal.

C. Roller Shaft Counterbalance: Steel pipe and [helical] steel spring system, capable of producing torque sufficient to ensure smooth operation of curtain from any position and capable of holding position at mid-travel; with adjustable spring tension.

D. Hood Enclosure and Fascia: Square shape, minimum 24 gauge thick galvanized steel; internally reinforced to maintain rigidity and shape.

E. Hardware:

1. Locks: Furnish locks to allow doors to be secured.
   a. Manual Doors: Manufacturer's standard cylinder dead lock on inside at door jamb, key operated from interior.
2. Cylinders: Minimum six-pin cylinders Furnished under Section 08 71 00, Door Hardware installed as part of Work of this section; doors keyed alike master keyed.
3. Handle: Inside [center] [side] mounted, adjustable keeper, spring activated latch bar with feature to keep in locked or retracted position; interior [and exterior] handle.
4. Weatherstripping (Exterior Assemblies): Moisture and rot proof, resilient type for complete weathertight installation.
   a. Rubber, neoprene, or vinyl water seal at hood to prevent airflow around coil on exterior doors.
   b. Weather seal sealing strip on guide to close space between guide and curtain on exterior doors.
5. Smoke Seals (Fire Rated Assemblies): Perimeter gaskets and closures to prevent spread of smoke through door assembly and to maintain required fire rating and fire label.

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F. Manual Operation: Manual hand chain lift unit with overhead counter balance device, requiring 25 lb nominal force to operate.

2.04 FINISHES

A. Curtain Slats: Stainless steel, NAAMM No. 4 satin directional polished finish.

B. Steel Guides and Hood Enclosure: Primed and painted

2.05 SOURCE QUALITY CONTROL

A. Attach label from agency approved by authority having jurisdiction to identify each fire rated door.

1. Oversize Door Certification: Provide UL Certificate of Inspection or comparable certification acceptable to authorities having jurisdiction, in lieu of label for oversize door assemblies exceeding 120 square feet or 24 feet in any dimension.

B. Apply label from agency approved by authority having jurisdiction to identify each foam plastic insulation board.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Verify opening sizes, tolerances and conditions are acceptable.

3.02 INSTALLATION

A. Use anchorage devices to securely fasten assembly to wall construction and building framing without distortion or stress.

B. Securely and rigidly brace components suspended from structure. Secure guides to structural members only.

C. Fit and align assembly including hardware; level and plumb, to provide smooth operation.

D. Coordinate installation of sealants and backing materials at frame perimeter as specified in Section 07 92 00, Joint Sealants.

E. Install perimeter trim and closures.

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3.03 TOLERANCES

A. Maintain dimensional tolerances and alignment with adjacent Work.

B. Maximum Variation from Plumb: 1/16 inch.

C. Maximum Variation from Level: 1/16 inch.

D. Longitudinal or Diagonal Warp: Plus or minus 1/8 inch per 10 ft straight edge.

3.04 ADJUSTING

A. Adjust door, hardware and operating assemblies for smooth and noiseless operation.

B. Test smoke activated assemblies for proper activation.

3.05 CLEANING

A. Leave door and components clean.

B. Remove labels and visible markings.

END OF SECTION

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SECTION 08 71 00
DOOR HARDWARE

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. Builders Hardware Manufacturer's Association (BHMA):
   a. A156.1, Butts and Hinges.
   b. A156.2, Bored and Preassembled Locks and Latches.
   c. A156.3, Exit Devices.
   d. A156.4, Door Controls - Closers.
   e. A156.13, Mortise Locks & Latches.
   f. A156.16, Auxiliary Hardware.
   g. A156.18, Materials and Finishes.
2. International Code Council (ICC): A117.1, Accessible and Usable Buildings and Facilities.
3. Underwriters Laboratories, Inc. (UL): Fire Protection Equipment List.

1.02 SUBMITTALS

A. Action Submittals:
   1. Shop Drawings:
      a. Product Data: Manufacturer's literature for each item of finish hardware required herein, clearly marked.
      b. Finish Hardware Schedule: Furnish complete and detailed schedule, show product items, numbers, and finishes for hardware for each separate opening.
      c. Special Tools: Provide listing and description of usage.

B. Informational Submittals:
   1. Operation and Maintenance Data as specified in Section 01 78 23, Operation and Maintenance Data.
   2. Manufacturer's Field Service Report.
   3. Certification of Hardware Consultant.
   4. Manufacturer's Certificate of Proper Installation, in accordance with Section 01 43 33, Manufacturers' Field Services.

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1.03 QUALITY ASSURANCE

A. Qualifications of Supplier: Recognized supplier of architectural finish hardware, with warehousing facilities, who has been furnishing hardware in vicinity of Project for not less than 5 years, and who is, or who employs, architectural hardware consultant.

B. Qualifications of Architectural Hardware Consultant (AHC): Certified by Door and Hardware Institute.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Before delivery, clearly identify and tag each item of hardware with respect to specified description and location of installation.

B. Provide secure storage for finish hardware until installation is made.

1.05 EXTRA MATERIALS

A. Special Tools: Two sets for installation and maintenance of hardware.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Provide end products of one manufacturer for each product in order to achieve standardization for appearance, maintenance, and replacement.

B. Finishes: BHMA A156.18.

C. [Some products listed below may not be used on this Project.]

2.02 FASTENERS

A. Stainless steel.

2.03 BUTT HINGES

A. BHMA A156.1.

B. Quantity per Door Leaf (Minimum):

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Door Height	Hinges
Up to 5'-0"	1 pair
5'-1" to 7'-7"	1-1/2 pair
7'-8" to 10'-0"	2 pairs
10'-1" to 12'-6"	2-1/2 pairs

C. Hinge Height (Minimum):

Door Width	Hinge Height
Up to 3'-0"	4-1/2"
3'-1" to 4'-0"	5"
Over 4'-0"	6"

C. Width: Minimum for clearance of trim and 180-degree swing.

D. Exterior Hinges: Nonremoveable pin.

E. Joint Tolerance: 0.012 inch maximum, gauged in CLOSED position.

F. Finish: [Satin stainless steel No. 630.] [Satin bronze No. 612.] [Satin chromium-plated brass or bronze No. 626.] [Satin chromium-plated steel No. 652.] [Primed for paint No. 600.] [As indicated for each type.]

G. Types and Manufacturers:

No.	Type Description	Stanley	Mc-Kinney	Lawrence	BHMA
H1	Regular weight, two ball-races, full mortise, [brass, bronze] [steel] [stainless steel]	 [FBB191] [FBB179] [FBB191-32D]	 [TB2314] [TB2714] [TB2314]	 [BB4101-1] [BB4101] [BB4101-32D]	 [A2112] [A8112] [A5112]
H2	Plain bearing, full mortise, [brass or bronze] [steel] [stainless steel]	 [F191-32D] [F191] [AA: F179]	 [T2314] [T2314] [AB: T2714]	 [4181-32D] [4181-1] [AC: 4181]	 [A2133] [A8133] [AD: A5133]
H3	Hinges or pivots furnished by door manufacturer				
H4	Extra heavy-weight, four ball races, full mortise, stainless steel	FBB199-32D	T4B3386	BB5151-A	A5111
H5	Heavyweight, four ball races, half mortise, stainless steel	FBB98	T4B3384	BB5651-32D	A5211

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No.	Type Description	Stanley	Mc-Kinney	Lawrence	BHMA
H6	Heavyweight, four ball races, half mortise, stainless steel	FBB113	T4B3382	BB9351-32D	A5411

2.04 LOCKS AND LATCH SETS

A. Cylindrical or Bored Locks: BHMA A156.2, highest grade.

1. Trim: Wrought or cold-forged metal knobs and roses.
2. Core Cylinders: Interchangeable, removable; minimum of six pins.
3. Strikes: Lip dimensions to fit configuration of trim.
4. Bolt Throw: 3/4 inch minimum, on latchbolts for pair of doors.
5. Knob Backset: [3-3/4] [2-3/4] inches.
6. Manufacturers and Products:
   a. Sargent; AC.
   b. Schlage; Plymouth.
   c. Best; 4C Washington.

B. Mortise Locks: BHMA A156.13, Series 1000, Grade 1.

1. Materials: Brass or stainless steel.
2. Trim: Wrought or forged lever handles and roses.
3. Core Cylinders: Interchangeable, removable; minimum of six pins.
4. Bolt Throw: 5/8 inch minimum.
5. Lever Backset: 2-3/4 inches.
6. Manufacturers and Products:
   a. Sargent; LNJ.
   b. Schlage; 03.
   c. [Best; 3H Fairbanks.]

C. Tactile Warning: Knurl knob backs and lever handles for touch identification; ICC A117.1, Section 4.29.3.

D. Finish:

1. [Satin stainless steel No. 630.] [Satin chromium-plated No. 626.]
2. [Coat exterior [knobs] [and] [levers] with Teflon.]

E. [Locks and Latches: Match existing in manufacturer, design, finish, and keying. No substitutions allowed.]

F. Types and Manufacturers:

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No.	Type Description	Best	Sargent	Schlage	BHMA
L1	Mortise entrance lock with lever handle	45H7TA3H	8245-LNJ	L9456P-03	F12, F13
L2	Bored, entrance lock	84K7AB4C	9G05	C53PD	F81, F82
L3	Mortise latch with lever handle	45H0N3H	8215-LNJ	L9010-03	F01
L4	Bored latch	84K0N4C	9U15	C10S	F75
L5	Mortise utility room lock with lever handle	45H7D3H	8204-LNJ	L9080-03	F07
L6	Bored, utility room lock	84K7D4C	9G04	C80PD	F86
L7	Deadlock	83T7K	15-475	B560	E2151
L8	Mortise privacy lock with lever handle	45H7L3H	8265-LNJ	L9040-03	F19, F22
L9	Bored, privacy lock	84K0L4C	9U65	C40S	F76
L10	Cabinet lock, drawer and door	3L7RD	1654	46-002	E07121
L11	Lock by door manufacturer; furnish cylinders for keying to other locks as required				
L12	Bored, exit only, lock	84K0Y4C	9G13	C12D	F89
L13	Padlock	61BRT	756HS	45-101	
L14	Fixed knob pull and roller; Latch: Ives 336, Stanley C44S	84K1DT4C	9U93	D170	
L15	Push-pull latch		115	Corbin 1860	
L16	Lock by exit device manufacturer; furnish cylinders for keying to other locks as required				

G. Keying:

1. Lock Cylinders: Operate by [grand] master key system that allows for future expansion.

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2. Keylocks: [As indicated in Door and Hardware Schedule.] [Key new locks into existing [Best] master key system.] [As directed by Owner.]
3. Keys: Two per lock; tag with schedule information.
4. Master Keys: Four; send by registered mail to [Engineer] [Owner].
5. [Key cabinet and casework locks into building system.]
6. [Furnish lock manufacturer's removable core maximum security keying system.]

2.05 CONSTRUCTION KEY SYSTEM

A. Removable construction core system for locks.

B. See Article Manufacturer's Services under Part 3, Execution.

2.06 CONSTRUCTION KEY SYSTEM

A. Assemble permanent cylinders with construction inserts and ship with all lock sets.

B. Change Keys: Pack in separately identified envelopes and ship.

C. Construction Keys: Pack in cartons marked "packing list" and ship.

D. Construction Insert Extractor Keys, Master Keys, and Grand Master Keys: Ship by registered mail to [Engineer] [Owner].

E. On completion of job, deliver construction keys to Owner.

2.07 EXIT DEVICES

A. BHMA A156.3.

B. Furnish fire exit devices and mullions at fire-rated doors.

C. [Key Lockable,] Removable Mullion: [Steel] [Aluminum] construction, by exit device manufacturer.

D. Trim:

1. Knobs: Sargent PRK; Von Duprin K.
2. Levers: Sargent ETJ; Von Duprin 03.

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E. Finish:

1. Exit Device: Satin chromium-plated No. 626.
2. Removable Mullion: [Steel with prime coat.] [Aluminum with prime coat.] [Mill aluminum.]

F. Types and Manufacturers:

No.	Type Description	Sargent	VonDuprin	BHMA
X1	Rim type, active leaf; with removable mullion for pairs	[8813PRK] [8813ETJ]	[99K] [99L]	Type 1 08
X2	Rim type, exit only	8810	99EO	Type 1 01
X3	Vertical rod type	[8713PRK] [8713ETJ]	[9927K] [9927L]	Type 2 08
X4	Vertical rod type for pairs	[8713PRK and 8710] [8713ETJ and 8710]	[9927K and 9927EO] [9927L and 9927EO]	Type 2 08 and 01
X5	Vertical rod type, exit only, for singles or pairs	8710	9927EO	Type 2 01
X6	Concealed vertical rod type	[8613PRK] [8613ETJ]	[9947K] [9947L]	Type 8 08
X7	Concealed vertical rod type for pairs	[8613PRK and 8610] [8613ETJ and 8610]	[9947K and 9947EO] [9947L and 9947EO]	Type 8 08 and 01
X8	Concealed vertical rod type, exit only, for singles and pairs	8610	9947EO	Type 8 01
X9	Exit device by door manufacturers			
X10	Rim type, active leaf, latch function; with removable mullion for pairs	[8815PRK] [8815ETJ]	[99K-BE] [99L-BE]	Type 1
X11	Vertical rod type, latch function	[8715PRK] [8715ETJ]	[9927K-BE] [9927L-BE]	Type 2
X12	Vertical rod type for pairs, latch function	[8715PRK and 8710] [8715ETJ and 8710]	[9927K-BE and 9927EO] [9927L-BE and 9927EO]	Type 2
X13	Concealed vertical rod type, latch function	[8615PRK] [8615ETJ]	[9947K-BE] [9947L-BE]	Type 8

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No.	Type Description	Sargent	VonDuprin	BHMA
X14	Concealed vertical rod type for pairs, latch function	[8615PRK and 8610] [8615ETJ and 8610]	[9947K-BE and 9947EO] [9947L-BE and 9947EO]	Type 8

2.08 CLOSERS

A. BHMA A156.4.

B. Size closers in accordance with manufacturer's standards. Mount regular arm closers on pull side of doors. Mount parallel arm closers on push side of doors. On pair of doors provide closer on active leaf only, unless noted otherwise.

C. Finish: [Satin chromium-plated No. 626.] [_____] [Manufacturer's standard painted or powder coated finish] [, with special rust inhibiting (SRI) pretreatment] [, in color selected by Engineer from manufacturer's standard color range].

D. Types and Manufacturers:

No.	Type/Description	LCN	Sargent	BHMA
C1	Regular arm	4010 Series	351 Series	C02011
C2	Parallel arm	4110 Series	351-P Series	C02021
C3	Regular arm with hold-open	4010H Series	351-H Series	C02051
C4	Parallel arm with integral stop	4110 Cush-N-Stop Series	351-PS Series	C02021
C5	Parallel arm with hold-open	4110H Series	351-PH Series	C02061
C6	Parallel arm with integral stop and hold-open	4110H Cush-N-Stop Series	351-PSH Series	C02061
C7	Closer furnished by door and frame manufacturer			

2.09 PUSH-PULLS

A. Solid metal, not plated.

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B. Finish: [Satin stainless steel No. 630,] [Satin chromium-plated No. 626,] [Satin bronze No. 612,] unless indicated otherwise.

C. Plates: Beveled four edges, square corners.

D. Pulls: Bolted through door.

E. Push Plates: Countersink pull-through bolts and cover with push plate.

F. Types and Manufacturers:

No.	Type Description	BBW	Baldwin
P1	8" x 3/4" Pull handle on plate: 0.050" x 4" x 16", and push plate: 0.050" x 8" x 16"	1017-3B and 47-G	2367 and 2125
P2	Push bar and pull handle: Furnished by door manufacturer		
P3	8" x 3/4" Pull handles: Both sides	2903	2552

2.10 STOPS AND HOLDERS

A. BHMA A156.16.

B. Machine Screws: In threaded anchors at concrete or masonry.

C. Self-Tapping Screws: At stud partitions, wood, or metal mountings.

D. Metal Risers: For mounting at carpet floors.

E. Finish: Satin chromium-plated No. 626.

F. Types and Manufacturers for Each Leaf:

No.	Type Description	BBW or GJ	Baldwin	BHMA
S1	Floor stop	F121X	4086	L02131
S2	Wall bumper	[WC9X] [WC9T]	[4031] [4032]	[L02241] [L02251]
S3	Wall stop-holder	[W140] [W141X]	[4090] [4091]	[L02251] [L01351]
S4	Floor stop-holder	F823X	4096	L01371

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No.	Type Description	BBW or GJ	Baldwin	BHMA
S5	Door-attached holder	872	4105	L01381
S6	Overhead stop	GJ90S Series	Sargent 590S Series	C02511
S7	Overhead stop with hold-open	GJ90H Series	Sargent 590H Series	C05541
S8	Heavy-duty overhead stop	GJ79HDS		
S9	Spring and chain stop	Ives 115	4485	
S10	Stop or holder furnished by door manufacturer			

2.11 BOLTS

A. BHMA A156.16.

B. Finish: Bright nickel No. 645.

C. Types and Manufacturers:

No.	Type/Description	Stanley	Lawrence	BHMA
B1	Top and bottom flush bolts	393-1/2	280	L04201
B2	Top and bottom surface bolts	CD4060	283	(L04151)
B3	Top: 8" bolt w/48" chain	1055	T146	
	Bottom: 8" foot-bolt or surface bolt	1056 4060	T145 283	
B4	Surface bolt, 4"	4060	283	
B5	Cane bolt, 18"	1010	T250	
B6	Automatic flush bolts	GJ [FB7] [FB8]	Ives [559] [556]	

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2.12 KICKPLATES

A. [Solid metal, not plated.] [Plastic laminate.] Bevel four edges.

B. Width of door leaf less than 1-1/2 inches at single leaf and less than 1 inch at pairs.

C. Finish: [Satin stainless steel No. 630.] [Color as scheduled.] [Color: _____.]

D. Types and Manufacturers: Builders Brass Works, Baldwin, or Cipco as follows:

1. K1: 10 inches high by [0.05] [0.125] inch thick.
1. K2: 36 inches high by [0.05] [0.125] inch thick.

2.13 THRESHOLDS

A. Thresholds: One-piece full width of opening; extend beyond jamb where indicated.

B. Provide with stainless steel machine screws in threaded expansion anchors at concrete.

C. Finish: [Mill finish] [Dark bronze anodized] aluminum, unless indicated otherwise.

D. Types and Manufacturers:

No.	Type Description	Pemko	Reese
T1	Saddle (smooth, 4" x 1/2")	[175A] [175D]	[S104A] [S104D]
T2	Saddle (serrated, 4" x 1/4")	[270A] [270D]	[S404A] [S404D]
T3	Threshold furnished by door manufacturer		
T4	Thermal break saddle (6-1/8")	[253XAFG] [253XDFG]	[S473A] [S473D]
T5	Carpet edge	[174C] [174D]	[266A] [266D]
T6	Panic exit saddle	[2005AV] [2005DV]	[S483AV] [S483DV]

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2.14 WEATHERSTRIP

A. Finish: [Clear] [Dark bronze] anodized aluminum, unless indicated otherwise.

B. Seal Types and Manufacturers:

No.	Type Description	Pemko	Reese
W1	Rubber or vinyl bulb at jambs and head, and at meeting stiles of pairs	S88D	797B
	Door shoe	[222AV] [222DV]	[DB596AF] [DB596DF]
	Rain drip	[346C] [346D]	[R201C] [R201D]
W2	Rubber or vinyl bulb at jambs and head, and at meeting stiles of pairs	S88D	797B
	Door shoe	[222AV] [222DV]	[DB596AF] [DB596DF]
W3	Rubber vinyl bulb at jambs and head, and at meeting stiles of pairs	S88D	797B
	Door bottom with drip	[345AV] [345DV]	[353A] [353D]
	Interlocking watershed	[68 AR & 347A] [68DR & 347D]	[202C & 203C] [202D & 203D]
W4	Flexible plastic at jambs, head, and at meeting stiles of pairs	PF114PS	794B
W5	Weatherstripping furnished by door manufacturer		
W6	Rubber or vinyl bulb at jambs and head, and at meeting stiles of pairs	S88D	797B
	Automatic door bottom	[412CRL] [412DRL]	[320C] [320D]

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2.15 MISCELLANEOUS ITEMS

A. Provide as indicated in Door and Hardware Schedule:

M1	Nameplate as specified in Section 10 14 00, Signage, in text noted in Door and Hardware Schedule		
M2	Nameplate and barrier-free pictorial symbol as specified in Section 10 14 00, Signage, in text noted in Door and Hardware Schedule		
M3	Barrier-free pictorial symbol, 6 inch by 6 inch, as specified in Section 10 14 00, Signage, in text noted in Door and Hardware Schedule		
M4	Bypassing Door Hardware:		
		Lawrence	Stanley
	Set	EDF500 Series, with integral fascia	Series 1700, with integral fascia
	Brass pulls	405	303-STL3
M5	Pocket Door Hardware:		
		Lawrence	Stanley
	Set	PF619	Series 40-3940
	Brass pulls	411	100-B
M6	Bifold Door Hardware:		
		Lawrence	Stanley
	Set	ED600	Series 2700
	Brass pulls	Quality 813	4484
M7	Coordinator:		
		GJ	Ives
	Model	COR-65	469

2.16 SILENCERS

A. Ives, Glynn-Johnson.

B. At metal frame of each hinged door that does not have seals scheduled.

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2.17 THREE AT SINGLE LEAVES AND TWO AT PAIRS.

2.18 NAMEPLATES

A. Material: Plastic plate; 1/8 inch thick with beveled edges.

B. Types and Manufacturers: Builders Brass Works, Trimco, and as follows:

1. N1: 2-inch-high black plate with 1-inch-high white Helvetica medium letters in text noted in Door and Hardware Schedule
2. N2: Same as N1 with addition of barrier-free pictorial symbol

2.19 TEMPLATES

A. Fabricate to template hardware applied to metal doors and frames.

B. Ensure that required templates are furnished to various manufacturers for fabrication purposes.

C. Templates: Make available not more than 10 days after receipt of approved Hardware Schedule.

2.20 EXIT AND FIRE DOORS

A. Exit Doors: Always openable from inside by simple turn of [knob] [lever handle] or push on panic bar without use of key or any special knowledge or effort, to include each leaf of door pairs.

B. Hardware for Fire Doors: Underwriters Laboratories Inc., Fire Protection Equipment List.

2.21 KEY CONTROL SYSTEM

A. System: Key Control Systems Co., Telkee, Inc., expandable system with [150 (E8351)] [25 (E8331)]-key capacity expandable to [425] [125].

B. Cabinet:

1. Manufacturer’s standard surface mounted cabinet, single-door with continuous hinge, and pin tumbler lock, color as selected from standard colors to match Engineer’s color schedule. [Use Telkee AWC 150-S] [Use Telkee RWC-P 25-S].
2. Complete system with standard components such as envelopes, transient key tags, reserve key tags, receipts and holders, and card index.

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PART 3 - EXECUTION

3.01 INSTALLATION

A. In accordance with manufacturer's written instructions.

B. Make Work neat and secure, develop full strength of components, and provide proper function.

C. Prevent marring, scratching, or otherwise damaging adjacent finishes during hardware installation.

D. Latchbolts:

1. Install to engage in strikes automatically, whether activated by closers or manually.
2. In no case shall additional manual pressure be required to engage latchbolt in strike.

E. Stops and Holders: Set to allow doors to open as far as possible.

F. Wall Mounted Hardware: Install over solid structural backing or solid blocking in hollow walls.

G. Thresholds:

1. Cope ends neatly to profile of jamb.
2. Set in sealant and seal ends to jambs.

H. Key Control System Cabinet: Install where shown.

I. Hardware: Adjust for easy, noise-free operation.

J. Replace damaged hardware items.

3.02 MOUNTING DIMENSIONS

A. Standard Door Hardware Locations: As recommended and published by Door and Hardware Institute, except as noted or detailed otherwise.

B. Door Silencers: Install 3 inches from top and bottom of jamb and 1 inch above strike at single doors, and 3 inches from edges of doors in head for pairs of doors.

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C. Nameplates: Attach to doors [or walls adjacent to doors] 5 feet 6 inches above floor using [Phillips head screws] [self-sticking [permanent] [removable] adhesive].

3.03 MANUFACTURER'S SERVICES

A. Deliver permanent lock cores to Site.

B. Remove temporary construction cores and insert permanent cores.

C. Inspect each lock set to ensure permanent cores are operating satisfactorily.

D. Deliver to Owner change and control keys for permanent system.

E. Return temporary construction cores to manufacturer.

F. Furnish manufacturer's representative for the following services at Site or classroom as designated by [Owner,] [_____,] for minimum person-days listed below, travel time excluded:

1. [_____] person-days for installation assistance, inspection, and Manufacturer's Certificate of Proper Installation.
2. [_____] person-days for [functional] [and] [performance] testing.

3.04 PROTECTION

A. Cover and protect exposed surfaces of hardware during installation and until Substantial Completion.

B. Fit, dismantle, and reinstall finish hardware as required for finish painting work.

C. Protect and prevent staining of hardware during construction in accordance with manufacturer's recommendations.

D. Remove protective measures and permanent lock cylinders installed prior to final cleaning.

3.05 DOOR AND HARDWARE SCHEDULE

A. Door and Hardware Schedule [on Drawings] [in Section 08 06 01, Door and Hardware Schedule,] is guide to functional requirements of each opening.

B. Provide finish hardware as scheduled. Sizes omitted shall be as recommended by manufacturer.

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C. HARDWARE SETS

HDW-1:	**Item**	**Type**
	3 Pair butts	H1
	2 Exit devices (rim type) with cylinders for keying to other locks as required	X1
	1 Removable mullion	X1
	2 Closers	C2
	2 Floor stops and holders	S4
	2 Metal kickplates	K1
	1 Threshold	T1
	1 Set weatherstrip	W1
HDW-2:	Item	Type
	1-1/2 Pair butts	H1
	1 Lock	L2
	1 Closer	C2
	1 Floor stop	S1
	1 Metal kickplate	K1
	1 Threshold	T1
	1 Set weatherstrip (narrow stop)	W2
HDW-3:	Item	Type
	1-1/2 Pair butts	H1
	1 Lock	L1
	1 Closer	C2
	1 Floor stop and holder	S4
	1 Threshold	T1
	1 Set weatherstrip	W2
HDW-4:	Item	Type
	1-1/2 Pair butts	H1

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HDW-1:	**Item**	**Type**
	1 Latch	L4
	1 Closer	C1
	1 Wall bumper	S2
	1 Plastic kickplate	K1
	1 Nameplate	M2
HDW-5:	Item	Type
	1-1/2 Pair butts	H1
	1 Privacy lock	L9
	1 Closer	C1
	1 Wall bumper	S2
	1 Nameplate	N1
HDW-6:	Item	Type
	1-1/2 Pair butts	H2
	1 Latch	L4
	1 Floor stop	S1
HDW-7:	Item	Type
	1-1/2 Pair butts	H2
	1 Lock	L2
	1 Floor stop	S1
HDW-8:	Item	Type
	3 Pair butts	H1
	1 Lock	L2
	2 Floor stop and holders	S4
	2 Flush bolts	B1
HDW-9:	Item	Type
	4 Pair butts, stainless steel	H4
	1 Lock	L2
	2 Wall stop and holders	S3

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HDW-1:	**Item**	**Type**
	1 - 8" Chain and foot-bolts	B3
	1 Threshold	T1
	1 Set weatherstrip	W1
HDW-10:	All hardware by door manufacturer except cylinder	

END OF SECTION

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SECTION 08 90 00
LOUVERS [AND VENTS]

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. Air Movement and Control Association (AMCA): 500-L, Laboratory Methods of Testing Louvers for Rating.
2. The Aluminum Association, Incorporated (AA): Designation System for Aluminum Finishes.
3. ASTM International (ASTM):
   a. A480/A480M, Standard Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip.
   b. D1187, Standard Specification for Asphalt-Base Emulsions for Use as Protective Coatings for Metal.
   c. E84, Standard Test Method for Surface Burning Characteristics of Building Materials.
4. Underwriters Laboratories, Inc. (UL): Building Materials Directory.

1.02 DESIGN REQUIREMENTS

A. Installed Louvers:

1. Capable of resisting [wind load of] [20] [30] [_____] [pounds per square foot].
2. [_____]

1.03 SUBMITTALS

A. Action Submittals:

1. Shop Drawings: Large scale details of louvers, anchorage, and relationship to adjoining construction.
   a. Manufacturer’s Literature:
      1) Descriptive and performance data of louvers, including standard drawings and louver-free area.
   b. [Seismic anchorage and bracing drawings and data sheets, as required by Section 01 88 15, Seismic Anchorage and Bracing.]
2. Samples: Manufacturer’s standard finishes and colors.

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B. Informational Submittals:

1. Seismic anchorage and bracing calculations as required by Section 01 88 15, Seismic Anchorage and Bracing.
2. Factory test data.
3. Certificates of AMCA ratings.
4. Installation instructions.
5. Parts list, if applicable.
6. Maintenance procedures.
7. Special Guarantee.

1.04 SPECIAL GUARANTEE

A. Manufacturer's extended guarantee or warranty, with Owner named as beneficiary, in writing, as Special Guarantee. Special Guarantee shall provide for correction, or at option of Owner, removal and replacement of special fluorocarbon or baked-on finish found defective during a period of 20 years after date of Substantial Completion. Duties and obligations for correction or removal and replacement of defective Work as specified in General Conditions.

PART 2 - PRODUCTS

2.01 GENERAL

A. Nonacoustical louver sizes are based on [50] [_____] percent free area and [800] [_____] fpm maximum velocity through free area. If louvers furnished do not meet these parameters, Contractor is responsible for resizing louvers and wall openings, and for making other adjustments to allow for larger openings.

B. Water Penetration Rate: No greater than 0.02 ounce per square foot.

C. Louvers: Rated and tested in accordance with AMCA 500-L.

D. Furnish louvers with interior duct collars.

2.02 FIXED STORMPROOF LOUVERS (TYPE SP)

A. Frame: Extruded aluminum channel, 0.081 inch thick, 4 inches deep, with concealed mullions.

B. Blades: Extruded aluminum, 0.081 inch thick, Z-shaped, 35-degree to 45-degree pitch angle, spaced 3 inches to 4.25 inches on center.

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C. Pressure Loss: AMCA certified rating of no greater than 0.10-inch WC.

D. Sizes: As shown on Drawings.

E. Screen: Inside mounted, painted aluminum, 1/2-inch mesh.

F. Finish: Kynar 500 fluorocarbon coating [in color as scheduled [AA-M1022A41, clear anodized] [AA-M1022A44, [light] [medium] [dark] bronze anodized].]

G. Manufacturers and Products:

1. Construction Specialties; Model 4110.
2. Dowco; Series LEB-4.
3. Ruskin; Model ELF-375DXH.

2.03 ACCESSORIES

A. Anchors and Fasteners: Stainless steel.

B. Flashings: Match louver frame.

C. Isolation Tape: Tremco 440, 3M EC1202, or Presstite 579.6.

D. Isolation Paint: ASTM D1187, bituminous coating.

2.04 SOURCE QUALITY CONTROL

A. Factory Performance Tests:

1. Airflow versus pressure loss.
2. Rain penetration data.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Check openings to ensure dimensions conform to Drawings.

B. Ensure openings are free of irregularities that would interfere with installation.

C. Do not install louvers until defects have been corrected.

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3.02 INSTALLATION

A. Install louvers as shown on reviewed Shop Drawings. Coordinate with heating or ventilation ductwork to be connected.

B. Follow procedures in manufacturer's recommended installation instructions.

C. Install insulated blank-off panels where indicated, completely closing space between ducts and louver frames.

D. Separate aluminum from other metals with isolation tape or paint.

3.03 CLEANING

A. After erection, protect exposed portions from damage by machines, paint, lime, acid, cement, or other harmful compounds.

B. Remove protective materials and clean with plain water, water with soap, or household detergents.

3.04 SUPPLEMENTS

A. The supplement listed below, following "End of Section," is a part of this Specification.

1. Louver [and Vent] Schedule: A tabulation of louver [and vent] characteristics for each opening numbered on Drawings. Provide items as scheduled.

END OF SECTION

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LOUVER [AND VENT] SCHEDULE

LOUVER TYPES:

AC	Acoustical
AJ	Adjustable
BV	Block Vent
DB	Drainable
FX	Fixed
LD	Combination Louver/Damper
MO	Manually Operable
SP	Stormproof
TR	Transom

ABBREVIATIONS:

AL	Aluminum
AS	As Selected
FCTY	Factory
FRP	Fiber Reinforced Plastic
GALV	Galvanized Steel

NOTES:

No. 1	For details see [Drawing No. .] [Design Details.]
No. 2	Numbers in "Fnsh" column refer to paint systems in Specification Section 09 90 00.
No. 3	Codes in "Col" column refer to color list [in Specification Section 09 06 00.] [on Drawings.]

Opening			Louver				Details			
No.	**Width**	**Height**	**Type**	**Matl**	**Fnsh**	**Col**	**Head**	**Jamb**	**Sill**	**Other Requirements**

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LOUVER [AND VENT] SCHEDULE (*EXAMPLE*)

LOUVER TYPES:

AC	Acoustical
AJ	Adjustable
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NOTES:

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No. 2	Numbers in "Fnsh" column refer to paint systems in Specification Section 09 90 00.
No. 3	Codes in "Col" column refer to color list [in Specification Section 09 06 00.] [on Drawings.]

Opening			Louver				Details			Other Requirements
No.	**Width**	**Height**	**Type**	**Matl**	**Fnsh**	**Col**	**Head**	**Jamb**	**Sill**	
L-1	4'-0"	4'-8"	DB	AL	FCTY	O-3	6	6 SIM	7	
L-2	6'-0"	3'-4"	DB	AL	FCTY	O-3	6	6 SIM	7	
L-3	1'-4"	8"	BV	AL	FCTY	O-3	10	10	10	

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SECTION 09 29 00
GYPSUM BOARD

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM):
   a. A641/A641M, Standard Specification for Zinc-Coated (Galvanized) Carbon Steel Wire.
   b. C208, Standard Specification for Cellulosic Fiber Insulating Board.
   c. C475/C475M, Standard Specification for Joint Compound and Joint Tape for Finishing Gypsum Board.
   d. C514, Standard Specification for Nails for the Application of Gypsum Board.
   e. C645, Standard Specification for Nonstructural Steel Framing Members.
   f. C665, Standard Specification for Mineral-Fiber Blanket Thermal Insulation for Light Frame Construction and Manufactured Housing.
   g. C754, Standard Specification for Installation of Steel Framing Members to Receive Screw-Attached Gypsum Panel Products.
   h. C840, Standard Specification for Application and Finishing of Gypsum Board.
   i. C1002, Standard Specification for Steel Self-Piercing Tapping Screws for the Application of Gypsum Panel Products or Metal Plaster Bases to Wood Studs or Steel Studs.
   j. C1047, Standard Specification for Accessories for Gypsum Wallboard and Gypsum Veneer Base.
   k. C1177/C1177M, Standard Specification for Glass Mat Gypsum Substrate for Use as Sheathing.
   l. C1178/C1178M, Standard Specification for Glass Mat Water-Resistant Gypsum Backing Panel.
   m. C1396/C1396M, Standard Specification for Gypsum Board.
   n. D4977, Standard Test Method for Granule Adhesion to Mineral Surfaced Roofing by Abrasion.
   o. D5420, Standard Test Method for Impact Resistance of Flat, Rigid Plastic Specimen by Means of a Striker Impacted by a Falling Weight (Gardner Impact).
   p. E84, Standard Test Method for Surface Burning Characteristics of Building Materials.

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q. E90, Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements.
r. E119, Standard Test Methods for Fire Tests of Building Construction and Materials.
s. E413, Classification for Rating Sound Insulation.
t. E695, Standard Test Method of Measuring Relative Resistance of Wall, Floor, and Roof Construction to Impact Loading.

2. Gypsum Association (GA):
   a. 214, Recommended Levels of Gypsum Board Finish.
   b. 216, Application and Finishing of Gypsum Panel Products.
3. Underwriters Laboratories Inc. (UL): UL Fire Resistance Directory.

1.02 SUBMITTALS

A. Submittals:

1. Control joint pattern proposed for gypsum board.
2. Control joint pattern proposed for gypsum soffit.
3. Manufacturer's list of items and materials proposed for use, with descriptive literature for each system used.

1.03 QUALITY ASSURANCE

A. General: Regardless of the minimum specifications herein, utilize materials and applications recommended by manufacturer.

B. Applicator's Qualifications: Use only workers regularly employed in this type of work who can show experience in application of similar materials and specific systems specified.

C. Single Source Responsibility: Use gypsum board and related joint treatment materials from a single manufacturer for each type used.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Delivery: Deliver fire-rated materials bearing testing agency label and required fire classification numbers.

B. Storage:

1. Store materials inside, under cover, stacked flat, off floor.
2. Stack gypsum board so that long lengths are not over short lengths.
3. Avoid overloading floor system of storage area.

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4. Store adhesives and finishing compounds in dry areas; protect against freezing at all times.

1.05 ENVIRONMENTAL CONDITIONS

A. Temperature: In areas receiving gypsum board installation, maintain minimum temperature of 40 degrees F for 48 hours before, during, and after gypsum board application. Maintain minimum temperature of 50 degrees F for 48 hours before, during, and after application of adhesive methods of attachment and finishing compounds until drying is complete.

B. Ventilation:

1. Provide ventilation during and following adhesives and joint treatment applications.
2. Use temporary air circulators in enclosed areas lacking natural ventilation.
3. Under slow drying conditions, allow additional drying time between coats of joint treatment.
4. Protect installed materials from drafts of ambient air during hot, dry weather.
5. Protect materials from drying too rapidly during hot and dry weather.

PART 2 - PRODUCTS

2.01 GYPSUM BOARD

A. Regular Board (GWB): ASTM C1396/C1396M, 5/8-inch thick with tapered edges tapered and featured rounded or beveled for prefilling.

B. Water-Resistant Board (WRB): ASTM C1396/C1396M, 5/8-inch thick with tapered edges.

C. Gypsum Soffit Board (GSB): 5/8-inch thick, Edges tapered.

2.02 FASTENERS

A. Gypsum Board:

1. Annular Ring Nail: ASTM C514, GWB-54, 1-1/4 inches long for 1/2-inch gypsum board, and 1-3/8 inches long for 5/8-inch gypsum board.
2. Smooth Shank Nail: ASTM C514, 1-3/8 inches long for 1/2-inch gypsum board, and 1-1/2 inches long for 5/8-inch gypsum board.
3. Screws: ASTM C1002, self-drilling, self-tapping, bugle head, for use with power-driven tool.

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a. Type S, 1 inch long for gypsum board to sheet metal.
b. Type W, 1-1/4 inches long for gypsum board to wood.

2.03 JOINT TREATMENT MATERIALS

A. Tape:

1. General Interior Applications: ASTM C475/C475M, perforated paper tape.
2. Soffit Board, Glass Mesh Mortar Units, and Cementitious Backer Board: 2-inch wide 10 by 10 open weave glass mesh tape as recommended by manufacturer.

B. Compound:

1. General Interior Applications: ASTM C475/C475M, all-purpose, ready-mixed compound.
2. Water-Resistant GWB and Soffit Boards: Chemically curing, polyindurate type material as recommended by manufacturer.

2.04 ANCILLARY MATERIALS

A. Adhesives: As recommended by gypsum board manufacturer for intended use. Use adhesives that have VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

2.05 TRIM ACCESSORIES

A. ASTM C1047, Zinc-Coated Metal.

B. Manufacturers and Products:

C. Corner Bead:

1. 1-1/4 inches by 1-1/4 inches:
   a. United States Gypsum; Dur-A-Bead.
   b. Gold Bond; standard corner beads.
2. Edge Trim:
   a. United States Gypsum; 200B metal trim.
   b. Gold Bond; No. 200 casing bead.
3. Metal Control Joint:
   a. United States Gypsum; No. 093.
   b. Gold Bond; E-Z strip control joint.

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2.06 NONSTRUCTURAL METAL FRAMING MEMBERS

A. ASTM C645, galvanized C-studs with 1-5/8-inch flanges.

B. Sizes and Gauge: As noted on Drawings

C. Manufacturers:

1. United States Gypsum.
2. Dale/Incor.
3. Gold Bond.
4. Unimast, Inc.

2.07 LIGHT-GAUGE METAL FRAMING ACCESSORIES

A. Cold-Rolled Carrying Channel: Cold-rolled steel, 18-gauge metal with minimum 1/2-inch wide flange, free of rust galvanized [1-1/2] [2] [2-1/2] inches deep.

B. Cold-Rolled Bridging Channel: Cold-rolled steel, 18-gauge metal with minimum 1/2 inch wide flange galvanized [1-1/2] [_____] inches deep.

C. Cold-Rolled Furring Channel: Cold-rolled steel, 25-gauge metal with minimum 1/2-inch wide flange, free of rust galvanized 3/4 inches deep.

D. Z-Furring: Galvanized 18-gauge, [1-1/2] [2] [2-1/2] [3] inch(es) deep.

E. Hat-Shaped Furring Channels: Roll-formed hat shaped section of [25] [22] [20] [18] [16]-gauge galvanized steel with a face width of 1-1/4 inches and a depth of [7/8] [1-1/2] inch(es).

F. Resilient Furring Channels: Roll-formed section of 25-gauge galvanized steel with face width of 1-1/2 inches designed for resilient attachment of gypsum board to framing.

G. Hanger Wire: ASTM A641/A641M, Class 1 zinc coating, soft temper, 0.162-inch diameter.

H. Tie Wire: ASTM A641/A641M, Class 1 zinc coating, soft temper, 0.625-inch diameter or double strand of 0.0475-inch diameter wire.

2.08 DRY WALL CEILING SUSPENSION SYSTEM

A. Use system of main runners, cross tees, and furring channels.

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B. Manufacturers:

1. Armstrong World Industries, Inc.; Furring Systems/Drywall.
2. Chicago Metallic Corporation.
3. USG Interiors, Inc.; Drywall Suspension System.

2.09 SPRAY TEXTURE

A. Manufacturers and Products:

1. Aggregate Finish:
   a. National Gypsum Company; ProForm Spray Quick.
   b. United States Gypsum Company; Ceiling Spray Texture.

B. Manufacturers and Products:

1. Nonaggregate Finish:
   a. National Gypsum Company; ProForm Perfect Spray EM/HF.
   b. United States Gypsum Co.; SHEETROCK Wall and Ceiling Spray Texture (unaggregated).

PART 3 - EXECUTION

3.01 EXAMINATION

A. Inspect surfaces to receive gypsum board and related materials before beginning work and report to Engineer any defects in such work which will adversely affect the quality of work specified herein.

3.02 PREPARATION

A. General: Provide, install, and maintain necessary scaffold, staging, trestles, planking, and temporary heating, lighting, and ventilation as necessary for duration of gypsum board work.

B. Protection: Protect work of other trades.

C. Coordination:

1. Coordinate work with that of other trades. Check specifications and drawings of other trades to determine parts of work requiring coordination.
2. Cut and repair gypsum board systems for installation of omitted work.

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D. Surface Preparation: Repair defective surfaces prior to starting work. Prepare as specified for application of specific materials.

3.03 ERECTION OF SUSPENDED CEILING

A. General:

1. Securely brace all ceiling areas against sway as required by code for seismic control.
2. Prevent runner and furring channels from contacting masonry walls.
3. Provide 1-1/2-inch channels around recessed lighting fixture openings to support fixtures.

B. Hangers:

1. Space not over 4 feet on center (OC) in direction of runners and within 6 inches of ends of runners.
2. Securely attach to structure above and provide for full saddle tie to main runner at indicated height.
3. Install additional hangers at ends of each suspension member and at light fixtures, 6 inches from vertical surfaces.
4. Do not splay wires more than 5 inches in a 4-foot vertical drop.
5. Provide four-way wire splays at 45 degrees from main runner to support structure for every 144 square feet of ceiling area to prevent sway.
6. Wrap wire minimum three times horizontally, turning ends upward.
7. Where hanger wires cannot be hung vertically from structure above because of ducts, pipes, cable trays, or other interferences, provide trapezes of steel channels (minimum 2-inch deep, 16-gauge cold-rolled carrying channels) hung on steel rods or 8-gauge wire from structural members above. Hang ceiling wires from trapezes or similar members supporting ducts or pipes. Do not hang directly from ducts or pipes.

C. Main Runner Channels:

1. Run main runner channels spaced not more than 4 feet OC, and 6 inches from parallel walls, at right angles to the length of joists.
2. Overlap splices in main runners 12 inches minimum, interlock flanges, and securely tie near each end of splice with double loops of tie wire.

D. Furring Channels:

1. Attach furring channels to main runners at right angles, space at 16 inches OC.

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2. Securely saddle tie furring to the main runners at each crossing or equivalent clips or attachments.
3. Splices in Cross-Furring: Lap 8 inches minimum, interlock flanges, and securely tie near each end of splice with two loops of tie wire.

3.04 ERECTION OF DRY WALL CEILING SUSPENSION SYSTEM

A. Follow manufacturer's printed instructions.

B. Hangers:

1. Space not over 4 feet OC in direction of runners and within 6 inches of ends of runners.
2. Securely attach to structure above and provide for full saddle tie to main runner at indicated height.
3. Connections shall develop full strength of hanger wire.

C. Bracing:

1. Securely brace ceiling areas against sway.
2. Where required by code, install for seismic control.
3. Prevent runner and furring channels from contacting masonry walls.

D. Where ducts interfere with normal spacing of hangers and carrying channels, install additional hangers and channels to properly suspend ceiling.

3.05 ERECTION OF LIGHT-GAUGE NONSTRUCTURAL METAL FRAMING

A. Layout: Align partitions as shown on Drawings.

B. Tracks:

1. Attach metal runner tracks to floor slabs with suitable fasteners located 2 inches from each end and spaced not more than 24 inches OC.
2. Where partitions terminate at suspended or framed ceilings attach top tracks to suspended ceiling with toggle or molly bolts spaced 24 inches OC.
3. Where partitions terminate at underside of concrete or metal decking attach deflection channels to substrate with suitable fasteners located 2 inches from each end and spaced not more than 24 inches OC. Locate partition top tracks within deflection channels with a minimum top clearance of 1 inch. Do not attach track to channel.

C. Studs:

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1. ASTM C754.
2. Following manufacturer's printed instructions, position studs vertically, engaging floor and ceiling tracks and spaced as noted on Drawings.
3. Splice: When necessary, use 8-inch nested lap and one positive attachment per stud flange.
4. Place in direct contact with doorframe jambs, abutting partitions, and partition corners. Provide for anchorage of doorframes to studs.
5. Anchor studs for shelf-walls and those adjacent to window and doorframes, partition intersections, and corners to ceiling and floor runner flanges. Securely anchor studs to jamb and head anchor clips of door or borrowed-light frames by bolt or screw attachment.
6. Over metal door and borrowed-light frames, place horizontally a cut-to-length section of runner, with a web-flanged bend at each end, and secure with one positive attachment per flange. Position a cut-to-length stud (extending to ceiling runner) at vertical panel joints over doorframe header.
7. Locate studs at abutting construction, partition intersections, and partition corners.
8. Spacing: At [24] [16] inches OC, unless otherwise required by manufacturer.
9. At Doorframes and Cased Openings:
    a. Full height double studs, No. 20 gauge minimum, secured to jamb anchors by bolts, screws, or welds.
    b. Header Track: Secure to frame head anchors and double studs.
    c. Provide double channel stiffeners through studs above frame and extend at least one stud space beyond each jamb.
10. Windows: Similar framing to door openings with stiffeners both above and below.
11. Wall Mounting Accessories: Provide channels, horizontal studding, No. 16 gauge sheet 8 inches by 2 inches greater than stud spacing, or other members within walls as required to provide secure and adequate support.

D. Furring:

1. Space furring channels the same as studs or as shown.
2. Around columns and beams construct furring as shown using metal studs and furring channels securely tied together and anchored in-place.
3. Attach resilient furring channels to wood framing with screws.

3.06 APPLICATION OF GYPSUM BOARD

A. Inspection and Preparation:

1. Check framing for accurate spacing and alignment.

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2. Verify spacing of installed framing does not exceed maximum allowable for thickness of gypsum board to be used.
3. Verify frames are set for thickness of gypsum board to be used.
4. Do not proceed with installation of gypsum board until deficiencies are corrected and surfaces to receive gypsum board are acceptable.
5. Repair protrusions of framing, twisted framing members, or unaligned members before installation of gypsum board is started.

B. General:

1. Meet requirements of ASTM C840 and GA 216.
2. Joints: Use gypsum board of maximum lengths to minimize end joints. Stagger end joints when they occur. Locate end joints as far as possible from center of wall or ceiling. Abut gypsum board without forcing. Neatly fit ends and edges of gypsum board. Do not place butt ends against tapered edges.
3. Support ends and edges of gypsum board panels on framing or furring members except for face layer of double layer and where ends are back blocked and floated.
4. Use metal edge trim where gypsum board abuts another material, at corners, and where shown or noted on Drawings.
5. [Use [water-resistant board] [glass mesh mortar units] [cementitious backer board] in toilet, shower, and janitor room walls behind ceramic tile [and elsewhere as indicated on Drawings].]
6. Follow manufacturer’s recommendation of good practice.

C. Over Framing:

1. Apply gypsum board first to ceiling and then to walls for single layer horizontal application.
2. Use vertical application for fire-rated walls.
3. Fasten gypsum board securely to framing using double nailing, screw, or adhesive method.

D. Sound-Rated Partitions:

1. Fabricate and erect in accordance with manufacturer’s printed instructions for required rating.
2. Install sound-deadening board and attenuation blankets as detailed.
3. Seal with acoustical sealant perimeter edges of gypsum board, joints around penetrations, and other joints as noted.

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E. Fireproofing:

1. Install fireproofing of columns, beams, and shaft walls as shown.
2. Close tops of duct and pipe shafts, and elevator hoistways with horizontal metal framing and gypsum board to provide [1] [2]-hour rated assembly.

3.07 INSTALLATION OF [GLASS MESH MORTAR UNIT (GMMU)] [CEMENTITIOUS BACKER BOARD]

A. Follow manufacturer's printed instructions for erection, cutting, attachments, and joint treatment.

B. Verify framing is installed at maximum 16 inches OC, and necessary blocking to support fixtures and accessories has been installed. Where backing plates or straps are used, space out from framing to ensure a smooth finish application. Do not proceed until defects are corrected and are acceptable.

C. Precut boards to required sizes and make necessary cutouts. Fasten with appropriate fasteners. Space fasteners 6 inches OC maximum or as directed by manufacturer. Fit ends closely but not forced together. Maintain 1/4-inch spacing between edge of board and fixture. Caulk all joints and corners that are to receive tiles. Apply 2-inch glass fiber tape over joints and corners embedded with tile setting mortar.

3.08 JOINT SYSTEM FOR GYPSUM WALLBOARD

A. Interior Gypsum Board: Conform to ASTM C840.

B. Required: On exposed gypsum board, under ceramic tile and wall covering, and behind casework.

C. Prefill: Fill V-grooves formed by abutting rounded edges of gypsum board with prefill joint compound. Fill V-joint flush and remove excess compound beyond groove. Leave clear depression to receive tape. Permit prefill joint compound to harden prior to application of tape.

D. Taping and Finishing Joints:

1. Taping or Embedding Coat: Apply compound in thin, uniform layer to joints and angles to be reinforced. Apply reinforcing tape immediately. Center tape over joint and seat tape into compound. Leave approximately 1/64-inch to 1/32-inch compound under tape to provide bond. Apply skim coat immediately following tape embedment but not to function as fill or

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second coat. Fold tape and embed in angles to provide true angle. Dry embedding coat prior to application of fill coat.

2. Filling Coat: Apply joint compound over embedding coat. Fill taper flush with surface. Apply fill coat to cover tape. Feather out fill coat beyond tape and previous joint compound line. For joints with no taper, feather out at least 4 inches on either side of tape. Do not apply fill coat on interior angles. Allow fill coat to dry prior to application of finish coat.
3. Finishing Coat: Spread joint compound evenly over and beyond fill coat on joints. Feather to smooth uniform finish. Apply finish coat to taped angles to cover tape and taping compound. Sand final application of compound to provide surface ready for decoration.
4. Filling and Finishing Depressions: Apply joint compound as first coat to fastener depressions. Apply at least two additional coats of compound after first coat is dry. Leave filled and finished depressions level with plane of surface.

E. Finishing Beads and Trim:

1. First Fill Coat: Apply joint compound to bead and trim. Feather out from ground to plane of the surface. Dry compound prior to application of second fill coat.
2. Second Fill Coat: Apply joint compound in same manner as first fill coat. Extend beyond first coat onto face of gypsum board. Dry compound prior to application of finish coat.
3. Finish Coat: Apply joint compound to bead and trim. Extend beyond second fill coat. Feather finish coat from ground to plane of surface. Sand finish coat to provide flat surface ready for decoration.

3.09 FINAL FINISHES FOR GYPSUM WALLBOARD

A. Levels of Finish: Conform to GA 214.

B. Level 1:

1. Taping or embedding coat only.
2. Use in concealed areas, and where indicated, unless a higher level is required for fire-resistive or sound-rated assemblies.

C. Level 2:

1. Taping, filling, and finishing coats.
2. Use on water-resistant gypsum backing board.

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D. Level 3:

1. Taping, filling, and finishing coats.
2. Use on surfaces indicated to have spray texture or ceramic tile.

E. Level 4:

1. Taping, filling, and finishing coats plus two separate coats applied over joints, angles, fastener heads, and trim accessories.
2. Sand between coats and after last coat.
3. Use on surfaces indicated to receive wall coverings.

F. Level 5:

1. Same as Level 4, plus a thin, smooth, uniform skim coat of joint compound, or product specially formulated for this purpose, over entire surface.
2. Produce surfaces free of tool marks and ridges, ready for decoration.
3. Use on surfaces not indicated otherwise, those indicated to receive gloss, semi-gloss, and nontextured flat paints, and where indicated.

3.10 SPRAY TEXTURE

A. Application:

1. Apply [where scheduled] [on gypsum board wall [and ceiling] surfaces, except behind ceramic tile and wall covering,] following manufacturer's printed directions for a medium build [spray/spatter] [spatter] [orange peel] texture.
2. Before texture application, finish gypsum board as specified for Level 3.
3. When surfaces are prepared and dry, apply sealer and allow to dry. Mix texture finish material as directed by manufacturer.
4. Use spray equipment of a size and type to assure acceptable results.
5. Apply by spray only at a coverage rate as recommended by manufacturer and in accordance with directions printed on container. Apply material to blend uniformly and cover fully without starved spots or other evidence of thin application. Provide uniform texture without application patterns.
6. [After spray application, knockdown and flatten high spots with trowel to produce a Brocade or Travertine marble texture.]

3.11 ADJUST AND CLEAN

A. Clean: Remove droppings or texture overspray from walls, windows, and floor, leaving room clean for following trades.

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B. Nail Pop: Repair nail pop by driving new nail approximately 1-1/2 inches from nail pop and reseat nail. When face paper is punctured, drive new nail or screw approximately 1-1/2 inches from defective fastening and remove defective fastening. Fill damaged surface with compound.

C. Ridging:

1. Do not repair ridging until condition has fully developed, approximately 6 months after installation or one heating season.
   a. Sand ridges to reinforcing tape without cutting through tape.
   b. Fill concave areas on both sides of ridge with topping compound.
   c. After fill is dry, blend in topping compound over repaired area.
2. Fill cracks with compound and finish smooth and flush.

END OF SECTION

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SECTION 09 90 00
PAINTING AND COATING

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Water Works Association (AWWA):
   a. C203, Coal-Tar Protective Coatings and Linings for Steel Water Pipelines—Enamel and Tape—Hot-Applied.
   b. C209, Cold-Applied Tape Coatings for the Exterior of Special Sections, Connections, and Fittings for Steel Water Pipelines.
   c. C213, Fusion-Bonded Epoxy Coating for the Interior and Exterior of Steel Water Pipelines.
   d. C214, Tape Coating Systems for the Exterior of Steel Water Pipelines.
2. Environmental Protection Agency (EPA).
3. NACE International (NACE): RP0188, Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates.
4. NSF International (NSF): 61, Drinking Water System Components - Health Effects.
5. Occupational Safety and Health Act (OSHA).
6. The Society for Protective Coatings (SSPC):
   a. PA 2, Measurement of Dry Coating Thickness with Magnetic Gages.
   b. PA 3, Guide to Safety in Paint Applications.
   c. SP 1, Solvent Cleaning.
   d. SP 2, Hand Tool Cleaning.
   e. SP 3, Power Tool Cleaning.
   f. SP 5, White Metal Blast Cleaning.
   g. SP 6, Commercial Blast Cleaning.
   h. SP 7, Joint Surface Preparation Standard Brush-Off Blast Cleaning.
   i. SP 10, Near-White Blast Cleaning.
   j. SP 11, Power Tool Cleaning to Bare Metal.
   k. SP 12, Surface Preparation and Cleaning of Metals Waterjetting Prior to Recoating.
   l. SP 13, Surface Preparation of Concrete.
   m. Guide 15, Field Methods for Retrieval and Analysis of Soluble Salts on Steel and Other Nonporous Substrates.

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1.02 DEFINITIONS

A. Terms used in this section:

1. Coverage: Total minimum dry film thickness in mils or square feet per gallon.
2. FRP: Fiberglass Reinforced Plastic.
3. HCl: Hydrochloric Acid.
4. MDFT: Minimum Dry Film Thickness, mils.
5. MDFTPC: Minimum Dry Film Thickness per Coat, mils.
6. Mil: Thousandth of an inch.
7. PDS: Product Data Sheet.
8. PSDS: Paint System Data Sheet.
9. PVC: Polyvinyl Chloride.
10. SFPG: Square Feet per Gallon.
11. SFPGPC: Square Feet per Gallon per Coat.
12. SP: Surface Preparation.

1.03 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. Data Sheets:
      1) For each product, furnish a Product Data Sheet (PDS), the manufacturer's technical data sheets, and paint colors available (where applicable). The PDS form is appended to the end of this section.
      2) For each paint system, furnish a Paint System Data Sheet (PSDS). The PSDS form is appended to the end of this section.
      3) Technical and performance information that demonstrates compliance with Specification.
      4) Furnish copies of paint system submittals to the coating applicator.
      5) Indiscriminate submittal of only manufacturer's literature is not acceptable.
   b. Detailed chemical and gradation analysis for each proposed abrasive material.
2. Samples:
   a. Proposed Abrasive Materials: Minimum 5-pound sample for each type.
   b. Reference Panel:
      1) Surface Preparation:

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a) Prior to start of surface preparation, furnish a 4-inch by 4-inch steel panel for each grade of sandblast specified herein, prepared to specified requirements.
b) Provide panel representative of the steel used; prevent deterioration of surface quality.
c) Panel to be reference source for inspection upon approval by ENGINEER.

2) Paint:
a) Unless otherwise specified, before painting work is started, prepare minimum 8-inch by 10-inch sample with type of paint and application specified on similar substrate to which paint is to be applied.
b) Furnish additional samples as required until colors, finishes, and textures are approved.
c) Approved samples to be the quality standard for final finishes.

B. Informational Submittals:

1. [Applicator's Qualification: List of references substantiating experience.]
2. Coating manufacturer's Certificate of Compliance, in accordance with Section 01 43 33, Manufacturers' Field Services.
3. Factory Applied Coatings: Manufacturer's certification stating factory applied coating system meets or exceeds requirements specified.
4. Manufacturer's written verification that submitted material is suitable for the intended use.
5. If the manufacturer of finish coating differs from that of shop primer, provide finish coating manufacturer's written confirmation that materials are compatible.
6. Manufacturer's written instructions and special details for applying each type of paint.

1.04 QUALITY ASSURANCE

A. Applicator Qualifications: Minimum 5 years' experience in application of specified products.

B. Regulatory Requirements:

1. Meet federal, state, and local requirements limiting the emission of volatile organic compounds.
2. Perform surface preparation and painting in accordance with recommendations of the following:

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a. Paint manufacturer's instructions.
b. SSPC PA 3, Guide to Safety in Paint Applications.
c. Federal, state, and local agencies having jurisdiction.

C. Mockup:

1. Before proceeding with Work under this section, finish one complete space or item of each color scheme required showing selected colors, finish texture, materials, quality of work, and special details.
2. After ENGINEER approval, sample spaces or items shall serve as a standard for similar work throughout the Project.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Shipping:

1. Where precoated items are to be shipped to the Site, protect coating from damage. Batten coated items to prevent abrasion.
2. Protect shop painted surfaces during shipment and handling by suitable provisions including padding, blocking, and use of canvas or nylon slings.

B. Storage:

1. Store products in a protected area that is heated or cooled to maintain temperatures within the range recommended by paint manufacturer.
2. Primed surfaces shall not be exposed to weather for more than 2 months before being topcoated, or less time if recommended by coating manufacturer.

1.06 PROJECT CONDITIONS

A. Environmental Requirements:

1. Do not apply paint in temperatures or moisture conditions outside of manufacturer's recommended maximum or minimum allowable.
2. Do not perform final abrasive blast cleaning whenever relative humidity exceeds 85 percent, or whenever surface temperature is less than 5 degrees F above dew point of ambient air.

B. Status of Existing Coatings:

1. The following information on existing coatings or substrate conditions is provided for information only, and is generally believed to be accurate, but

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is not guaranteed. Perform tests as required to verify applicability of this information to the Work.
a. [_____]

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Nationally recognized manufacturers of paints and protective coatings who are regularly engaged in the production of such materials for essentially identical service conditions.

B. Minimum of 5 years' verifiable experience in manufacture of specified product.

C. Each of the following manufacturers is capable of supplying most of the products specified herein:

1. [_____]

2.02 ABRASIVE MATERIALS

A. Select abrasive type and size to produce surface profile that meets coating manufacturer's recommendations for specific primer and coating system to be applied.

2.03 PAINT MATERIALS

A. General:

1. Manufacturer's highest quality products suitable for intended service.
2. Compatibility: Only compatible materials from a single manufacturer shall be used in the Work. Particular attention shall be directed to compatibility of primers and finish coats.
3. Thinners, Cleaners, Driers, and Other Additives: As recommended by coating manufacturer.

2.04 PRODUCTS:

Product	**Definition**
Acrylic Latex	Single-component, finish as required
Acrylic Latex (Flat)	Flat latex
Acrylic Sealer	Clear acrylic
Alkyd (Semigloss)	Semigloss alkyd

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Product	Definition
Alkyd Enamel	Optimum quality, gloss or semigloss finish as required, medium long oil
Alkyd Wood Primer	Flat alkyd
Bituminous Paint	Single-component, coal-tar pitch based
Block Filler	Primer-sealer designed for rough masonry surfaces, 100% acrylic emulsion
Coal-Tar Epoxy	Amine, polyamide, or phenolic epoxy type 70% volume solids minimum, suitable for immersion service
DTM Acrylic Primer	Surface tolerant, direct-to-metal water borne acrylic primer
DTM Acrylic Finish	Surface tolerant, direct-to-metal water borne acrylic finish coat
Elastomeric Polyurethane	100% solids, plural component, spray applied, high build, elastomeric polyurethane coating, suitable for the intended service
Epoxy Filler/Surfacer	100% solids epoxy trowel grade filler and surfacer, nonshrinking, suitable for application to concrete and masonry. Approved for potable water contact and conforming to NSF 61, where required
Epoxy Nonskid (Aggregated)	Polyamidoamine or amine converted epoxies aggregated; aggregate may be packaged separately
Epoxy Primer—Ferrous Metal	Anticorrosive, converted epoxy primer containing rust-inhibitive pigments
Epoxy Primer—Other	Epoxy primer, high-build, as recommended by coating manufacturer for specific galvanized metal, copper, or nonferrous metal alloy to be coated
Fusion Bonded Coating	100% solids, thermosetting, fusion bonded, dry powder epoxy, suitable for the intended service
Fusion Bonded, TFE Lube or Grease Lube	Tetrafluoroethylene, liquid coating, or open gear grease as supplied by McMaster-Carr Supply Corporation., Elmhurst, IL; RL 736 manufactured by Amrep, Inc., Marietta, GA
High Build Epoxy	Polyamidoamine epoxy, minimum 69% volume solids, capability of 4 to 8 MDFT per coat

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Product	Definition
Inorganic Zinc Primer	Solvent or water based, having 85% metallic zinc content in the dry film; follow manufacturer's recommendation for topcoating
Latex Primer Sealer	Waterborne vinyl acrylic primer/sealer for interior gypsum board and plaster. Capable of providing uniform seal and suitable for use with specified finish coats
NSF Epoxy	Polyamidoamine epoxy, approved for potable water contact and conforming to NSF 61
Epoxy, High Solids	Polyamidoamine epoxy, 80% volume solids, minimum, suitable for immersion service
Polyurethane Enamel	Two-component, aliphatic or acrylic based polyurethane; high gloss finish
Rust-Inhibitive Primer	Single-package steel primers with anticorrosive pigment loading
Sanding Sealer	Co-polymer oil, clear, dull luster
Silicone/Silicone Acrylic	Elevated temperature silicone or silicone/acrylic based
Stain, Concrete	Acrylic, water repellant, penetrating stain
Stain, Wood	Satin luster, linseed oil, solid or transparent as required
Varnish	Nonpigmented vehicle based on a variety of resins (alkyd, phenolic, urethane) in gloss, semigloss, or flat finishes, as required
Water Base Epoxy	Two-component, polyamide epoxy emulsion, finish as required

2.05 MIXING

A. Multiple-Component Coatings:

1. Prepare using each component as packaged by paint manufacturer.
2. No partial batches will be permitted.
3. Do not use multiple-component coatings that have been mixed beyond their pot life.
4. Furnish small quantity kits for touchup painting and for painting other small areas.
5. Mix only components specified and furnished by paint manufacturer.

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6. Do not intermix additional components for reasons of color or otherwise, even within the same generic type of coating.

B. Colors: Formulate paints with colorants free of lead, lead compounds, or other materials that might be affected by presence of hydrogen sulfide or other gas likely to be present at Site.

2.06 SHOP FINISHES

A. Shop Blast Cleaning: Reference Paragraph, Shop Coating Requirements.

B. Surface Preparation: Provide ENGINEER minimum 7 days' advance notice to start of shop surface preparation work and coating application work.

C. Shop Coating Requirements:

1. When required by equipment Specifications, such equipment shall be primed and finish coated in shop by manufacturer and touched up in field with identical material after installation.
2. Where manufacturer's standard coating is not suitable for intended service condition, ENGINEER may approve use of a tie-coat to be used between manufacturer's standard coating and specified field finish. In such cases, tie-coat shall be surface tolerant epoxy as recommended by manufacturer of specified field finish coat. Coordinate details of equipment manufacturer's standard coating with field coating manufacturer.

D. Pipe:

1. Ductile Iron Pipe:
   a. Use SSPC standards as a guide for desired prepared surface. Follow recommendations of pipe and coating manufacturers for means and methods to achieve SSPC-equivalent surface.
   b. The surface preparation and application of the primer [and finish coats] shall be performed by pipe manufacturer.
   c. For high performance (epoxy) coatings, follow additional recommendations of pipe and coating manufacturers.
   d. Prior to blast cleaning, grind smooth surface imperfections, including, but not limited to delaminating metal or oxide layers.
   e. [For conventional (alkyd) coatings, clean asphalt varnish supplied on pipe and apply one full coat of a tar stop before two full coats of the color coats specified.]

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PART 3 -EXECUTION

3.01 GENERAL

A. Provide ENGINEER minimum 7 days' advance notice to start of field surface preparation work and coating application work.

B. Perform the Work only in presence of ENGINEER, unless ENGINEER grants prior approval to perform the Work in ENGINEER's absence.

C. Schedule inspection of cleaned surfaces and all coats prior to succeeding coat in advance with ENGINEER.

D. External coatings on aboveground equipment outside PG&E property will consist of muted, earth tone colors that are consistent with the surrounding natural color palette, and matte finishes, unless overridden by OSHA requirements. Colors for aboveground equipment inside PG&E property will be selected based on PG&E standards.

3.02 EXAMINATION

A. Factory Finished Items:

1. Schedule inspection with ENGINEER before repairing damaged factory-finished items delivered to Site.
2. Repair abraded or otherwise damaged areas on factory-finished items as recommended by coating manufacturer. Carefully blend repaired areas into original finish. If required to match colors, provide full finish coat in field.

B. Surface Preparation Verification: Inspect and provide substrate surfaces prepared in accordance with these Specifications and printed directions and recommendations of paint manufacturer whose product is to be applied. The more stringent requirements shall apply.

3.03 PROTECTION OF ITEMS NOT TO BE PAINTED

A. Remove, mask, or otherwise protect hardware, lighting fixtures, switchplates, aluminum surfaces, machined surfaces, couplings, shafts, bearings, nameplates on machinery, and other surfaces not specified elsewhere to be painted.

B. Provide drop cloths to prevent paint materials from falling on or marring adjacent surfaces.

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C. Protect working parts of mechanical and electrical equipment from damage during surface preparation and painting process.

D. Mask openings in motors to prevent paint and other materials from entering.

E. Protect surfaces adjacent to or downwind of Work area from overspray.

3.04 SURFACE PREPARATION

A. Field Abrasive Blasting:

1. Perform blasting for items and equipment where specified and as required to restore damaged surfaces previously shop or field blasted and primed or coated.
2. Refer to coating systems for degree of abrasive blasting required.
3. Where the specified degree of surface preparation differs from manufacturer's recommendations, the more stringent shall apply.

B. Surface Contamination Testing:

1. A surface contamination analysis test shall be performed every [500] [_____] square feet by means of a [Chlor Test CSN Salts] [_____] [or approved equivalent].
2. Surface with chloride levels exceeding 3 µg/square centimeter for submerged surfaces and 5 µg/square centimeter for exposed surfaces shall be treated with a liquid soluble salt remover equivalent to CHLOR*RID (CHLOR*RID International, Chandler, AZ).
3. Follow manufacturer's recommendations and procedures for the use of this product to remove the surface contamination.

C. Metal Surface Preparation:

1. Where indicated, meet requirements of SSPC Specifications summarized below:
   a. SP 1, Solvent Cleaning: Removal of visible oil, grease, soil, drawing and cutting compounds, and other soluble contaminants by cleaning with solvent.
   b. SP 2, Hand Tool Cleaning: Removal of loose rust, loose mill scale, loose paint, and other loose detrimental foreign matter, using nonpower hand tools.
   c. SP 3, Power Tool Cleaning: Removal of loose rust, loose mill scale, loose paint, and other loose detrimental foreign matter, using power-assisted hand tools.

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d. SP 5, White Metal Blast Cleaning: Removal of visible oil, grease, dust, dirt, mill scale, rust, coatings, oxides, corrosion products, and other foreign matter by blast cleaning.
e. SP 6, Commercial Blast Cleaning: Removal of visible oil, grease, dust, dirt, mill scale, rust, coatings, oxides, corrosion products, and other foreign matter, except for random staining limited to no more than 33 percent of each unit area of surface which may consist of light shadows, slight streaks, or minor discolorations caused by stains of rust, stains of mill scale, or stains of previously applied coatings.
f. SP 7, Brush-Off Blast Cleaning: Removal of visible rust, oil, grease, soil, dust, loose mill scale, loose rust, and loose coatings. Tightly adherent mill scale, rust, and coating may remain on surface.
g. SP 10, Near-White Blast Cleaning: Removal of visible oil, grease, dust, dirt, mill scale, rust, coatings, oxides, corrosion products, and other foreign matter, except for random staining limited to no more than 5 percent of each unit area of surface which may consist of light shadows, slight streaks, or minor discolorations caused by stains of rust, stains of mill scale, or stains of previously applied coatings.
h. SP 11, Power Tool Cleaning to Bare Metal: Removal of visible oil, grease, dirt, dust, mill scale, rust, paint, oxide, corrosion products, and other foreign matter using power-assisted hand tools capable of producing suitable surface profile. Slight residues of rust and paint may be left in lower portion of pits if original surface is pitted.
i. SP 12, Surface Preparation and Cleaning of Metals by Waterjetting Prior to Recoating: Surface preparation using high-pressure and ultrahigh-pressure water jetting to achieve specified surface cleanliness condition. Surface cleanliness conditions are defined in SSPC SP 12 and are designated WJ-1 through WJ-4 for visual surface preparation definitions and SC-1 through SC-3 for nonvisual surface preparation definitions.

2. The words “solvent cleaning”, “hand tool cleaning”, “wire brushing”, and “blast cleaning”, or similar words of equal intent in these Specifications or in paint manufacturer’s specification refer to the applicable SSPC Specification.
3. Where OSHA or EPA regulations preclude standard abrasive blast cleaning, wet or vacu-blast methods may be required. Coating manufacturers’ recommendations for wet blast additives and first coat application shall apply.
4. Ductile Iron Pipe Supplied with Asphaltic Varnish Finish: Remove asphaltic varnish finish prior to performing specified surface preparation.
5. Hand tool clean areas that cannot be cleaned by power tool cleaning.
6. Round or chamfer sharp edges and grind smooth burrs, jagged edges, and surface defects.

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7. Welds and Adjacent Areas:
8. Prepare such that there is:
    a. No undercutting or reverse ridges on weld bead.
    b. No weld spatter on or adjacent to weld or any area to be painted.
    c. No sharp peaks or ridges along weld bead.
    d. Grind embedded pieces of electrode or wire flush with adjacent surface of weld bead.
9. Preblast Cleaning Requirements:
    a. Remove oil, grease, welding fluxes, and other surface contaminants prior to blast cleaning.
    b. Cleaning Methods: Steam, open flame, hot water, or cold water with appropriate detergent additives followed with clean water rinsing.
    c. Clean small isolated areas as above or solvent clean with suitable solvent and clean cloth.
10. Blast Cleaning Requirements:
    a. Type of Equipment and Speed of Travel: Design to obtain specified degree of cleanliness. Minimum surface preparation is as specified herein and takes precedence over coating manufacturer's recommendations.
    b. Select type and size of abrasive to produce surface profile that meets coating manufacturer's recommendations for particular primer to be used.
    c. Use only dry blast cleaning methods.
    d. Do not reuse abrasive, except for designed recyclable systems.
    e. Meet applicable federal, state, and local air pollution and environmental control regulations for blast cleaning, confined space entry (if required), and disposition of spent aggregate and debris.
11. Post-Blast Cleaning and Other Cleaning Requirements:
    a. Clean surfaces of dust and residual particles from cleaning operations by dry (no oil or water vapor) air blast cleaning or other method prior to painting. Vacuum clean enclosed areas and other areas where dust settling is a problem and wipe with a tack cloth.
    b. Paint surfaces the same day they are blasted. Reblast surfaces that have started to rust before they are painted.

D. Galvanized Metal, Copper, and Nonferrous Metal Alloy Surface Preparation:

1. Remove soil, cement spatter, and other surface dirt with appropriate hand or power tools.
2. Remove oil and grease by wiping or scrubbing surface with suitable solvent, rag, and brush. Use clean solvent and clean rag for final wiping to avoid contaminating surface.

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3. Obtain and follow coating manufacturer's recommendations for additional preparation that may be required.

E. Concrete Surface Preparation:

1. Do not begin until 30 days after concrete has been placed.
2. Meet requirements of SSPC SP 13.
3. Remove grease, oil, dirt, salts or other chemicals, loose materials, or other foreign matter by solvent, detergent, or other suitable cleaning methods.
4. Brush-off blast clean to remove loose concrete and laitance, and provide a tooth for binding. Upon approval by ENGINEER, surface may be cleaned by acid etching method. Approval is subject to producing desired profile equivalent to No. 80 grit flint sandpaper. Acid etching of vertical or overhead surfaces shall not be allowed.
5. Secure coating manufacturer's recommendations for additional preparation, if required, for excessive bug holes exposed after blasting.
6. Unless otherwise required for proper adhesion, ensure surfaces are dry prior to painting.

F. Plastic and FRP Surface Preparation:

1. Hand sand plastic surfaces to be coated with medium grit sandpaper to provide tooth for coating system.
2. Large areas may be power sanded or brush-off blasted, provided sufficient controls are employed so surface is roughened without removing excess material.

G. Masonry Surface Preparation:

1. Complete and cure masonry construction for 14 days or more before starting surface preparation work.
2. Remove oil, grease, dirt, salts or other chemicals, loose materials, or other foreign matter by solvent, detergent washing, or other suitable cleaning methods.
3. Clean masonry surfaces of mortar and grout spillage and other surface deposits using one of the following:
   a. Nonmetallic fiber brushes and commercial muriatic acid followed by rinsing with clean water.
   b. Brush-off blasting.
   c. Water blasting.
4. Do not damage masonry mortar joints or adjacent surfaces.
5. Leave surfaces clean and, unless otherwise required for proper adhesion, dry prior to painting.

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6. Masonry Surfaces to be Painted: Uniform texture and free of surface imperfections that would impair intended finished appearance.
7. Masonry Surfaces to be Clear Coated: Free of discolorations and uniform in texture after cleaning.

H. Wood Surface Preparation:

1. Replace damaged wood surfaces or repair in a manner acceptable to ENGINEER prior to start of surface preparation.
2. Solvent clean (mineral spirits) knots and other resinous areas and coat with shellac or other knot sealer, prior to painting. Remove pitch by scraping and wipe clean with mineral spirits or turpentine prior to applying knot sealer.
3. Round sharp edges by light sanding prior to priming.
4. Filler:
   a. Synthetic-based wood putty approved by paint manufacturer for paint system.
   b. For natural finishes, color of wood putty shall match color of finished wood.
   c. Fill holes, cracks, and other surface irregularities flush with surrounding surface and sand smooth.
   d. Apply putty before or after prime coat, depending on compatibility and putty manufacturer's recommendations.
   e. Use cellulose type putty for stained wood surfaces.
5. Ensure surfaces are clean and dry prior to painting.

I. Gypsum Board Surface Preparation: Typically, new gypsum board surfaces need no special preparation before painting.

1. Surface Finish: Dry, free of dust, dirt, powdery residue, grease, oil, or any other contaminants.

J. Existing Painted Surfaces to be Repainted Surface Preparation:

1. Detergent wash and freshwater rinse.
2. Clean loose, abraded, or damaged coatings to substrate by hand or power tool, SP 2 or SP 3.
3. Feather surrounding intact coating.
4. Apply one spot coat of specified primer to bare areas, overlapping prepared existing coating.
5. Apply one full finish coat of specified primer to entire surface.
6. If an aged, plural-component material is to be topcoated, contact coating manufacturer for additional surface preparation requirements.

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7. For ductile iron pipe with asphaltic varnish finish not specified to be abrasive blasted, apply coat of tar stop prior to application of cosmetic finish coat.
8. Application of Cosmetic Coat:
    a. It is assumed that existing coatings have oxidized sufficiently to prevent lifting or peeling when overcoated with paints specified.
    b. Check compatibility by application to a small area prior to starting painting.
    c. If lifting or other problems occur, request disposition from ENGINEER.
9. Perform blasting as required to restore damaged surfaces. Materials, equipment, procedures shall meet requirements of SSPC.

3.05 SURFACE CLEANING

A. Brush-off Blast Cleaning:

B. Equipment, procedure, and degree of cleaning shall meet requirements of SSPC SP 7.

1. Abrasive: Either wet or dry blasting sand, grit, or nutshell.
2. Select various surface preparation parameters, such as size and hardness of abrasive, nozzle size, air pressure, and nozzle distance from surface such that surface is cleaned without pitting, chipping, or other damage.
3. Verify parameter selection by blast cleaning a trial area that will not be exposed to view.
4. ENGINEER will review acceptable trial blast cleaned area and use area as a representative sample of surface preparation.
5. Repair or replace surface damaged by blast cleaning.

C. Acid Etching:

1. After precleaning, spread the following solution by brush or plastic sprinkling can: One part commercial muriatic acid reduced by two parts water by volume. Adding acid to water in these proportions gives an approximate 10 percent solution of HCl.
2. Application:
    a. Rate: Approximately 2 gallons per 100 square feet.
    b. Work acid solution into surface by hard-bristled brushes or brooms until complete wetting and coverage is obtained.
    c. Acid will react vigorously for a few minutes, during which time brushing shall be continued.

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d. After bubbling subsides (10 minutes), hose down remaining slurry with high pressure clean water.
e. Rinse immediately to avoid formation on the surface of salts that are difficult to remove.
f. Thoroughly rinse to remove any residual acid surface condition that may impair adhesion.
g. Ensure surface is completely dry before application of coating.

3. Apply acid etching to obtain a "grit sandpaper" surface profile. If not, repeat treatment.

D. Solvent Cleaning:

1. Consists of removal of foreign matter such as oil, grease, soil, drawing and cutting compounds, and any other surface contaminants by using solvents, emulsions, cleaning compounds, steam cleaning, or similar materials and methods that involve a solvent or cleaning action.
2. Meet requirements of SSPC SP 1.

3.06 APPLICATION

A. General:

1. The intention of these Specifications is for [existing and] new, [interior] [and exterior] [wood,] [masonry,] [concrete,] [and] [metal,] [and submerged metal] surfaces to be painted, whether specifically mentioned or not, except as specified otherwise. [Do not paint exterior concrete surfaces, unless specifically indicated.]
2. Extent of Coating (Immersion): Coatings shall be applied to internal vessel and pipe surfaces, nozzle bores, flange gasket sealing surfaces, carbon steel internals, and stainless steel internals, unless otherwise specified.
3. For coatings subject to immersion, obtain full cure for completed system. Consult coatings manufacturer's written instructions for these requirements. Do not immerse coating until completion of curing cycle.
4. Apply coatings in accordance with these Specifications and paint manufacturers' printed recommendations and special details. The more stringent requirements shall apply. Allow sufficient time between coats to assure thorough drying of previously applied paint.
5. Sand wood lightly between coats to achieve required finish.
6. Vacuum clean surfaces free of loose particles. Use tack cloth just prior to applying next coat.
7. Fusion Bonded Coatings Method Application: Electrostatic, fluidized bed, or flocking.

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8. Coat units or surfaces to be bolted together or joined closely to structures or to one another prior to assembly or installation.
9. Water-Resistant Gypsum Board: Use only solvent type paints and coatings.
10. On pipelines, terminate coatings along pipe runs to 1 inch inside pipe penetrations.
11. Keep paint materials sealed when not in use.
12. Where more than one coat is applied within a given system, alternate colors to provide a visual reference showing required number of coats have been applied.

B. Galvanized Metal, Copper, and Nonferrous Metal Alloys:

1. Concealed galvanized, copper, and nonferrous metal alloy surfaces (behind building panels or walls) do not require painting, unless specifically indicated herein.
2. Prepare surface and apply primer in accordance with System No. 10 specification.
3. Apply intermediate and finish coats of the coating system appropriate for the exposure.

C. Porous Surfaces, Such As Concrete and Masonry:

1. Filler/Surfacer: Use coating manufacturer's recommended product to fill air holes, bug holes, and other surface voids or defects.
2. Prime Coat: May be thinned to provide maximum penetration and adhesion.
   a. Type and Amount of Thinning: Determined by paint manufacturer and dependent on surface density and type of coating.
3. Surface Specified to Receive Water Base Coating: Damp, but free of running water, just prior to application of coating.

D. Film Thickness and Coverage:

1. Number of Coats:
   a. Minimum required without regard to coating thickness.
   b. Additional coats may be required to obtain minimum required paint thickness, depending on method of application, differences in manufacturers' products, and atmospheric conditions.
2. Application Thickness:
   a. Do not exceed coating manufacturer's recommendations.
   b. Measure using a wet film thickness gauge to ensure proper coating thickness during application.
3. Film Thickness Measurements and Electrical Inspection of Coated Surfaces:

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a. Perform with properly calibrated instruments.
b. Recoat and repair as necessary for compliance with Specification.
c. Coats are subject to inspection by ENGINEER and coating manufacturer's representative.

4. Visually inspect concrete, masonry, nonferrous metal, plastic, and wood surfaces to ensure proper and complete coverage has been attained.
5. Give particular attention to edges, angles, flanges, and other similar areas, where insufficient film thicknesses are likely to be present, and ensure proper millage in these areas.
6. Apply additional coats as required to achieve complete hiding of underlying coats. Hiding shall be so complete that additional coats would not increase the hiding.

3.07 PROTECTIVE COATINGS SYSTEMS AND APPLICATION SCHEDULE

A. [Unless otherwise shown or specified, paint surfaces in accordance with the following application schedule. In the event of discrepancies or omissions in the following, request clarification from ENGINEER before starting work in question.]

B. [As shown in Section 09 06 00, Schedules for Finishes.] [As shown in Finish Schedule on Drawings.] [Additional requirements are included in the Piping Schedule.]

C. System No. 1 Submerged Metal—Potable Water:

Surface Prep.	**Paint Material**	**Min. Coats, Cover**
SP 5, White Metal Blast Cleaning	NSF Epoxy	3 coats, 3 MDFTPC

1. Use on the following items or areas:

a. Metal surfaces [new and] [existing] below a plane 1 foot above the maximum liquid surface; metal surfaces above the maximum liquid surface that are a part of the immersed equipment; surfaces of metallic items, such as wall pipes, pipes, pipe sleeves, access manholes, gate guides and thimbles, and structural steel that are embedded in concrete; and the following specific surfaces:
1) Interior surfaces of steel piping noted in the Piping Schedule.
2) [_____]

D. System No. 2 Submerged Metal—Domestic Sewage:

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Surface Prep.	Paint Material	Min. Coats, Cover
SP 5, White Metal Blast Cleaning	Prime in accordance with manufacturer's recommendations	
	Coal-Tar Epoxy -OR- High Build Epoxy	2 coats, 16 MDFT 2 coats, 16 MDFT

1. Use on the following items or areas:
   a. Metal surfaces [new and] [existing] below a plane 1 foot above maximum liquid surface, metal surfaces above maximum liquid surface that are a part of immersed equipment, concrete embedded surfaces of metallic items, such as wall pipes, pipes, pipe sleeves, access manholes, gate guides and thimbles, and structural steel, and the following specific surfaces:
      1) Interior surfaces of steel piping noted in the Piping Schedule.
      2) [_____]

E. System No. 3 Submerged Metal—Other:

1. Use on the following items or areas:
   a. Metal surfaces [new and] [existing] below a plane 1 foot above maximum liquid surface, metal surfaces above maximum liquid surface which are a part of immersed equipment, and the following specific surfaces:
      1) Interior surfaces of steel piping noted in the Piping Schedule.
      2) [_____]

F. System No. 4 Exposed Metal—Highly Corrosive:

Surface Prep.	Paint Material	Min. Coats, Cover
SP 10, Near-White Blast Cleaning	Epoxy Primer—Ferrous Metal	1 coat, 2.5 MDFT
	High Build Epoxy	1 coat, 4 MDFT
	[Polyurethane Enamel	1 coat, 3 MDFT]

1. Use on the following items or areas:
   a. Exposed metal surfaces, [new and] [existing] located inside or outside of structures and exposed to weather [, and the following specific surfaces:
      1) [_____]].

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G. System No. 5 Exposed Metal—Mildly Corrosive:

Surface Prep.	Paint Material	Min. Coats, Cover
SP 10, Near-White Blast Cleaning	Epoxy Primer—Ferrous Metal	1 coat, 2.5 MDFT
	Polyurethane Enamel	1 coat, 3 MDFT

1. Use on the following items or areas:
   a. Exposed metal surfaces, [new and] [existing] located inside or outside of structures and exposed to weather or in a highly humid atmosphere, such as pipe galleries and similar areas [, and the following specific surfaces:
      1) [_____]].

H. System No. 6 Exposed Metal—Atmospheric:

Surface Prep.	Paint Material	Min. Coats, Cover
SP 6, Commercial Blast Cleaning	Rust-Inhibitive Primer	1 coat, 2 MDFT
	Alkyd Enamel	2 coats, 4 MDFT

1. Use on the following items or areas:
   a. Exposed metal surfaces, [new and] [existing] located inside or outside of structures or exposed to weather, including [metal doors and frames,] vents, [louvers,] exterior metal ductwork, flashing, sheet metalwork and miscellaneous architectural metal trim [, and the following specific surfaces:
      1) Inside duct stack heads behind diffusers, registers, and grilles with flat black.
      2) Instrumentation and control systems exposed enclosures for process.
      3) [_____]].
   b. Apply surface preparation and primer to surfaces prior to installation. Finish coats need only be applied to surfaces exposed after completion of construction.

I. System No. 7 Concrete Encased Metal:

Surface Prep.	Paint Material	Min. Coats, Cover
SP 6, Commercial	[Coal-Tar Epoxy]	[2 coats, 16 MDFT]

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Surface Prep.	Paint Material	Min. Coats, Cover
	[High Build Epoxy]	[_____]
	[_____]	

1. Use on the following items or areas:
   a. Use on concrete encased ferrous metals including wall pipes, pipe sleeves, access manholes, gate guides, and thimbles; and the following specific surfaces:
      1) [_____]

J. System No. 8 Buried Metal—General:

Surface Prep.	Paint Material	Min. Coats, Cover
SP 10, Near-White Blast Cleaning	Standard Hot Coal-Tar Enamel -OR- Coal-Tar Epoxy	AWWA C203 2 coats, 16 MDFT
	For Highly Abrasive Soil, Brackish Water: Tape Coat System	AWWA C214 with Double Outer Wrap

1. For steel pipe and fittings, follow AWWA C209 and AWWA C214 [with double outer wrap].
2. Use on the following items or areas:
   a. Buried, belowgrade portions of steel items, except buried stainless steel or ductile iron [, and the following specific surfaces:
      1) [_____]].

K. System No. 9 Special Coatings—Metal:

1. Use on the following items or areas:
   a. [_____]

L. System No. 10 Galvanized Metal, Copper, and Nonferrous Metal Alloy Conditioning:

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Surface Prep.	Paint Material	Min. Coats, Cover
In accordance with Paragraph Galvanized Metal, Copper, and Nonferrous Metal Alloy Surface Preparation	Epoxy Primer—Other	As recommended by coating manufacturer Remaining coats as required for exposure

1. Use on the following items or areas:
   a. Galvanized surfaces requiring painting [, and the following specific surfaces:
      1) [_____]].
      2) After application of System No. 10, apply finish coats as required for exposure.

M. System No. 12 Skid-Resistant—Steel:

Surface Prep.	Paint Material	Min. Coats, Cover
SP 10, Near-White Blast Cleaning	Epoxy Primer—Ferrous Metal	1 coat, 2.5 MDFT
	Epoxy Nonskid (Aggregated)	1 coat, 16 MDFT

1. Use on the following items or areas:
   a. [_____]

N. System No. 13 Skid-Resistant—Aluminum and FRP:

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Surface Prep.	Paint Material	Min. Coats, Cover
Aluminum: In accordance with Article Galvanized Metal, Copper, and Nonferrous Metal Alloy Surface Preparation -OR- FRP: In accordance with Article Plastic and FRP Surface Preparation	Epoxy Nonskid (Aggregated)	1 coat, 16 MDFT

1. Use on the following items or areas:
   a. [_____]

O. System No. 14 High Heat-Resistant—700 Degrees F Maximum:

Surface Prep.	Paint Material	Min. Coats, Cover
SP 6, Commercial Blast Cleaning	Inorganic Zinc Primer	1 coat, 2.5 MDFT
	Silicone	1 coat, 2 MDFT

1. Use on the following items or areas:
   a. [_____]

P. System No. 15 Heat-Resistant—425 Degrees F Maximum:

Surface Prep.	Paint Material	Min. Coats, Cover
SP 6, Commercial Blast Cleaning	Inorganic Zinc Primer	1 coat, 2.5 MDFT
	Silicone Acrylic (limited colors)	2 coats, 2 MDFT

3. Use on the following items or areas:
   a. [_____]

Q. System No. 16 Elastomeric Coating:

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Surface Prep.	Paint Material	Min. Coats, Cover
Concrete: In accordance with Paragraph Concrete Surface Preparation -OR-Masonry: In accordance with Paragraph Masonry Surface Preparation -OR- Steel: SP 5, White Metal Blast Cleaning	Prime in accordance with manufacturer's recommendations	
	Elastomeric Polyurethane	1 coat, 32 SFPG

4. Use on the following items or areas:
   a. [_____]

B. System No. 17 Special Coating—Concrete:

1. Use on the following areas:
   a. [_____]

C. System No. 18 Concrete Tank Lining—Potable Water:

Surface Prep.	Paint Material	Min. Coats, Cover
In accordance with Paragraph Concrete Surface Preparation	Epoxy Filler/Surfacer (NSF-approved)	As required to fill voids and level surface
	NSF Epoxy	3 coats, 250 SFPGPC

1. Use on the following items or areas:
   a. Concrete surfaces below a plane 1 foot above maximum liquid surface [, and the following specific surfaces:
      1) [_____]].

D. System No. 19 Concrete Tank Lining—Domestic Sewage:

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Surface Prep.	Paint Material	Min. Coats, Cover
In accordance with Paragraph Concrete Surface Preparation	Epoxy Filler/Surfacer	As required to fill voids and level surface
	Epoxy, High Solids	3 coats, 250 SFPGPC

1. Use on the following items or areas:
   a. Concrete surfaces below a plane 1 foot above maximum liquid surface [, and the following specific surfaces:
      1) [_____]].

E. System No. 20 Concrete Tank Lining—Other:

1. Use on the following items or areas:
   a. Concrete surfaces below a plane 1 foot above maximum liquid surface [, and the following specific surfaces:
      1) [_____]].

F. System No. 21 Skid-Resistant—Concrete:

Surface Prep.	Paint Material	Min. Coats, Cover
In accordance with Paragraph Concrete Surface Preparation	Epoxy Nonskid (Aggregated)	1 coat, 160 SFPG

1. Use on the following items or areas:
   a. [_____]

G. System No. 22 Chemical-Resistant Wall, Heavy-Duty—[Concrete] [Masonry]:

Surface Prep.	Paint Material	Min. Coats, Cover
In accordance with Paragraph [Concrete] [Masonry] Surface Preparation	Epoxy Filler/Surfacer	1 coat, as required to fill voids
	High Build Epoxy	1 coat, 160 SFPG
	High Build Epoxy, Gloss	1 coat, 160 SFPG

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1. Use on the following items or areas:
   a. [_____]

H. System No. 23 Chemical-Resistant Wall—[Concrete] [Masonry]:

Surface Prep.	**Paint Material**	**Min. Coats, Cover**
In accordance with Paragraph [Concrete] [Masonry] Surface Preparation	Epoxy Filler/Surfacer	1 coat, as required to fill voids
	High Build Epoxy	1 coat, 160 SFPG

1. Use on the following items or areas:
   a. [_____]

I. System No. 25 Exposed FRP, PVC:

Surface Prep.	**Paint Material**	**Min. Coats, Cover**
In accordance with Paragraph Plastic and FRP Surface Preparation	Acrylic Latex [Semigloss] [Gloss] [Flat]	2 coats, 320 SFPGPC

1. Use on the following items or areas:
   a. All exposed-to-view PVC and CPVC surfaces, and FRP surfaces without integral UV-resistant gel coat.
   b. [_____]

J. System No. 27 Aluminum and Dissimilar Metal Insulation:

Surface Prep.	Paint Material	Min. Coats, Cover
Solvent Clean (SP 1)	Prime in accordance with manufacturer's recommendations	
	Bituminous Paint	1 coat, 10 MDFT

1. Use on aluminum surfaces embedded or in contact with concrete [, and the following items or areas:
   a. [_____]].

K. System No. 28 Repair of Existing Coatings:

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1. Use on the following items or areas:
   a. [_____]

L. System No. 29 Fusion Bonded Coating:

Surface Prep.	Paint Material	Min. Coats, Cover
SP 10, Near-White Blast Cleaning	Fusion Bonded Coating 100% Solids Epoxy	1 or 2 coats, 7 MDFT

1. For steel pipe and fittings, meet all requirements of AWWA C213.
2. Use on the following items:
   a. [_____]
   b. [_____]

M. System No. 29A Fusion Bonded, Steel Dowel Coating:

Surface Prep.	Paint Material	Min. Coats, Cover
SP 10, Near-White Blast Cleaning	Fusion Bonded Coating 100% Solids Epoxy	1 or 2 coats, 7 MDFT
TFE Lube, Shop Applied; Grease Lube Alternative, Field Applied Just Prior to Installation	TFE Lube or Grease Lube	1 coat, as required

1. Use on steel expansion joint dowels as specified in Section 03 15 00, Concrete Joints and Accessories.

N. System No. 30 Moisture-Cure Polyurethane:

O. System No. 31 Direct-to-Metal Acrylic:

3.08 ARCHITECTURAL PAINT SYSTEMS AND APPLICATION SCHEDULE

A. [Unless otherwise shown or specified, paint surfaces in accordance with the following application schedule. In the event of discrepancies or omissions in the following, request clarification from ENGINEER before starting work in question.]

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B. [As shown in Section 09 06 00, Schedules for Finishes.] [As shown in Finish Schedule on Drawings.] [Additional requirements are included in the Piping Schedule.]

C. System No. 101 Wood, Stained (Interior or Exterior):

Surface Prep.	**Paint Material**	**Min. Coats, Cover**
In accordance with Paragraph Wood Surface Preparation	Wood Stain [Solid] [Transparent]	2 coats, 250 SFPGPC

1. Use on the following items or areas:
   a. [_____]

D. System No. 102 Wood, Semigloss (Interior or Exterior):

Surface Prep.	**Paint Material**	**Min. Coats, Cover**
In accordance with Paragraph Wood Surface Preparation	Alkyd Wood Primer	1 coat, 400 SFPG
	Alkyd (Semigloss)	1 coat, 400 SFPG

1. Use on the following items or areas:
   a. [_____]

E. System No. 103 Wood, Flat (Interior or Exterior):

Surface Prep.	**Paint Material**	**Min. Coats, Cover**
In accordance with Paragraph Wood Surface Preparation	Alkyd Wood Primer	1 coat, 400 SFPG
	Acrylic Latex (Flat)	2 coats, 350 SFPGPC

1. Use on the following items or areas:
   a. [_____]

F. System No. 104 Wood, Natural (Interior or Exterior):

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Surface Prep.	Paint Material	Min. Coats, Cover
In accordance with Paragraph Wood Surface Preparation	Sanding Sealer	1 coat, 450 SFPG
	Varnish Satin or Gloss; Gloss Only on Exterior	2 coats, 450 SFPG

1. Use on the following items or areas:
   b. [_____]

G. System No. 105 Wood, Stained and Varnished (Interior or Exterior):

Surface Prep.	Paint Material	Min. Coats, Cover
In accordance with Paragraph Wood Surface Preparation	Stain, Wood	Match Sample
	Sanding Sealer	1 coat, 450 SFPG
	Varnish (Gloss or Satin), Exterior Gloss Only	2 coats, 450 SFPGPC

1. Use on the following items or areas:
   c. [_____]

H. System No. 106 Galvanized Metal:

Surface Prep.	Paint Material	Min. Coats, Cover
In accordance with Paragraph Galvanized Metal, Copper, and Nonferrous Metal Alloy Surface Preparation	Manufacturer's Recommended Primer	1 coat, as recommended by manufacturer
	Alkyd Enamel (Semigloss)	2 coats, 4 MDFT

1. Use on the following items or areas:
   d. [Hollow metal frames and doors.]

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e. [_____]

I. System No. 107 Metal Trim and Structural Steel:

Surface Prep.	Paint Material	Min. Coats, Cover
SP 6, Commercial Blast Cleaning	Rust-Inhibitive Primer	1 coat, 2 MDFT
	Alkyd Enamel (Semigloss)	2 coats, 4 MDFT

1. Use on the following items or areas:
   a. [_____]

J. System No. 108 Masonry, Flat:

Surface Prep.	Paint Material	Min. Coats, Cover
In accordance with Paragraph Masonry Surface Preparation	Block Filler	1 coat, 75 SFPG
	Acrylic Latex (Flat)	2 coats, 240 SFPGPC

1. Use on the following items or areas:
   a. [_____]

K. System No. 109 Masonry, Semigloss:

Surface Prep.	Paint Material	Min. Coats, Cover
In accordance with Paragraph Masonry Surface Preparation	Block Filler	1 coat, 75 SFPG
	Acrylic Latex (Semigloss)	2 coats, 240 SFPGPC

1. Use on the following items or areas:
   a. [_____]

L. System No. 110 Masonry Sealer:

Surface Prep.	Paint Material	Min. Coats, Cover

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Surface Prep.	Paint Material	Min. Coats, Cover
In accordance with Paragraph Masonry Surface Preparation	Acrylic Sealer	2 coats, 100 SFPGPC

1. Use on the following items or areas:
   a. [_____]

M. System No. 111 Concrete and Masonry, Stain and Seal:

Surface Prep.	Paint Material	Min. Coats, Cover
Concrete: In accordance with Paragraph Concrete Surface Preparation -OR- Masonry: In accordance with Paragraph Masonry Surface Preparation	Stain, Concrete	2 coats, 250 SFPGPC
	Acrylic Sealer	2 coats, 100 SFPGPC

1. Use on the following items or areas:
   a. [_____]

N. System No. 112 Concrete, Flat:

Surface Prep.	Paint Material	Min. Coats, Cover
In accordance with Paragraph Concrete Surface Preparation	Acrylic Latex (Flat)	2 coats, 240 SFPGPC

1. Use on the following items or areas:
   a. [_____]

O. System No. 113 Concrete, Semigloss:

Surface Prep.	Paint Material	Min. Coats, Cover
In accordance with Paragraph Concrete Surface Preparation	Acrylic Latex (Semigloss)	2 coats, 240 SFPGPC

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2. Use on the following items or areas:
   a. [_____]

P. System No. 114 Gypsum Board and Plaster, Flat:

Surface Prep.	Paint Material	Min. Coats, Cover
In accordance with Paragraph Gypsum Board Surface preparation	Latex Primer Sealer	1 coat, 350 SFPG
	Acrylic Latex (Flat)	2 coats, 240 SFPGPC

1. Use on the following items or areas:
   a. [_____]

Q. System No. 115 Gypsum Board and Plaster, Semigloss:

Surface Prep.	Paint Material	Min. Coats, Cover
In accordance with Paragraph Gypsum Board Surface Preparation	Latex Primer/Sealer	1 coat, 350 SFPG
	Acrylic Latex (Semigloss) or Alkyd (Semigloss)	2 coats, 400 SFPGPC

1. Use on the following items or areas:
   a. [_____]

R. System No. 116 Gypsum Board and Plaster, Gloss Epoxy:

Surface Prep.	Paint Material	Min. Coats, Cover
In accordance with Paragraph Gypsum Board Surface Preparation	Manufacturer's Recommended Primer	1 coat, 350 SFPG
	Water Base Epoxy (Gloss)	1 coat, 250 SFPG

1. Use on the following items or areas:
   a. [_____]

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P. System No. 117 Concrete Masonry, Gloss Epoxy:

Surface Prep.	Paint Material	Min. Coats, Cover
In accordance with Paragraph Masonry Surface Preparation	Block Filler	1 coat, 75 SFPG
	Water Base Epoxy (Gloss)	2 coats, 300 SFPGPC

2. Use on the following items or areas:
   a. [_____]

S. System No. 121 Concrete, Skid-Resistant:

Surface Prep.	Paint Material	Min. Coats, Cover
In accordance with Paragraph Concrete Surface Preparation	Epoxy Nonskid (Aggregated)	1 coat, 160 SFPG

1. Use on the following items or areas:
   a. [_____]

3.09 COLORS

A. Provide as [shown in Section 09 06 00, Schedules for Finishes] [designated herein] [shown for equipment and appurtenances and designated herein] [and shown in Piping Schedule] [selected by] [Owner or] [ENGINEER].

B. Proprietary identification of colors is for identification only. Selected manufacturer may supply matches.

C. Equipment Colors:

1. Equipment includes the machinery or vessel itself plus the structural supports and fasteners and attached electrical conduits.
2. [Paint equipment and piping one color as selected.]
3. Paint nonsubmerged portions of equipment the same color as the piping it serves, except as itemized below:
   a. Dangerous Parts of Equipment and Machinery: OSHA Orange.
   b. Fire Protection Equipment and Apparatus: OSHA Red.
   c. Radiation Hazards: OSHA Purple.

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d. Physical hazards in normal operating area and energy lockout devices, including, but not limited to, electrical disconnects for equipment and equipment isolation valves in air and liquid lines under pressure: OSHA Yellow.

D. Pipe Identification Painting:

1. Color code nonsubmerged metal piping, except electrical conduit. Paint fittings and valves the same color as pipe, except equipment isolation valves.
2. Pipe Color Coding: [In accordance with Piping Schedule.] [As shown in table below.]
3. On exposed stainless steel piping, apply color 24 inches in length along pipe axis at connections to equipment, valves, or branch fittings, at wall boundaries, and at intervals along piping not greater than 9 feet on center.
4. Pipe Supports: Painted light gray, as approved by [Owner] [ENGINEER].
5. [Fiberglass reinforced plastic (FRP) pipe, polyvinylidene fluoride (PVDF), and polyvinyl chloride (PVC) pipe located inside of buildings and enclosed structures will not require painting, except as noted or scheduled.]

E. Pipe System Color Code:

Pipe System	**Color**
Air, Process	Federal Safety Green
Air, Instrument	Federal Safety Purple
Ammonia, Liquid	Federal Safety Orange
Ammonia, Solution	Federal Safety Orange
Alum	Dark Green
Chlorine, Gas	Federal Safety Yellow
Chlorine, Liquid	Federal Safety Yellow
Chlorine, Residual Sampling	Silver/Gray
Chlorine Solution	Federal Safety Yellow
Chlorine Ejector Water	Silver/Gray
Chlorine Vent	Federal Safety Yellow
Compressed Air	Federal Safety Purple
Carbon	Black
Drains and Sludge	Light Brown
Decant	Light Brown

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Pipe System	Color
Dewatering	Black
Drains	Black
Effluent, Final	Silver/Gray
Effluent, Primary	Silver/Gray
Effluent, Flushing Water, High Pressure	Dark Green
Effluent, Flushing	Dark Green
Fuel Oil Supply	Federal Safety Orange
Fuel Oil Return	Federal Safety Orange
Flocculation Basin Influent	Buff
Filter Backwash Supply	Medium Blue
Filter Surface Wash Supply	Medium Blue
Hot Flushing Loop	Federal Safety Blue
Headworks	Buff
Lime	White
Mixed Liquor	Silver/Gray
Overflow	Silver/Gray
Plant Service Water	Medium Blue
Potable Water	Light Blue
Polymer/Cationic	Buff
Polymer Nonionic or Anionic	Buff
Raw Sewage	Dark Gray
Rapid Mix Influent	Light Brown
Scum	Light Brown
Sample	Medium Green
Seal Water	Federal Safety Blue
Sludge, Digested	Dark Brown
Sludge, Primary	Dark Brown
Sludge, Return Activated	Light Brown
Sludge, Thickened	Light Brown
Sludge, Waste Activated	Dark Brown
Sludge, Stored	Dark Brown

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Pipe System	Color
Sludge, Recirculated	Dark Brown
Sludge, Mixed	Light Brown
Thickener Dilution Water	Dark Green

3.10 FIELD QUALITY CONTROL

A. Testing Equipment:

1. Provide magnetic type dry film thickness gauge to test coating thickness specified in mils, as manufactured by Nordson Corp., Anaheim, CA, Mikrotest.
2. Provide low-voltage wet sponge electrical holiday detector to test completed coating systems, 20 mils dry film thickness or less, except zinc primer, high-build elastomeric coatings, and galvanizing, for pinholes, holidays, and discontinuities, as manufactured by Tinker and Rasor, San Gabriel, CA, Model M-1.
3. Provide high-voltage spark tester to test completed coating systems in excess of 20 mils dry film thickness. Unit as recommended by coating manufacturer.

B. Testing:

1. Thickness and Continuity Testing:
   a. Measure coating thickness specified in mils with a magnetic type, dry film thickness gauge, in accordance with SSPC PA 2. Check each coat for correct millage. Do not make measurement before a minimum of 8 hours after application of coating.
   b. Holiday detect coatings 20 mils thick or less, except zinc primer and galvanizing, with low voltage wet sponge electrical holiday detector in accordance with NACE RP0188.
   c. Holiday detect coatings in excess of 20 mils dry with high voltage spark tester as recommended by coating manufacturer and in accordance with NACE RP0188.
   d. After repaired and recoated areas have dried sufficiently, retest each repaired area. Final tests may also be conducted by ENGINEER.

C. Inspection: Leave staging and lighting in place until ENGINEER has inspected surface or coating. Replace staging removed prior to approval by ENGINEER. Provide additional staging and lighting as requested by ENGINEER.

D. Unsatisfactory Application:

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1. If item has an improper finish color or insufficient film thickness, clean surface and topcoat with specified paint material to obtain specified color and coverage. Obtain specific surface preparation information from coating manufacturer.
2. Evidence of runs, bridges, shiners, laps, or other imperfections is cause for rejection.
3. Repair defects in accordance with written recommendations of coating manufacturer.

E. Damaged Coatings, Pinholes, and Holidays:

1. Feather edges and repair in accordance with recommendations of paint manufacturer.
2. Hand or power sand visible areas of chipped, peeled, or abraded paint, and feather the edges. Follow with primer and finish coat. Depending on extent of repair and appearance, a finish sanding and topcoat may be required.
3. Apply finish coats, including touchup and damage-repair coats in a manner that will present a uniform texture and color-matched appearance.

3.11 MANUFACTURER'S SERVICES

A. In accordance with Section 01 43 33, Manufacturers' Field Services, coating manufacturer's representative shall be present at Site as follows:

1. On first day of application of any coating system.
2. A minimum of [two] [_____] additional Site inspection visits, each for a minimum of 4 hours, in order to provide Manufacturer's Certificate of Proper Installation.
3. As required to resolve field problems attributable to or associated with manufacturer's product.
4. To verify full cure of coating prior to coated surfaces being placed into immersion service.

3.12 CLEANUP

A. Place cloths and waste that might constitute a fire hazard in closed metal containers or destroy at end of each day.

B. Upon completion of the Work, remove staging, scaffolding, and containers from Site or destroy in a legal manner.

C. Remove paint spots, oil, or stains upon adjacent surfaces and floors and leave entire job clean.

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3.13 SUPPLEMENTS

A. The supplements listed below, following "End of Section," are a part of this Specification:

1. Paint System Data Sheet (PSDS)
2. Product Data Sheet (PDS).
3. [_____]

END OF SECTION

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PAINT SYSTEM DATA SHEET

Complete this PSDS for each coating system, include all components of the system (surface preparation, primer, intermediate coats, and finish coats). Include all components of a given coating system on a single PSDS.

Paint System Number (from Spec.):		
Paint System Title (from Spec.):		
Coating Supplier:		
Representative:		
Surface Preparation:		
Paint Material (Generic)	**Product Name/Number (Proprietary)**	**Min. Coats, Coverage**

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PAINT PRODUCT DATA SHEET

Complete and attach manufacturer's Technical Data Sheet to this PDS for each product submitted. Provide manufacturer's recommendations for the following parameters at temperature (F)/relative humidity:

Temperature/RH	50/50	70/30	90/25
Induction Time			
Pot Life			
Shelf Life			
Drying Time			
Curing Time			
Min. Recoat Time			
Max. Recoat Time			

Provide manufacturer's recommendations for the following:

Mixing Ratio:

Maximum Permissible Thinning:_____

Ambient Temperature Limitations: min.: max.:_____

Surface Temperature Limitations: min.: max.:_____

Surface Profile Requirements: min.: max.:_____

[Attach additional sheets detailing manufacturer's recommended storage requirements and holiday testing procedures.]

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SECTION 09 90 05
ARCHITECTURAL PAINTING

PART 1 -GENERAL

1.01 DEFINITIONS

A. Terms used in this section:

1. Coverage: Total minimum dry film thickness in mils, or square feet per gallon.
2. FRP: Fiberglass Reinforced Plastic.
3. HCl: Hydrochloric Acid.
4. MDFT: Minimum Dry Film Thickness.
5. MDFTPC: Minimum Dry Film Thickness Per Coat.
6. mil: Thousandth of an inch.
7. Military Specification-Paint.
8. PSDS: Paint System Data Sheet.
9. SFPG: Square Feet Per Gallon.
10. SFPGPC: Square Feet Per Gallon Per Coat.
11. SP: Surface Preparation.
12. Existing: Those coated surfaces that are cut into, connected to, or otherwise changed or affected by the work of this contract.

B. Paint Terms: Conform to ASTM D16.

1.02 SUBMITTALS

A. Action Submittals:

1. Product Data: Manufacturer’s descriptive literature for coating materials and coating application accessories.
   a. For each paint system used, furnish a Paint System Data Sheet (PSDS) and technical data sheet for each product used in the paint system. PSDS form is appended to the end of this section.
   b. Submit required information on a system by system basis.
   c. Provide copies of paint system submittals to applicator.
2. Verification Samples: Two samples, minimum size 6 inches (152 mm) square, representing actual color and finish of each finish coating type, color, and finish to be applied.

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B. Informational Submittals:

1. List of references substantiating applicator's experience.
2. Manufacturer's printed application instructions for each product, including product storage requirements and surface preparation requirements.

1.03 QUALITY ASSURANCE

A. Applicator's Experience: Minimum 5 years' practical experience in application of specified products and approved by the paint manufacturer.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Store products of this section in manufacturer's unopened packaging until installation.

B. Establish and maintain storage area conditions for products of this Section in accordance with manufacturer's instructions until installation.

C. Store and dispose of solvent-based materials, and materials used with solvent-based materials, in accordance with requirements of local authorities having jurisdiction over project.

1.05 PROJECT CONDITIONS

A. Do not apply coatings to exterior surfaces except under environmental conditions recommended by coating manufacturer.

B. Establish and maintain environmental conditions recommended by coating manufacturer before, during, and after application of coatings to interior surfaces.

C. During application of coating materials, post "WET PAINT" signs.

D. During application of solvent-based materials, post "NO SMOKING" signs.

1.06 SEQUENCING

A. Do not allow application of finish coats in an area until moisture-producing construction activities, dust-producing construction activities, and other construction activities which could impair performance or appearance of finish coatings, have been completed in that area.

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1.07 EXTRA MATERIALS

A. Supply for each finish coating material, color, and finish specified 2 gallons (7.75L) of paint material, in sealed 1-gallon (3.875L) containers, marked with color and finish identification.

B. Custom Colors: Provide details of color formulae and product availability.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Manufacturers: Products of the following manufacturers, meeting these specifications, may be used on this Project:

1. Ameritone, Long Beach, CA.
2. Fuller/O'Brien Paint Company, San Francisco, CA.
3. Benjamin Moore Paint Company, San Francisco, CA.
4. Pratt & Lambert, Inc., Buffalo, NY.
5. Sherwin Williams, Cleveland, OH.
6. Duron, Inc., Beltsville, MD.

B. Unless otherwise specified for an individual product or material, supply products specified in this section from the same manufacturer.

2.02 MATERIALS

A. General:

1. Unless otherwise indicated, furnish factory-mixed paints. When required, mix coatings to correct consistency in accordance with manufacturer's instructions before application. Do not dilute or thin paints, except as instructed.
2. Do not add additives, except as instructed or recommended by paint manufacturer.
3. Furnish each coating material in quantity required for this section from a single production run.
4. Colors: [Indicated in Interior Finish Schedule and Color List.] [On Drawings.] [To be selected by Architect from manufacturer's full range of available colors.]

B. Paint Application Accessories: As specified in this section or as recommended by paint manufacturer's application instructions, including but not limited to

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thinners, sealers, primers, cleaning agents, etching agents, cleaning cloths, sanding materials, and clean-up materials.

C. Oil Stain: Sherwin-Williams; WoodScapes Semi-Transparent A15 Series.

D. Interior Wood Stain: Sherwin-Williams; Wood Classics Interior Wood Stain A48-200 Series.

E. Alkyd Wood Primer: Sherwin-Williams; A-100 Alkyd Semi-Gloss Y24 Series.

F. Alkyd Semigloss: Sherwin-Williams; ProMar 200 Alkyd Semi-Gloss B34W200 Series.

G. Acrylic Low Sheen: Sherwin-Williams; ProMar 200 EgShel B20W200.

H. Acrylic Latex, Semigloss: Sherwin-Williams; ProMar 200 Semi-Gloss B31W200.

I. Latex Primer Sealer: Sherwin-Williams; PrepRite High-Build B28W600.

J. Sanding Sealer: Sherwin-Williams; Wood Classics FastDry Sanding Sealer B26V43.

K. Varnish: Sherwin-Williams; Wood Classic FastDry Oil Base Varnish Satin A66-300 Series.

L. Rust-Inhibitive Primer: Sherwin-Williams; Kem Kromik Universal Metal Primer B50Z Series.

M. Block Filler: Sherwin-Williams; ProMar Interior/Exterior Block Filler B25.

N. Masonry Primer: Sherwin-Williams; Loxon Interior Acrylic Masonry Primer B28 Series.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Immediately prior to coating application, ensure that surfaces to receive coatings are dry.

B. Ensure that moisture-retaining substrates to receive coatings have moisture content within tolerances allowed by coating manufacturer, using moisture measurement techniques recommended by coating manufacturer.

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C. Immediately prior to coating application, examine surfaces to receive coatings for surface imperfections and for contaminants which could impair performance or appearance of coatings, including but not limited to, loose primer, rust, scale, oil, grease, mildew, algae, or fungus, stains or marks, cracks, indentations, or abrasions.

D. Correct the above conditions and other conditions that could impair performance or appearance of coatings in accordance with specified surface preparation procedures before proceeding with coating application.

3.02 PREPARATION

A. Do not start work until surfaces to be finished are in proper condition to produce finished surfaces of uniform, satisfactory appearance.

B. Stains and Marks: Remove completely, if possible, using materials and methods recommended by coating manufacturer; cover stains and marks which cannot be completely removed with isolating primer or sealer recommended by coating manufacturer to prevent bleed-through.

C. Mildew, Algae, and Fungus: Remove, using materials and methods recommended by coating manufacturer.

D. Remove dust and loose particulate matter from surfaces to receive coatings immediately prior to coating application.

E. Remove or protect hardware, electrical plates, mechanical grilles and louvers, lighting fixture trim, and other items not indicated to receive coatings that are adjacent to surfaces to receive coatings.

F. Existing Painted Surfaces: Remove loose and peeling paint. Degloss surface if recommended by manufacturer. Sand smooth. Clean entire surface prior to painting.

G. Aluminum Surfaces: Remove surface contamination by steam or high pressure water. Remove oxidation by phosphoric acid-water solution etching and solvent washing. Apply specified primer as soon as cleaned surfaces are dry.

H. Concrete and Concrete Masonry: Clean surfaces free of loose particles, sand, efflorescence, laitance, form oil, curing compounds, and other substances which could impair coating performance or appearance.

I. Concrete Floors: Remove contaminants which could impair coating performance or appearance, acid-etch, flush with clean water; verify alkaline-acid balance

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recommended by coating manufacturer; mechanically abrade surface, if required, to achieve medium-sandpaper texture.

J. Galvanized Surfaces: Remove surface contamination and oils by solvent cleaning (SSPC-SP1) and allow to dry. Apply Galvanized Metal Primer in accordance with manufacturer instructions.

K. Wood:

1. Seal knots, pitch streaks, and sap areas with sealer recommended by coating manufacturer; fill nail recesses and cracks with filler recommended by coating manufacturer; sand surfaces smooth.
2. Apply primer coat to back of wood trim and paneling.

L. Gypsum Board: Repair cracks, holes, indentations, and other surface defects using joint compound to produce surface flush with adjacent undamaged surface; sand to produce uniform flat surface when dry.

M. Gypsum Plaster: Cut out cracks, holes, indentations, and other surface defects to extent required for bonding adhesion; apply patching plaster or joint compound to produce surface flush with adjacent undamaged surface; sand to produce uniform flat surface when dry; allow to cure 30 days before coating application.

N. Wood and Metal Doors: Seal top and bottom edges with specified primer.

O. Uncoated Steel and Iron Surfaces: Remove grease, rust, scale, and dust from steel and iron surfaces in accordance with Solvent Cleaning SSPC-SP1. Where heavy coatings of scale or contaminants are evident, clean in accordance with Hand Tool Cleaning SSPC-SP2 or other approved SSPC-SP method as needed.

P. Shop Primed Steel Surfaces: Remove loose primer and dust. Sand and feather edges to smooth surface. Clean areas with solvent and spot prime bare metal surfaces with appropriate primer recommended by manufacturer.

3.03 APPLICATION

A. Apply paint where indicated in Interior Finish Schedule.

B. Apply each coat to uniform coating thickness following manufacturer’s instructions, not exceeding manufacturer’s specified maximum spread rate for indicated surface; thins, brush marks, roller marks, orange-peel, or other application imperfections are not permitted.

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C. For opaque finishes, tint each coat, including primer coat and intermediate coats, one-half shade lighter than succeeding coat, with final finish coat as base color.

D. Allow manufacturer's specified drying time, and ensure correct coating adhesion, for each coat before applying next coat.

E. Inspect each coat before applying next coat; touch-up surface imperfections with coating material, feathering, and sanding if required; touch-up areas to achieve flat, uniform surface without surface defects visible from 5 feet (1.5 m).

F. Do not apply succeeding coat until previous coat has been approved by Engineer; only Engineer-approved coats will be considered in determining number of coats applied.

G. Remove dust and other foreign materials from substrate immediately prior to applying each coat.

H. Where coating application abuts other materials or other coating color, terminate coating, making clean sharp termination line without coating overlap.

I. Where color changes occur between adjoining spaces, through framed openings that are of same color as adjoining surfaces, change color at outside stop corner nearest to face of closed door.

J. Re-prepare and recoat unsatisfactory finishes; refinish entire area to corners or other natural terminations.

3.04 ITEMS NOT TO BE PAINTED

A. Do not paint the following:

1. Items specified or provided with factory finish.
2. Items indicated to receive other finishes.
3. Items indicated to remain unfinished.
4. Brick, precast concrete, integrally colored plaster.
5. Concrete masonry in utility, mechanical, and electrical spaces.
6. Stainless steel, anodized aluminum, bronze, terne, or lead.
7. Equipment nameplates, fire rating labels, and operating parts of equipment.
8. Acoustical materials.
9. Concealed piping, ductwork, and conduit.

B. Materials and products having factory-applied primer are not considered factory finished.

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3.05 PAINT SYSTEMS

A. System No. 101 Wood, Stained (Interior or Exterior):

Surface Prep.	Paint Material	Min. Coats, Cover
Wood	Oil Stain Transparent	2 coats, 250 SFPGPC

B. System No. 102 Wood, Semigloss (Interior or Exterior):

Surface Prep.	Paint Material	Min. Coats, Cover
Wood	Alkyd Wood Primer	1 coat, 1.4 MDFT
	Alkyd (Semigloss)	2 coats, 3.0 MDFTPC

C. System No. 103 Wood, Flat (Interior or Exterior):

Surface Prep.	Paint Material	Min. Coats, Cover
Wood	Alkyd Wood Primer	1 coat, 1.4 MDFT
	Acrylic Latex (Semigloss)	2 coats, 1.3 MDFTPC

D. System No. 104 Wood, Natural (Interior or Exterior):

Surface Prep.	Paint Material	Min. Coats, Cover
Wood	Sanding Sealer	1 coat, 450 SFPG
Lightly Hand Sand	Varnish Satin	2 coats, 1.3 MDFTPC

E. System No. 105 Wood, Stained and Varnished (Interior or Exterior):

Surface Prep.	Paint Material	Min. Coats, Cover
Wood	Interior Wood Stain	Match Sample
	Sanding Sealer	1 coat, 450 SFPG
Lightly Hand Sand	Varnish (Satin)	2 coats, 1.3 MDFTPC

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A. System No. 107 Ferrous Metal:

Surface Prep.	Paint Material	Min. Coats, Cover
Abrasive Blast, or Centrifugal Wheel Blast (SP 6) -OR- Pickle (SP 8)	Rust-Inhibitive Primer	1 coat, 3 MDFT
	Alkyd Semigloss	2 coats, 1.7 MDFTPC

F. System No. 109 Concrete Masonry, Low Sheen:

Surface Prep.	Paint Material	Min. Coats, Cover
Masonry	Block Filler	1 coat, 75 SFPG
	Acrylic Low Sheen	2 coats, 1.6 MDFTPC

G. System No. 113 Concrete, Semigloss:

Surface Prep.	Paint Material	Min. Coats, Cover
Concrete	Masonry Primer	1 coat, 3.0 MDFT
	Acrylic Low Sheen	2 coats, 1.6 MDFTPC

H. System No. 115 Gypsum Board and Plaster, Semigloss:

Surface Prep.	Paint Material	Min. Coats, Cover
Gypsum Board or Plaster	Latex Primer/Sealer	1 coat, 3.0 MDFT
	Acrylic Latex Semigloss	2 coats, 1.3 MDFTPC

END OF SECTION

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SECTION 09 96 35
CHEMICAL-RESISTANT COATINGS

PART 1 - GENERAL

1.01 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. List materials in proposed system.
   b. Manufacturer's product specification.
   c. Chemical resistance test results for exposure to service conditions.
   d. Application instructions.
   e. Configuration details of materials at terminations, construction joints, floor drains, and trenches.
2. Samples: 4-inch square complete system proposed for use showing thickness and finish.

B. Informational Submittals:

1. Letter from manufacturer stating applicator is qualified to do the Work and meets the quality assurance minimum experience requirements.
2. Sample of warranty, prior to starting the Work.
3. Installation instructions.
4. Field inspection and test reports.
5. Manufacturer's Certificate of Proper Installation.
6. Special guarantee.

1.02 QUALITY ASSURANCE

A. Manufacturer's Experience: Minimum 5 years manufacturing proposed products.

B. Applicator's Experience: Minimum 3 years applying proposed products.

1.03 DELIVERY, STORAGE, AND HANDLING

A. Deliver materials in manufacturer's original, unopened containers.

B. Storage: Maintain #materials in clean and dry condition. Follow manufacturer's instructions.

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1.04 ENVIRONMENTAL REQUIREMENTS

A. Temperature: Apply coating only when substrate, ambient air, and coating material are 65 degrees F or above.

B. Substrate: Not wet or have standing water.

C. Ventilation: Provide during and after application to meet all applicable safety and health regulations.

1.05 EXTRA MATERIALS

A. Furnish minimum 2 gallons of unopened topcoating material for future use by OWNER.

1.06 SPECIAL GUARANTEE

A. Furnish manufacturer's extended guarantee or warranty, with OWNER named as beneficiary, in writing, as special guarantee. Special guarantee shall provide for correction, or at the option of the OWNER, removal and replacement of Work specified in this Specification section found defective during a period of [_____] years after the date of Substantial Completion. Duties and obligations for correction or removal and replacement of defective Work as specified in the General Conditions.

PART 2 -PRODUCTS

2.01 MANUFACTURERS

A. [_____]

2.02 SERVICE CONDITIONS

A. Location: [Outdoors, exposed to weather.] [Covered, ambient temperature conditions.]

B. Surface: [Concrete] [and] [masonry] floors, walls, and vault for chemical storage and handling.

C. Traffic: Foot, light hand truck, forklifts.

D. Chemicals Stored in Containment Areas:

1. Sulfuric acid, 20 percent and 93 percent solutions.

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2. Hydrochloric acid solutions to 37 percent.
3. Anionic and cationic polymers, various concentrations.
4. Acetone.
5. Methyl ethyl ketone.
6. Acidic compounds such as hydrofluoric, phosphoric, and sulfuric.
7. Sodium bisulfite, 38 percent solution.

2.03 COATING SYSTEMS

A. Chemical-Resistant Coatings: A mixture of liquid resin-based material, setting agent, and filler designed to be troweled into place to cure to a hard state.

B. Mat-Reinforced Vinyl Ester (System CRC-1): Primer, fiberglass mat, saturant, and two trowel-applied coats of vinyl ester resin with silica fillers. Finished system thickness 150 mils minimum.

C. Epoxy (System CRC-2): Primer and one trowel-applied coat of epoxy resin with silica fillers. Finished system thickness 100 mils minimum.

2.04 MIXING

A. Thoroughly mix until homogeneous following manufacturer's instructions.

B. Mix only components furnished by coating manufacturer.

PART 3 -EXECUTION

3.01 EXAMINATION

A. Surface Preparation:

1. Inspect and provide substrate surfaces prepared in accordance with these Specifications and the printed directions and recommendations of the system manufacturer whose product is to be applied.
2. Provide ENGINEER minimum 3 days' advance notice of start of surface preparation and system application Work.
3. Perform Work only in presence of ENGINEER, unless ENGINEER grants prior approval to perform Work in ENGINEER's absence.

B. Schedule inspection with ENGINEER in advance for cleaned surfaces and system application Work.

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3.02 PREPARATION

A. In accordance with [Section 09 90 00, Painting and Coating] [, and] the manufacturer's printed directions and recommendations.

B. Fill holes and cracks with manufacturer's recommended materials to produce even surface for application of systems.

C. Concrete Surfaces:

1. Do not begin until 30 days after concrete has been placed.
2. Remove grease, oil, dirt, salts or other chemicals, loose materials, or other foreign matter by solvent, detergent, or other suitable cleaning methods.
3. Brushoff blast clean to remove loose concrete and provide a tooth for binding. Upon approval by ENGINEER, surface may be acid etched with muriatic acid solution. Approval, subject to producing desired profile.
4. Secure coating manufacturer's recommendations for additional preparation if required for excessive bug holes exposed after blasting.
5. Unless otherwise required for proper adhesion, ensure surfaces are dry prior to painting.

D. Masonry Surfaces:

1. Complete and cure masonry construction for 14 days or more before starting surface preparation Work.
2. Remove oil, grease, dirt, salts or other chemicals, loose materials, or other foreign matter by solvent, detergent washing, or other suitable cleaning methods.
3. Clean masonry surfaces of mortar and grout spillage and other surface deposits using one of the following:
   a. Nonmetallic fiber brushes and commercial muriatic acid followed by rinsing with clean water.
   b. Brushoff blasting.
   c. Water blasting.
4. Do not damage masonry mortar joints or adjacent surfaces.
5. Leave surfaces clean and, unless otherwise required for proper adhesion, dry prior to painting.
6. Masonry Surfaces to be Coated: Uniform texture and free of surface imperfections which would impair the intended finished appearance.

3.03 APPLICATION

A. Install coating systems in accordance with manufacturer's printed instructions.

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B. Install coating systems on vertical and horizontal surfaces, including caps, within containment wall for storage tanks, pumps, and piping.

C. Extend surfacing completely under structures and equipment located within the containment area. Install at construction joints in substrate and floor drains, trenches, and other components within the containment area.

3.04 FIELD QUALITY CONTROL

A. Inspection:

1. Inspect finished system for complete, uniform coverage of specified area. Evidence of defects include improper thickness, hardness, and appearance.
2. ENGINEER may require electrical spark test or other tests to be performed by CONTRACTOR when evidence of incomplete coverage exists.

3.05 MANUFACTURER'S SERVICES

A. Provide manufacturer's representative at Site [in accordance with Section 01 43 33, Manufacturers' Field Services,] for installation assistance, inspection, and Manufacturer's Certificate of Proper Installation.

3.06 APPLICATION SCHEDULE

A. [As shown in Section 09 06 00, Schedules for Finishes.]

B. [Unless otherwise shown or specified, apply coatings in accordance with the following application schedule. In the event of discrepancies or omissions in the following, request clarification from ENGINEER before starting Work in question.]

C. Coating System CRC-1: Use in the following areas:

1. [_____]
2. [_____]

D. Coating System CRC-2: Use in the following areas:

1. [_____]
2. [_____]

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3.07 SUPPLEMENT

A. The supplements listed below, following "End of Section," are a part of this Specification:

1. Corrosion Control Assistance Form

END OF SECTION

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CORROSION CONTROL ASSISTANCE FORM

To: Corrosion Control Dept.
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Date: _____

From: Name: _____ Title: _____

Address: _____

Project Description: _____

Project No.: _____

Area Requiring Specific Protection: _____

_____

Items to be Coated: _____

_____

Site Location: _____

SERVICE CONDITIONS

(Check Appropriate Items)

Immersion _____ Splash/Spillage _____ Chemical Fumes ___

Marine/Offshore _____ Industrial _____ Other _____

Chemicals Involved _____

New Construction _____ Existing Structure _____ Uncoated _____

Coated _____ Coated With (If Known) __

Operating Temp. Range __ Ambient Conditions _____

Surface Preparation Possible: Abrasive Blast ____

Power Tool Cleaning: _____ Other _____

Other Pertinent Data: _____

_____

Feedback Required By: _____

(Date): _____

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SECTION 09 97 13
STEEL TANK COATINGS

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. NACE International: RP0188, Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates.
2. NSF International (NSF): 61, Drinking Water System Components - Health Effects.
3. Society for Protective Coatings (SSPC):
   a. Surface Preparation Standards:
      1) SP 1, Solvent Cleaning.
      2) SP 2, Hand Tool Cleaning.
      3) SP 3, Power Tool Cleaning.
      4) SP 5, White Metal Blast Cleaning.
      5) SP 7, Brush-Off Blast Cleaning.
      6) SP 10, Near White Blast Cleaning.
      7) SP 11, Power Tool Cleaning to Bare Metal.
      8) SP 12, Surface Preparation and Cleaning of Metals by Waterjetting Prior to Recoating.
   b. Paint Application Guides:
      1) PA 1, Shop, Field, and Maintenance Painting of Steel.
      2) PA 2, Measurement of Dry Coating Thickness with Magnetic Gages.
      3) PA Guide 3, A Guide to Safety in Paint Application.
   c. [Technology Guide: Guide 6, Guide for Containing Debris Generated During Paint Removal Operations.]

1.02 DEFINITIONS

A. Terms used in this section:

1. Coverage: Total minimum dry film thickness in mils, or square feet per gallon.
2. MDFT: Minimum Dry Film Thickness, mils.
3. MDFTPC: Minimum Dry Film Thickness per Coat, mils.
4. Mil: Thousandth of an inch.
5. PPDS: Paint Product Data Sheet.

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6. PSDS: Paint System Data Sheet.
7. SP: Surface preparation.
8. VOC: Volatile Organic Compounds.

1.03 SUBMITTALS

A. Action Submittals:

1. Data Sheets:
   a. For each paint system used, furnish a Paint System Data Sheet (PSDS), Paint Product Data Sheet (PPDS), and paint colors available (where applicable) for each product used in paint system. The PSDS and PPDS forms are appended to the end of this section.
   b. Submit required information on a system-by-system basis.
   c. Provide copies of paint system submittals to coating applicator.
   d. Also provide copies of paint system submittals to the coating applicator.
   e. Indiscriminate submittal of manufacturer's literature only is not acceptable.
2. Detailed chemical and gradation analysis for each proposed abrasive material.
3. Samples:
   a. For each paint system used, furnish colors available (where applicable) for each product used in paint system.
   b. [Proposed Abrasive Materials: Minimum 1/2-pound Sample for each type proposed.]

B. Informational Submittals:

1. Coating manufacturer's Certificate of Compliance, in accordance with Section 01 43 33, Manufacturers' Field Services.
2. Current NSF certification for potable water contact, where applicable.
3. Anticipated tank coating sequence.
4. [Dehumidification plan, including equipment and air change rates. Submit plan based on type of equipment used, length of time required to hold blast, reservoir volume, and time of year that coating work is undertaken.]
5. [Applicator's Qualification: List of references substantiating experience.]
6. [Independent structural ENGINEER review of proposed tank containment system.]
7. Shop and field applicator's quality control program, including, but not limited to:
   a. Environmental test methods and frequency.

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b. Steel surface temperature and profile measurement procedure and frequency.
c. Record keeping form.
d. [Submit Quality Control Plan in accordance with Section 01 45 16.13, Contractor Quality Control.]

8. Manufacturer's written instructions for applying each type of coating.
9. [When self-contained blast cleaning equipment using recycled abrasives is proposed. Submit the following:
   a. List of at least three successful projects within past 3 years where equipment and procedures have been used on steel tank of similar size and dimensions.
   b. Provide tank owner's name and telephone numbers.
   c. Description of proposed equipment, procedures, and abrasive blast mix to be used.]
10. Field Testing: Inspection and test reports.
11. Manufacturer's Certificate of Proper Installation, in accordance with Section 01 43 33, Manufacturers' Field Services.

1.04 QUALITY ASSURANCE

A. Applicator Qualifications:

1. [Minimum 5 years' experience in application of specified products.] [_____]
2. [Certified by coating manufacturer for application of 100 percent solids epoxy.]

B. Regulatory Requirements: Meet federal, state, and local agencies having jurisdiction for Site and types of work activities included in Project, including, but not limited to:

1. Limitations on emission of volatile organic compounds, dust, and other contaminants.
2. Requirements for disturbance, handling, and disposal of paint waste and associated debris, including lead, coal tar, abrasive, and other regulated substances.

C. Industry Best Practices:

1. Perform surface preparation and painting in accordance with recommendations of the following:
   a. Paint manufacturer's instructions.

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b. SSPC–PA Guide 3.

2. Do not apply paint in temperatures outside of manufacturer's recommended maximum or minimum allowable, in dust, in smoke-laden atmosphere, in damp or humid weather.
3. Do not perform abrasive blast cleaning whenever relative humidity exceeds 85 percent or whenever surface temperature is less than 5 degrees F above dewpoint of ambient air.

D. Mockup:

1. Before proceeding with Work under this section, finish one complete space or item of each color scheme required showing selected colors, finish texture, materials, quality of work, and special details.
2. After approval, sample spaces or items shall serve as a standard for similar work throughout the Project.

E. [Preinstallation Meeting:

1. Prior to beginning painting Work, schedule a meeting and be prepared to discuss the following subjects, as a minimum:
   a. Required schedule.
   b. Sequence of critical path work items.
   c. Use of Site, access, office and storage areas, security, and temporary facilities.
   d. Major product delivery and priorities.
   e. Safety plan.
2. Attendees shall include:
   a. OWNER's representatives.
   b. CONTRACTOR's office representative.
   c. CONTRACTOR's resident superintendent.
   d. CONTRACTOR's quality control representative.
   e. Subcontractors' representatives whom CONTRACTOR may desire or ENGINEER may request to attend.
   f. ENGINEER's representative.
   g. Paint manufacturer's technical representative.
   h. Others as appropriate.]

1.05 DELIVERY, STORAGE, AND HANDLING

A. Shipping:

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1. Protect precoated items from damage. Batten coated items to prevent abrasion.
2. Use nonmetallic or padded slings and straps in handling.

B. Deliver materials to Site in unopened containers labeled with designated name, date of manufacture, color, and manufacturer.

C. Store paints in a protected area that is heated or cooled as required to maintain temperatures within range recommended by paint manufacturer.

1.06 SPECIAL GUARANTEE

A. Furnish manufacturer's extended guarantee or warranty, with OWNER named as beneficiary, in writing, as special guarantee. Special guarantee shall provide for correction, or at the option of OWNER, removal and replacement of Work specified in this Specification section found defective during a period of [2] [_____] years after date of Substantial Completion. Duties and obligations for correction or removal and replacement of defective Work as specified in General Conditions.

1. [24] [_____]-Month Warranty Period Inspection: OWNER will conduct inspection of interior and exterior coated surfaces prior to the end of warranty period. OWNER will notify CONTRACTOR in advance of inspection and CONTRACTOR may attend at its option. OWNER will prepare list of coating defects and failures identified during inspection and transmit to CONTRACTOR. List shall serve as notice of repairs required under warranty.
2. Repairs:
   a. If repairs are required, requirements of Contract shall apply including, but not limited to, requirements to remove standing water in tanks, perform repair work, and tank cleaning prior to disinfection.
   b. Repair defective coatings using coating materials, equipment, and methods similar to those used in original work. Materials shall be of fresh manufacture and within manufacturer's stated shelf life at time of application.
   c. Provide extended warranty of 1 year for repairs.
   d. [Provide separate bond for 1-year repair warranty period.]
   e. Complete repairs within 30 calendar days of Warranty Period Inspection.

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1.07 EXISTING COATING STATUS

A. The following information is provided for CONTRACTOR's information. Information shall not relieve CONTRACTOR from responsibility to inspect reservoir and assess existing coatings and structural dimensions.

1. [_____]
2. [_____]
3. [_____]

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Materials, equipment, and accessories specified in this section shall be products of:

1. Carboline Coatings Company, St. Louis, MO.
2. ICI Devoe, Louisville, KY.
3. International Protective Coatings, Houston, TX.
4. Sherwin-Williams, Cleveland, OH.
5. Tnemec Coatings, Kansas City, MO.
6. PPG Coatings, Pittsburgh, PA.

2.02 MATERIALS

A. Quality: Manufacturer's highest quality products and suitable for intended use.

B. Materials Including Primer and Finish Coats: Produced by same paint manufacturer.

C. Thinners, Cleaners, Driers, and Other Additives: As recommended by paint manufacturer of the particular coating.

D. [NSF Epoxy, Low VOC: 100 percent solids, two-component epoxy for water tank lining, approved for potable water contact and conforming to NSF 61.]

E. [NSF Epoxy: Polyamidoamine or phenalkamine cured epoxy coatings approved for potable water contact and conforming to NSF 61.]

F. Epoxy Primer: Two-component, polyamidoamine, phenalkamine, or polyamide cured epoxy, capable of 4-mil to 6-mil dry film thickness, and compatible with specified finish.

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G. Polyurethane Enamel: Two-component, aliphatic or acrylic based polyurethane; [semi-gloss] [high-gloss] finish.

H. Flexible Polyurethane: Modified polyurethane flexible lining membrane, approved for potable water contact conforming to NSF 61 and compatible with the NSF epoxy.

I. Caulking: Two-component polyurethane caulk, suitable for potable water contact conforming to NSF 61 and compatible with the NSF Epoxy.

2.03 COLORS

A. Formulate with colorants free of lead and lead compounds [or other materials which might be affected by presence of hydrogen sulfide or other gas likely to be present on the Project].

B. Furnish as [designated herein] [selected by [OWNER or] ENGINEER].

C. Proprietary identification of colors is for identification only. Selected manufacturer may supply matches.

2.04 MIXING

A. Multiple-Component Coatings:

1. Prepare using contents of container for each component as packaged by paint manufacturer.
2. No partial batches will be permitted.
3. Do not use multiple-component coatings that have been mixed beyond their pot life.
4. Furnish small quantity kits for touchup painting and for painting other small areas.
5. Mix only components specified and furnished by paint manufacturer.
6. Do not intermix additional components for reasons of color or otherwise, even within the same generic type of coating.

B. Keep paint material containers sealed when not in use.

2.05 ABRASIVES

A. Select abrasive type and size to produce a surface profile that meets coating manufacturer’s recommendations for specific primer and coating system to be applied.

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B. Select abrasives that conform to federal and state regulations for metals and toxicity.

2.06 SOURCE QUALITY CONTROL

A. Prime coat structural steel surfaces.

B. Notify ENGINEER at least 7 days prior to start of shop blast cleaning to allow for inspection of the Work during surface preparation and shop application of paints. Work shall be subject to ENGINEER's approval before shipment to Site.

PART 3 - EXECUTION

3.01 GENERAL

A. Surface Preparation and Coating Application: Meet or exceed requirements of these Specifications and SSPC–PA 1, whichever is more stringent.

B. Inspect and provide substrate surfaces prepared in accordance with these Specifications and printed directions and recommendations of paint manufacturer whose product is to be applied.

C. Paint [new] [and] [existing] interior and exterior exposed metal surfaces whether specifically mentioned or not, except as modified herein.

D. Provide ENGINEER a minimum of 7 days' advanced notice prior to start of surface preparation work or coating application work. Perform such work only in the presence of ENGINEER, unless ENGINEER grants prior approval to perform such work in ENGINEER's absence.

E. Schedule inspection with ENGINEER in advance for cleaned surfaces and coats prior to succeeding coat.

F. Do not apply paint in temperatures outside of manufacturer's recommended maximum or minimum allowable, or in dust, smoke-laden atmosphere, damp or humid weather.

G. Do not perform abrasive blast cleaning whenever relative humidity exceeds 85 percent, or whenever surface temperature is less than 5 degrees F above dewpoint of ambient air.

H. Ventilation for Coating Cure: Provide fans to continuously ventilate tank interior, as required, to assist with coating cure.

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I. [Remove existing cathodic protection system anodes, reference electrodes, and wiring prior to starting surface preparation activities. After coating work has been completed, reinstall and test cathodic protection system as specified in Section 26 42 00, Cathodic Protection.]

3.02 PREPARATION

A. Items such as structural steel, metal floor doors, manways, and frames, metal louvers, and similar fabricated items may be shop prepared and primed. Centrifugal wheel blast cleaning is an acceptable alternative to shop blast cleaning.

B. Remove, mask, or otherwise protect hardware, machined surfaces, nameplates, and other surfaces not intended to be painted.

C. Protect surfaces adjacent to or downwind of Work area from overspray.

D. [Protect interior of inlet/outlet and overflow pipes from abrasive blast residue and dust with inflatable pipe plug, as approved by ENGINEER. Install temporary, appropriately sized polyethylene pig in pipe before installation of plug.]

3.03 ENVIRONMENTAL CONTROLS

A. Containment System:

1. Provide full containment of blast emissions during entire blast operation for tank exterior. Meet requirements of SSPC–Guide 6 as modified below.
    a. Design: Reviewed by structural ENGINEER, licensed in the State of [_____]. Consider load bearing capacity of roof for supporting containment system.
    b. Provide Class 1 containment structure. Completely shroud tank with opaque fabric that prevents spread of blast media, spent chips, corrosion byproducts, and dust.
    c. Exhaust air shall be filtered by appropriately sized dust collectors.
    d. Verify effectiveness using [Method A, General Surveillance, Level 2, as described in SSPC–Guide 6] [_____].
2. [As an option to containment, consideration will be given to use of self-contained blast cleaning equipment using recycled abrasives.
    a. Exterior coatings shall be roller-applied to surfaces prepared using contained blast cleaning equipment.]

B. Dehumidification Equipment:

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1. Provide [full-time] [_____] dehumidification for field painting interior of reservoir. Dehumidification and heating equipment shall be provided by a supplier with at least 3 years' experience with necessary equipment.
2. Use dehumidification and heating equipment to control environment [24] [_____] hours a day during blast cleaning and coating application. At CONTRACTOR's option, dehumidification equipment may also be used during curing process.
3. Provide desiccant dehumidifiers as manufactured by Cargocaire Corporation, or equal. Desiccant dehumidifiers shall have a single rotary desiccant wheel capable of fully continuous operation. No liquid, granular, or loose lithium chloride drying systems will be allowed.
4. Interior space of reservoir shall be sealed and a slight positive pressure maintained as recommended by supplier of dehumidification equipment.
5. During blasting operation, dehumidification equipment shall continuously maintain a dewpoint of air inside tank at least 5 degrees F less than temperature of coldest part of tank where the Work is underway. Inside relative humidity shall not exceed 45 percent, unless specifically required by paint manufacturer for coating application and cure.
6. Auxiliary heat may be necessary to maintain surface temperature at an acceptable level for application of coating. Auxiliary equipment shall be approved for use by dehumidification equipment supplier and shall meet the following requirements:
    a. Install heaters in process air supply duct between, and blended with, dehumidifier as close to space as possible.
    b. Use electric, indirect fired combustion, or steam coil auxiliary heaters. Direct fired space heaters will not be allowed during blasting, coating, or curing cycles.
    c. Equip heaters with controls that automatically turn heater off if airflow is interrupted or internal temperature of heater exceeds its design temperature or design temperature of supply duct.
7. Measure and record ambient temperature, relative humidity, dewpoint and reservoir wall temperature a minimum of twice daily (beginning and end of work shifts) to verify proper environmental levels are achieved inside reservoir. Field-measured test results shall be made available to ENGINEER upon request.

C. Filtration System:

1. Designed to remove dust from air so that it does not interfere with dehumidification equipment's ability to control dewpoint and relative humidity inside reservoir.

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2. Air from reservoir or dust filtration equipment shall not be recirculated through dehumidifier during coating application or when solvent vapors are present.

3.04 PREPARATION OF SURFACES

A. Metal Surfaces:

1. Meet requirements of the following SSPC Specifications:
   a. Solvent Cleaning: SP 1.
   b. Hand Tool Cleaning: SP 2.
   c. Power Tool Cleaning: SP 3.
   d. White Metal Blast Cleaning: SP 5.
   e. Brush-Off Blast Cleaning: SP 7.
   f. Near-White Blast Cleaning: SP 10.
   g. Power Tool Cleaning to Bare Metal: SP 11.
   h. High Pressure Water Jetting: SP 12.
2. Wherever the words “solvent cleaning”, “hand tool cleaning”, “wire brushing”, or “blast cleaning”, or similar words of equal intent are used in these Specifications or in paint manufacturer’s specifications, they shall be understood to refer to the applicable SSPC Specifications listed above.
3. Where OSHA or EPA regulations preclude standard abrasive blast cleaning, wet or vacu-blast methods may be required. Coating manufacturers’ recommendations for wet blast additives and first coat application shall apply.
4. Preblast Cleaning Requirements:
   a. Remove oil, grease, welding fluxes, and other surface contaminants prior to blast cleaning.
   b. Cleaning Methods: Steam, open flame, hot water, or cold water with appropriate detergent additives followed with clean water rinsing.
   c. Clean small isolated areas as above or solvent clean with suitable solvents and clean cloths.
   d. Round or chamfer sharp edges and grind smooth burrs, jagged edges, and surface defects.
   e. Welds and Adjacent Areas:
      1) Prepare such that there is:
         a) No undercutting or reverse ridges on weld bead.
         b) No weld spatter on or adjacent to weld or other area to be painted.
         c) No sharp peaks or ridges along weld bead.
      2) Grind embedded pieces of electrode or wire flush with adjacent surface of weld bead.

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5. Blast Cleaning Requirements:
    a. Type of Equipment and Speed of Travel: Design to obtain specified degree of cleanliness. Minimum surface preparation is as specified herein and takes precedence over coating manufacturer's recommendations.
    b. Select type and size of abrasive to produce a surface profile that meets coating manufacturer's recommendations for particular primer to be used.
    c. Use only dry blast cleaning methods.
    d. Do not reuse abrasive, except for designed recyclable systems.
    e. Meet applicable federal, state, and local air pollution and environmental control regulations for blast cleaning and disposition of spent aggregate and debris.
6. Post-blast Cleaning and Other Cleaning Requirements:
    a. Clean surfaces of dust and residual particles from cleaning operations by dry (no oil or water vapor) air blast cleaning or other method prior to painting. Vacuum clean enclosed areas and other areas where dust settling is a problem and wipe with a tack cloth.
    b. Paint surfaces the same day they are blast cleaned. Reblast surfaces that have started to rust before they are coated.

3.05 APPLICATION

A. General:

1. The intention of these Specifications is for [existing and] new, [interior] [and] [exterior] metal and submerged metal surfaces to be painted, whether specifically mentioned or not, except as modified herein.
2. Coatings Subject to Immersion:
    a. Apply coatings to internal vessel, pipe surfaces, nozzle bores, flange gasket sealing surfaces, carbon steel internals, and stainless steel internals unless otherwise specified.
    b. Curing:
        1) Obtain full cure for completed system.
        2) Consult coatings manufacturer's written instructions.
        3) Do not immerse coating until completion of curing cycle.
3. Apply coatings in accordance with paint manufacturer's recommendations. Allow sufficient time between coats to ensure thorough drying of previously applied coat.
4. Prior to assembly or installation, paint units to be bolted together and to structures.

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5. Where more than one coat of a material is applied within a given system, alternate color to provide a visual reference that required number of coats have been applied.
6. With brush, work coating into and behind anchor bolts, anchor chairs, and other areas that are difficult to paint by spray.

B. Shop Primed Surfaces:

1. Hand or power sand areas of chipped, peeled, or abraded coating, feathering the edges. Follow with a spot primer using specified primer.
2. For two-package or converted coatings, consult coatings manufacturer for specific procedures as relates to manufacturer's products.
3. Prior to application of finish coats, clean shop primed surfaces free of dirt, oil, and grease and apply one coat of specified primer.
4. After welding, prepare and prime holdback areas as required for specified paint system. Apply primer in accordance with manufacturer's instructions.

C. Stripe Coating:

1. Consists of one coat, brush applied, to coating thickness specified.
2. Apply between intermediate and final coats.
3. Color shall contrast intermediate coat to allow visual verification of application.
4. Apply to field welds, edges, angles, fasteners, and other irregular surfaces located inside tanks.

D. Film Thickness and Coverage:

1. Number of Coats:
   a. Minimum required without regard to coating thickness.
   b. Additional coats may be required to obtain minimum required paint thickness, depending on method of application, differences in manufacturers' products, and atmospheric conditions.
2. Maximum film build per coat shall not exceed coating manufacturer's recommendations.

3.06 PROTECTIVE COATINGS SYSTEMS AND APPLICATION SCHEDULE

A. System No. 1A Submerged Metal—Potable Water:

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Surface Prep.	Paint Material	Min. Coats, Cover
Shop: Solvent clean and abrasive blast or centrifugal wheel blast (SP-5) Field: [Detergent wash and fresh water rinse.] Brush-off blast shop primer, abrasive blast areas of damaged primer, and field weld holdback areas to white metal (SP-5)	NSF Epoxy (Shop Applied, White)	1 coat, 4 MDFT
	NSF Epoxy (white), Spot Repairs and Welds	1 coat, 4 MDFT
	NSF Epoxy Intermediate Coat (grey or beige)	1 coat, 4 MDFT
	Stripe Coat with NSF Epoxy	1 coat, 3 MDFT
	NSF Epoxy Finish Coat (white)	1 coat, 4 MDFT

1. Minimum Dry Film Thickness, Total System:
   a. Nonstripe Coated Areas: 12 MDFT.
   b. Stripe Coated Areas: 15 MDFT.
2. Application Schedule:
   a. Use on submerged metal surfaces inside tank, including, but not limited to, steel plates and structural steel, exposed surfaces of inlet, outlet, and overflow piping, hatches, covers, ladders, landings, and couplings.
   b. Coat exposed stainless steel surfaces inside tank. Coat interior surfaces of stainless steel pipe for a distance of 24 inches where stainless steel pipe is connected to coated carbon steel pipe.
   c. Use on exterior surfaces of direct buried and concrete encased steel pipe.
   d. Coating is not required for bottom side of floor plates.
   e. Provide full coating thickness to structural steel surfaces that will be covered by roof plates or otherwise shielded from full coating thickness, before structural members are installed. Not required for surfaces located behind members that are fully seal welded.

B. System No. 1B Special Coating under Column Baseplate:

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Surface Prep.	Paint Material	Min. Coats, Cover
Shop: Solvent clean and abrasive blast or centrifugal wheel blast (SP-5) Field: [Detergent wash and fresh water rinse.] Brush-off blast shop primer, and as required by paint manufacturer	NSF Epoxy (Shop Applied)	1 coat, 4 MDFT
	NSF Epoxy	Field applied, as required by paint manufacturer
	Flexible Polyurethane	1 coat, 50 MDFT

1. Minimum Dry Film Thickness, Total System: 54 mils.
2. Application Schedule:
   a. Use on bottom of column baseplate and top of steel floor surface under baseplate.
   b. Prepare surfaces and apply coating prior to installation of columns.
   c. Extend flexible polyurethane coating on floor 2 inches beyond outside perimeter of column baseplate.

C. System No. 1C Submerged Metal-Potable Water (Low VOC):

Surface Prep.	Paint Material	Min. Coats, Cover
Shop: Solvent clean and abrasive blast or centrifugal wheel blast (SP-5)	NSF Epoxy (Shop Primer)	1 coat, 4 mils MDFT
Field: [Detergent wash and fresh water rinse.] Brush-off blast shop primer, abrasive blast areas of damaged primer and field weld holdback areas to white metal (SP-5)	NSF Epoxy (Low VOC, Field Applied)	1 coat, multiple pass, [_____] MDFT

1. Minimum Dry Film Thickness, Total System: [_____] mils.
2. Application Schedule:

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a. Use on submerged metal surfaces inside tank, including, but not limited to, steel plates and structural steel, exposed surfaces of inlet, outlet, and overflow piping, hatches, covers, ladders, landings, and couplings.
b. Coat exposed stainless steel surfaces inside tank.
c. Coat interior surfaces of stainless steel pipe for a distance of 24 inches where stainless steel pipe is connected to coated carbon steel pipe.
d. Use on exterior surfaces of direct buried and concrete encased steel pipe.
e. Coating is not required for bottom side of floor plates.
f. Provide full coating thickness to structural steel surfaces that will be covered by roof plates or otherwise shielded from full coating thickness, before structural members are installed. Not required for surfaces that will be behind members that are fully seal welded.

D. System No. 1D Special Coating under Column Baseplate (Low VOC):

Surface Prep.	**Paint Material**	**Min. Coats, Cover**
Shop: Solvent clean and abrasive blast or centrifugal wheel blast (SP-5)	NSF Epoxy (Shop Applied)	1 coat, 4 MDFT
	NSF Epoxy Tie Coat	Field applied, as required by paint manufacturer
Field: [Detergent wash and fresh water rinse.] Brush-off blast shop primer, and as required by paint manufacturer	NSF Epoxy, Low VOC	1 or 2 coats, 30 MDFT

1. Minimum Dry Film Thickness, Total System: 34 mils.
2. Application Schedule:
   a. Use on bottom of column baseplate and top of steel floor surface under baseplate.
   b. Prepare surfaces and apply coating prior to installation of column.
   c. Extend coating on floor 2 inches beyond outside perimeter of column baseplate.

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E. System No. 5 Exposed Metal:

Surface Prep.	Paint Material	Min. Coats, Cover
Shop : Abrasive blast, or centrifugal wheel blast (SP 10) Field: [Detergent wash and fresh water rinse.] Brush-off blast shop primer, abrasive blast areas of damaged primer and field weld holdback areas to white metal (SP-10)	Polyamide, Anticorrosive Epoxy Primer	1 coat, 2.5 MDFT
	Polyamide, Anticorrosive Epoxy Primer	1 coat, 3 MDFT
	Polyurethane Enamel	1 coat, 3 MDFT

1. Minimum Dry Film Thickness, Total System: 8.5 mils.
2. Application Schedule:
   a. Use on the following:
      1) Exposed exterior metal surfaces of tank.
      2) For galvanized surfaces to be coated, reference System No. 10.
      3) [Exposed metal surfaces inside elevated tank supporting structures, including bottom of tank.]

F. System No. 10 Galvanized Metal Conditioning:

Surface Prep.	Paint Material	Min. Coats, Cover
Solvent Clean (SP 1) followed by Hand Tool (SP 2), Power Tool (SP 3), or Brush-off Blast (SP 7)	Coating manufacturers' recommended primer followed by System No. 5	

1. Application Schedule: Use on galvanized surfaces, including handrails and gratings, before application of System No. 5.

3.07 FIELD QUALITY CONTROL

A. Test Equipment:

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1. Provide a dry film thickness gauge to test coating thickness as specified in mils. Use [magnetic type dry as manufactured by Nordson Corp., Anaheim, CA, Mikrotest] [electronic dry film thickness, as manufactured by DeFelsko, Ogdensburg, NY, Positest] or approved equal.
2. Provide electrical holiday detector, low voltage, wet sponge type to test finish coat, except zinc primer, high-build elastomeric coatings, and galvanizing as manufactured by Tinker and Rasor, San Gabriel, CA; Model M-1.

B. Film Thickness Measurements and Electrical Inspection of Coated Surfaces:

1. Perform with properly calibrated instruments.
2. Repair or recoat defective areas as necessary for compliance with Specifications.
3. All coats are subject to inspection by ENGINEER and coating manufacturer's representative.
4. Give particular attention to edges, angles, flanges, and other similar areas, where insufficient film thicknesses are likely to be present, and ensure proper millage in these areas.

C. Thickness Testing:

1. Measure coating thickness specified in mils with magnetic or electronic type dry film thickness gauge in accordance with SSPC–PA 2.
2. Check each coat for correct thickness. Do not make measurement before a minimum of 8 hours after application of coating.
3. After repaired and recoated areas have dried sufficiently, tests will be conducted by ENGINEER.

D. Holiday (Pinhole) Testing: Test finish coat on 100 percent submerged surfaces for holidays and discontinuities with electrical holiday detector in accordance with NACE RP0188.

E. Unsatisfactory Application:

1. If improper finish color or insufficient film thickness, clean surface and topcoat with specified paint material to obtain specified color and coverage. Obtain specific surface preparation information from coating manufacturer.
2. Evidence of runs, bridges, shiners, laps, or other imperfections are causes for rejection.
3. Repair defects in coating systems in accordance with written recommendations of coating manufacturer.

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4. Leave staging up until ENGINEER has inspected surface or coating. Replace staging removed prior to approval by ENGINEER.

F. Damaged Coatings, Pinholes, and Holidays:

1. Feather edges and repair in accordance with recommendations of paint manufacturer.
2. Hand or power sand visible areas of chipped, peeled, or abraded paint, and feather edges. Follow with primer and finish coat in accordance with Specifications. Depending on extent of repair and appearance, a finish sanding and topcoat may be required.
3. Apply finish coats, including touchup and damage-repair coats in a manner that will present a uniform texture and color-matched appearance.

3.08 MANUFACTURER'S SERVICES

A. Coating manufacturer's technical representative shall be present at Site as follows:

1. On the first day of application of coating.
2. A minimum of three additional Site inspection visits, each for a minimum of 3 hours.
3. As required for application quality assurance, and to determine compliance with manufacturer's instructions and these Specifications.
4. As necessary to resolve field problems attributable to or associated with manufacturer's products furnished under this Contract.
5. To verify full cure of coating prior to placing coated surfaces into immersion service.

3.09 CLEANUP

A. Place cloths and waste that might constitute a fire hazard in closed metal containers or destroy at end of each day.

B. Upon completion of the Work, remove staging, scaffolding, and containers from Site or destroy in a legal manner.

C. Completely remove paint spots, oil, or stains upon adjacent surfaces and floors and leave Site clean.

3.10 SUPPLEMENTS

A. The supplements listed below, following "End of Section," are a part of this Specification:

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1. Data Sheet: Example Paint System Data Sheet (PSDS)
2. Data Sheet: Example Paint Product Data Sheet (PPDS)

END OF SECTION

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PAINT SYSTEM DATA SHEET

Complete and attach manufacturer's Technical Data Sheet to this PSDS for each coating system.

Paint System Number (from Spec.):		
Paint System Title (from Spec.):		
Coating Supplier:		
Representative:		
Surface Preparation:		
Paint Material (Generic)	**Product Name/Number (Proprietary)**	**Min. Coats, Coverage**

Provide manufacturer's recommendations for the following parameters at temperature (F)/relative humidity:

Temperature/RH	50/50	70/30	90/25
Induction Time			
Pot Life			
Shelf Life			
Drying Time			
Curing Time			
Min. Recoat Time			
Max. Recoat Time			

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Provide manufacturer's recommendations for the following:

Mixing Ratio: _____

Maximum Permissable Thinning:_____

Ambient Temperature Limitations: min.: _____ max.: _____

Surface Temperature Limitations: min.: _____ max.: _____

Surface Profile Requirements: min.: _____ max.: _____

[Attach additional sheets detailing manufacturer's recommended storage requirements and holiday testing procedures.]

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PAINT PRODUCT DATA SHEET

Complete and attach manufacturer's Technical Data Sheet to this PDS for each product submitted. Provide manufacturer's recommendations for the following parameters at temperature (F)/relative humidity:

Temperature/RH	50/50	70/30	90/25
Induction Time			
Pot Life			
Shelf Life			
Drying Time			
Curing Time			
Min. Recoat Time			
Max. Recoat Time			

Provide manufacturer's recommendations for the following:

Mixing Ratio: _____

Maximum Permissible Thinning:_____

Ambient Temperature Limitations: min.: _ max.: ____

Surface Temperature Limitations: min.: _ max.: ____

Surface Profile Requirements: min.: _ max.: ____

[Attach additional sheets detailing manufacturer's recommended storage requirements and holiday testing procedures.]

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SECTION 09 97 26
CEMENTITIOUS COATINGS

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM):
   a. C67, Standard Test Methods of Sampling and Testing Brick and Structural Clay Tile.
   b. C109, Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-inch or 50-mm Cube Specimens).
   c. C190, Tensile Strength of Hydraulic Cement Mortars, Test Method for.
   d. C348, Standard Test Method for Flexural Strength of Hydraulic Cement Mortars.
   e. C666, Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing.

1.02 SUBMITTALS

A. Action Submittals:

1. Manufacturer’s product descriptions and specifications.
2. Samples: Three 12-inch by 12-inch Samples of finish surface, color, and texture to be provided.

B. Informational Submittals:

1. Manufacturer’s application instructions.
2. Applicator Qualifications: Manufacturer’s letter of qualification.
3. Manufacturer’s Certificate of Compliance or independent test lab data.
4. Manufacturer’s intent to warrant the applied system.
5. Manufacturer’s Certificate of Proper Installation.
6. Special guarantee.

1.03 QUALITY ASSURANCE

A. Applicator Qualifications:

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1. Minimum of 5 years' local experience.
2. Approval by system manufacturer.

B. Mockup:

1. Prior to application of the materials, erect a Sample wall panel mockup using materials and joint details required in the final Work.
2. Build mockup at Site, where directed, of full thickness, approximately 4 feet by 4 feet indicating proposed color, texture, and workmanship to be expected in the completed Work.
3. Obtain Engineer's and manufacturer's acceptance [in writing] prior to start of Work.
4. Do not alter, move, or destroy mockup until so instructed by Engineer.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Store materials in area where temperatures are not less than 40 degrees F or over 85 degrees F, unless otherwise authorized by manufacturer.

1.05 ENVIRONMENTAL REQUIREMENTS

A. Approvals: Obtain Engineer's and manufacturer's representative's approval of substrate and environmental conditions prior to starting Work.

B. Temperature: Do not proceed with application of materials when ambient or substrate temperature is less than 40 degrees F or expected to fall below that within 24 hours. During cold weather maintain minimum temperature of between 40 degrees F and 50 degrees F throughout curing period.

C. Conditions: Do not apply in rainy conditions or within 3 days after surfaces become wet from rainfall. Protect surfaces to prevent rapid drying in high wind or hot sun.

1.06 SPECIAL GUARANTEE

A. Manufacturer's extended guarantee or warranty, with Owner named as beneficiary, in writing, as special guarantee. Special guarantee shall provide for correction, or at the option of the Owner, removal and replacement of Work specified in this Specification section found defective during a period of 5 years after the date of Substantial Completion. Duties and obligations for correction or removal and replacement of defective Work as specified in the General Conditions.

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PART 2 - PRODUCTS

A. CONCRETE FINISH COATING

B. Description: Heavy, cement base, waterproof, and decorative coating.

C. Performance Requirements After Curing for 28 Days:

Compressive Strength	6,000 psi (28 days)	ASTM C109
Tensile Strength	425 psi (28 days)	ASTM C190
Flexural Strength	1,000 psi (28 days)	ASTM C348
Absorption	3.6 percent	ASTM C67
Wind-Driven Rain	No penetration after 8 hours at 98 mph	
5,000-hour Weatherometer	No visible defects	

D. Materials:

1. Bonding Agent: Acrylic polymer resin.
2. Cementitious Coating: Heavy bodied, cement base, finely graded and sized aggregate type, heavy-duty, waterproof, and decorative coating formulated for brush or trowel application.
3. Water: Clean and potable.
4. Manufacturers and Products:
   a. Thoro System Products; Thoroseal.
   b. Tamms Industries Co.; Tamoseal.

2.02 CEMENTITIOUS COATING

A. Description: Heavy, cement base, waterproof, texture coating, for concrete and masonry surfaces, that hides concrete surface defects and masonry joints.

B. Performance Requirements After Curing for 28 Days:

Compressive Strength	4,000 psi	ASTM C109
Tensile Strength	310 psi	ASTM C190
Flexural Strength	850 psi	ASTM C348
Absorption	5 percent maximum	ASTM C67, 24-hour submersion

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Freeze/Thaw	DF >95 percent after 300 cycles	ASTM C666, Procedure B
Or	0.60 percent weight loss	ASTM C67 loss at 50 cycles
5,000-hour Weatherometer	No visible defects	

C. Materials:

1. Bonding Agent: Acrylic polymer resin.
2. Cementitious Leveling and Texture Coats: Heavy, cement base, aggregate type, graded, textured waterproof and decorative coating formulated for plaster spray gun or trowel application.
3. Color Coating: Acrylic masonry paint, 100 percent acrylic emulsion that is alkali, acid, and mildew resistant.
4. Water: Clean and potable.
5. Manufacturers and Products:
   a. Thoro System Products; Thoroseal Plaster Mix.
   b. Tamms Industries Co.; Concrete Finisher.

2.03 MIXES

A. Follow manufacturer's instructions.

B. Thoroughly mix cementitious materials to a uniform plastic and workable consistency and color using the proper amount of bonding agent and water. Avoid overwet or soupy mix.

PART 3 -EXECUTION

3.01 PREPARATION

A. Protection: Protect plants and vegetation that might be affected by fumes or alkalinity of the materials.

B. Surface Preparation:

1. Ensure surfaces to be coated are sound, clean, and free of efflorescence, form release agents, curing compounds, oils, dust, chalking, paint, or other imperfections that will cause loss of bond.
2. Clean and prepare new and existing surfaces in accordance with written instructions of material manufacturer.

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3. Remove loose material.
4. Patch holes deeper than 1/2 inch.
5. Cut out deep and deteriorated areas 2 inches or greater in area or depth, making a square or dove cut.
6. Vacuum, sweep, or blow out areas to be patched.
7. Dampen surface and patch as recommended by manufacturer.

3.02 APPLICATION

A. Special Techniques:

1. Do not apply materials in direct heat of sun. If extreme heat is encountered, cool surface with water prior to application.
2. Use only manufacturer's recommended application tools.

B. Concrete Finish Coating:

1. Follow manufacturer's instructions for surface preparation and application.
2. Brush apply first coat at a rate of 2 pounds per square yard.
3. Allow initial coat to set, then apply second coat at same rate.
4. After second coat has taken initial set, float to a uniform sand texture using a sponge float.

C. Cementitious Coating:

1. Leveling or Key Coat: Follow manufacturer's instructions for surface preparation, and application of minimum 1/8-inch thick coating.
2. Apply a brush coat of cementitious coating as directed by manufacturer.
3. Apply light trowel coating as directed by manufacturer. Use steel trowel and firmly press material into all voids. Level coat for application of finish coat. Mix consistency and rate of application and amount of acrylic bonding agent shall be as directed by manufacturer for the specific job conditions and requirements. Allow to cure for 7 days.
4. Evenly distribute spray applied coating. Keep spray gun a uniform distance from surface. Move nozzle with steady, even strokes. Do not angle nozzle. Float or brush out to fill holes, pores, and imperfections.
5. Finish Coat: After key coat has cured, apply a second trowel coat application mixed with at least 1 part acrylic bonding admixture to 3 parts clean water. Float with sponge float when surface is set so that it will not roll or lift. Do not use water. Mix consistency and rate of application shall be as directed by manufacturer for specific job conditions and requirements.

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6. Spray on one or more evenly distributed light coats after key coat has set and air and water bubbles have broken to achieve uniform finish. Over concrete masonry units, hide joints.
7. Finish Texture:
8. Finished Surface: [Medium to fine stippled or dash texture with irregular pattern.] [Sand float texture.] [Brocade texture.] [Vertically scraped texture.]
   a. [Leave surface clean and ready for paint.]

D. Color Coating: [Apply two coats, following manufacturer's instructions.] [As specified in Section 09 90 00, Painting and Coating] [_____].

3.03 MANUFACTURER'S SERVICES

A. Provide manufacturer's representative at Site in accordance with Section 01 43 33, Manufacturers' Field Services, for installation assistance, inspection and certification of proper installation.

B. Give manufacturer and Engineer reasonable notice as to the specific construction schedule of the surface preparation and material application. Technical service may be provided by the manufacturer or a trained, qualified representative appointed by the manufacturer.

END OF SECTION

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SECTION 10 14 00
SIGNAGE

PART 1 - GENERAL

1.01 SUMMARY

A. Section includes interior signs.

B. Related Sections:

1. Section 22 05 53, Identification for Plumbing Piping and Equipment.
2. Section 23 05 53, Identification for HVAC Piping and Equipment.

C. Allowances: Include under provisions of Section 01 20 00, Price and Payment Procedures: Allowances. Allowance includes [furnishing interior signs. Installation is included in this section and is part of Contract Sum/Price] [furnishing and installing interior signs].

1.02 REFERENCES

1.03 SUBMITTALS

A. Section 01 33 00, Submittal Procedures: Submittal procedures.

B. Action Submittals: Submit the following:

1. Shop Drawings:
   a. Indicate sign styles, lettering font, foreground and background colors, locations, overall dimensions of each sign.
   b. Schedule of all signage required for the Work, indicating signage type location, and other information to demonstrate compliance with the Contract Documents.
   c. Fabrication and erection information for each type of signage
   d. Valve schedule for small-diameter valves, in accordance with this Section.
   e. Mounting and Installation Data:
      1) Drawings of and information on anchorages and accessory items.
      2) Submit location template drawings for items supported or anchored to permanent construction.
      3) Coordinate mounting position, method, and proposed mounting accessories and fasteners with actual Project conditions. Indicate required mounting accessories on plan drawings showing locations

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of required exit signs based on measurements taken at the Site. Show final location and identify type of mounting surface for each exit sign. Coordinate location of exit signs for non-interference with other Work and as required by authorities having jurisdiction.

2. Product Data: Copies of manufacturer's technical data, including catalog information and specifications, for each product specified.
3. Samples:
   a. Each color and finish of exposed materials and accessories required for signage.
   b. Samples Sinage: Submit two full size signs illustrating type, style, letter font, and colors specified; method of attachment.
   c. Engineer's review of Samples will be for color and texture only. Compliance with other requirements is Contractor's responsibility.

C. Informational Submittals: Submit the following:

1. Manufacturer's Instructions:
   a. Templates for anchorages to be installed in concrete or masonry.
   b. Manufacturer's instructions and recommendations for support and foundations of signs installed outdoors.

1.04 QUALITY ASSURANCE

A. Perform Work in accordance with State of California standard.

B. Maintain one copy of each document on site.

1.05 QUALIFICATIONS

A. Manufacturer: Company specializing in manufacturing Products specified in this section with minimum three years documented experience.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Section 01 60 00, Product Requirements: Product storage and handling requirements.

B. Package signs, labeled in name groups.

1.07 ENVIRONMENTAL REQUIREMENTS

A. Section 01 60 00, Product Requirements: Environmental conditions affecting products on site.

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B. Do not install signs when ambient temperature is lower than recommended by manufacturer.

C. Maintain this minimum temperature during and after installation of signs.

PART 2 - PRODUCTS

2.01 GENERAL:

A. Details shown or indicated for signage, such as alpha-numeric and text type representation, letter spacing, designs of borders, and other graphic features, are generic and intended only to establish text, general positions, and symbols.

B. Colors shall be brilliant, distinctive shades, matching the safety colors specified in ANSI Z535.1 and OSHA 1910.144.

2.02 INTERIOR SIGNS

A. Manufacturers:

1. APCO Graphics Model
2. ASI Sign Systems Model
3. Daktronics, Inc.
4. FFI Group, Inc.
5. Mills Manufacturing
6. Unicor Model

2.03 COMPONENTS

A. Engraved Signs: Laminated colored plastic; lettering engraved through face to expose core color:

1. Face Color: [Clear.] [wood grain, [walnut] [_____].] [_____.] [Color as selected.]
2. Core Color: [_____].
3. Total Thickness: [1/16] [1/8] inch.
4. Height: [2] [3] [_____] inches.
5. Edges: [Square.] [Beveled.] [Radiused.]
6. Character Font: [Helvetica.] [_____.]

B. Sand Blasted Signs: Acrylic high gloss plastic; letters sand blasted to dull sheen:

1. Color: [Clear.] [Solid color.] [Color as selected.]
2. Total Thickness: [1/8] [_____] inch.

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3. Height: [2] [3] [_____] inches.
4. Edges: [Square.] [Beveled.] [Radiused.]
5. Character Font: [Helvetica.] [_____.]

C. Silk Screened Signs: Letters [_____] inch high silk screened onto plastic surface:

1. Sign Color: [Clear.] [Solid color.] [Color as selected.]
2. Character Color: [Contrasting] [_____] color.
3. Total Thickness: [1/8] [_____] inch.
4. Height: [2] [3] [_____] inches.
5. Edges: [Square.] [Beveled.] [Radiused.]
6. Character Font: [Helvetica.] [_____.]

D. Injection Molded [Cast] Signs: [Acrylic plastic] [Cast aluminum]:

1. Sign Color: [Clear.] [Solid color.] [Color as selected.]
2. Character Color: [Contrasting color.] [Ground satin surface.] [_____.]
3. Total Thickness: [1/8] [_____] inch.
4. Height: [2] [3] [_____] inches.
5. Edges: [Square.] [Beveled.] [Radiused.]
6. Character Font: [Helvetica.] [_____.]

E. Raised Letter Signs, Base Material: [Clear] [Solid color] acrylic plastic:

1. Total Thickness: [1/8] [_____] inch.
2. Height: [2] [3] [_____] inches.
3. Edges: [Square.] [Beveled.] [Radiused.]
4. Character Font: [Helvetica.] [_____.]

F. Raised Character Size and Style: Acrylic plastic, character adhered to base material:

1. Character Color: [Black.] [_____.]
2. Character Thickness: [1/8] [_____] inch.
3. Height: [1] [1-1/2] [_____] inch.
4. Edges: [Square.] [Beveled.] [Radiused.]
5. Character Font: [Helvetica.] [_____.]
6. Character Case: [Upper] [and] [lower] case.

G. Individual Graphics, Material: [Clear] [Solid color] acrylic plastic:

1. Thickness: [1/8] [_____] inch.
2. Height: [2] [3] [_____] inches.
3. Edges: [Square.] [Beveled.] [Radiused.]

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4. Character Color: [Black.] [_____.]
5. Character Font: [Helvetica.] [_____.]
6. Character Case: [Upper] [and] [lower] case.

H. Graphic Style: [Handicapped type.] [_____.]

2.04 ACCESSORIES

A. Tape Adhesive: Double sided tape, permanent adhesive.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Section 01 30 00, Administrative Requirements: Verification of existing conditions before starting work.

3.02 INSTALLATION

A. Install signs after doors surfaces are finished, in locations as directed by Engineer.

B. Center sign on door surface, level.

3.03 SCHEDULES

A. Office Door Signs: Individual Helvetica letters, 1 inch high, white color, identifying room name indicated on drawing schedule.

B. Service Room Signs: Plaque signs, 2 inches high, black face color, white core color, "UTILITY ROOM", "SERVICE ROOM", and "ELECTRICAL ROOM"; at each respective room location.

C. Rest Room Door Graphic: 6 inches high, "male" and "female" graphic image; black color, located on each rest room door.

END OF SECTION

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SECTION 10 44 00
FIRE PROTECTION SPECIALTIES

PART 1 - GENERAL

1.01 SUMMARY

A. Section includes fire extinguishers; fire blankets; fire extinguisher cabinets; and brackets for wall mounting.

B. Related Sections:

1. Section 06 10 53, Miscellaneous Rough Carpentry: Wood blocking and shims.
2. Section 09 90 00, Painting and Coating: Field applied paint finish.
3. Section 21 12 00, Fire-Suppression Standpipes: Cabinet enclosure for extinguishers [and blankets].

1.02 REFERENCES

A. National Fire Protection Association: NFPA 10, Standard for Portable Fire Extinguishers.

B. Underwriters Laboratories Inc.: UL, Fire Protection Equipment Directory.

1.03 PERFORMANCE REQUIREMENTS

A. Conform to NFPA 10.

B. Provide extinguishers classified and labeled by Underwriters Laboratories Inc.for purpose specified and indicated.

C. Provide fire extinguisher cabinets classified and labeled by Underwriters Laboratories Inc. for purpose specified and indicated.

1.04 SUBMITTALS

A. Section 01 33 00, Submittal Procedures: Submittal procedures.

B. Action Submittals: Submit the following:

1. Product Data: Manufacturer’s technical data, extinguisher operational features, color and finish, anchorage details, certification of UL rating, and installation instructions for fire protection specialties.

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2. Shop Drawings: Indicate cabinet physical dimensions, rough-in measurements for recessed cabinets, wall bracket mounted measurements, location, and fire ratings.
3. Manufacturer's Installation Instructions: Submit special criteria and wall opening coordination requirements.

1.05 CLOSEOUT SUBMITTALS

A. Section 01 70 00, Execution and Closeout Requirements: Closeout procedures.

B. Operation and Maintenance Data: Submit test, refill or recharge schedules and re-certification requirements.

1.06 QUALITY ASSURANCE

A. Perform Work in accordance with State of California standard.

B. Maintain one copyof each document on site.

C. Component Supply and Compatibility: Provide fire protection specialties products from one manufacturer.

D. Regulatory Requirements: Provide fire protection specialties approved and labeled by UL.

1.07 ENVIRONMENTAL REQUIREMENTS

A. Section 01 60 00, Product Requirements: Environmental conditions affecting products on site.

B. Do not install extinguishers when ambient temperature are capable of freezing extinguisher ingredients.

PART 2 - PRODUCTS

2.01 FIRE EXTINGUISHERS

A. General: Provide manufacturer’s standard mounting brackets for portable fire extinguishers size as specified.

B. Multi-Purpose Dry Chemical Fire Extinguishers:

1. Ten-pound capacity, enameled steel container with pressure-indicating gauge, for Class A, Class B, Class C fires, UL rating 4A-60 BC.

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2. Products and Manufacturers: Provide one of the following:
   a. Cosmic Model 10E by J.L. Industries.
   b. Or equal.

C. Carbon Dioxide Fire Extinguishers:

1. Ten-pound enameled steel container capacity, for Class B and Class C fires UL rating.
2. Products and Manufacturers: Provide one of the following:
   a. Sentinel Model 10 by J.L. Industries.
   b. Or equal.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Section 01 30 00, Administrative Requirements: Coordination and project conditions.

B. Examine substrates and conditions under which fire protection specialties will be installed and notify Engineer in writing of conditions detrimental to proper and timely completion of the Work. Do not proceed with Work until unsatisfactory conditions have been corrected in manner acceptable to Engineer.

3.02 INSTALLATION

A. When exact locations of fire protection specialties are not shown on Drawings, locate as directed by Engineer.

B. Securely fasten products to structure, square and plumb, per Supplier's instructions. Mounting heights shall be:

1. Install fire extinguishers with gross weight greater than 40 pounds with top of fire extinguisher no more than 3.5 feet above finished floor.
2. Install fire extinguishers with gross weight less than 40 pounds with top of fire extinguisher no more than 4.0 feet above finished floor.
3. Clearance between bottom of fire extinguisher and finished floor shall be at least four inches.

C. Identification Devices: Provide signs level and plumb directly above surface mounted portable fire extinguishers, securely mounted, and attached to substrate per sign manufacturer's instructions. Signage shall be per Section 10 14 00, Signage.

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D. Recharge fire extinguishers provided under this Contract so that most recent inspection date coincides as nearly as possible with date of Substantial Completion. Inform OWNER in writing of next required inspection and recharging date.

3.03 SCHEDULES

A. Type A – Dry chemical, wall mounted.

B. Type B – Carbon dioxide, wall mounted.

END OF SECTION

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SECTION 11 53 00
LABORATORY EQUIPMENT

PART 1 - GENERAL

1.01 SUMMARY

A. Section includes laboratory equipment; connection to utilities; and service fittings and outlets.

B. Related Sections: Section 03 10 00 - Concrete Forming and Accessories: Execution requirements for inserts for laboratory equipment specified by this section.

C. Allowances: Include under provisions of Section 01 20 00 - Price and Payment Procedures. Allowance includes purchase and delivery of laboratory equipment. Installation is included in this section and is part of Contract Sum/Price] [purchase, delivery, and installation of laboratory equipment].

1.02 REFERENCES

A. National Electrical Manufacturers Association: NEMA MG 1 - Motors and Generators.

1.03 SUBMITTALS

A. Section 01 33 00 - Submittal Procedures: Submittal requirements.

B. Shop Drawings: Indicate equipment locations, large scale plans, elevations, cross sections, rough-in and anchor placement dimensions and tolerances, clearances required and [_____].

C. Product Data: Submit equipment dimensions and construction, equipment capacities, physical dimensions, utility and service requirements and locations, point loads

D. Manufacturer's Installation Instructions: Submit special installation requirements

E. Manufacturer's Certificate: Certify [products] meet or exceed specified requirements

1.04 SUSTAINABLE DESIGN SUBMITTALS

A. Section 01 81 13 - Sustainable Design Requirements: Requirements for sustainable design submittals.

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B. Manufacturer's Certificate: Certify products meet or exceed specified sustainable design requirements.

1. Materials Resources Certificates:
   a. Certify recycled material content for recycled content products.
   b. Certify source for local and regional materials and distance from Project site.

C. Product Cost Data: Submit cost of products to verify compliance with Project sustainable design requirements. Exclude cost of labor and equipment to install products.

1. Provide cost data for the following products:
   a. Reused products.
   b. Products with recycled material content.
   c. Local and regional products.
   d. [_____.]

1.05 CLOSEOUT SUBMITTALS

A. Section 01 70 00 - Execution and Closeout Requirements: Closeout procedures.

B. Project Record Documents: Record actual locations of concealed utility connections

C. Operation and Maintenance Data: Submit description of equipment operation, adjusting, and testing required Identify system maintenance requirements, servicing cycles, lubrication types required and [local] spare part sources.

D. Warranty: Submit Manufacturer's warranty and ensure forms have been completed in Owner's name and registered with manufacturer.

1.06 QUALITY ASSURANCE

A. Sustainable Design Requirements:

1. Recycled Content Materials: Furnish materials with recycled content including cabinets and countertops:] [.]
   a. >25 percent

B. Maintain one copy of each document on site.

1.07 QUALIFICATIONS

A. Manufacturer: Company specializing in manufacturing products specified in this section with minimum three years documented experience.

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1.08 COORDINATION

A. Section 01 30 00, Administrative Requirements: Coordination and project conditions.

B. Leave building openings of sufficient size to permit transport of equipment to final position.

1.09 WARRANTY

A. Section 01 70 00, Execution and Closeout Requirements: Product warranties and product bonds.

B. Furnish five]year manufacturer warranty for laboratory equipment.

PART 2 - PRODUCTS

2.01 LABORATORY EQUIPMENT

A. Manufacturers:

1. [The Chicago Faucet Co.] Model [_____].
2. [Delta Faucet Co., Commercial Div.] Model [_____].
3. [Hemco Corporation] Model [_____].
4. [Mopec Inc.] Model [_____].
5. [T&S Brass & Bronze Works, Inc.] Model [_____].
6. Eagle Group Model #SR14-16-9.5-2.
7. Substitutions:

2.02 COMPONENTS

A. Equipment: Scheduled at end of section.

B. Rough-in: Frames, anchors, supports, accessories and closure trim; appropriate to scheduled equipment.

C. Resin counter top with splash guard; L-shaped counter-top (6.75’x2’ and 7.75’x2’) .

D. 16”x14” Type 304 stainless steel, double compartment lab sink, model #SR14-16-9.5.2 by Eagle group with faucet #300490 with 12” spout.

E. 36” Resin drying rack over each of the sink area.

F. 24” wide hinged glass door wall cabinet.

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G. Ergonomic chair (Teclab – Seatwise high ring chair Model CHRI-2432).

2.03 ELECTRICAL CHARACTERISTICS AND COMPONENTS

A. Electrical Characteristics: In accordance with Section 26 05 03 <<not in this package>>, and the following:

1. [[_____]hp] [[_____] rated load amperes.]
2. [115_____] volts, single phase, 60 Hz.
3. [_____] amperes maximum [fuse size] [circuit breaker size] [overcurrent protection].
4. [_____] minimum circuit ampacity.
5. [_____] percent minimum power factor at rated load.

B. Motors: NEMA MG 1.

2.04 SHOP FINISHING

A. Equipment and Accessories: [Zinc chromate] [_____] primer; two [baked] enamel finish coats in [_____] color [as selected].

PART 3 - EXECUTION

3.01 EXAMINATION

A. Section 01 30 00, Administrative Requirements: Coordination and project conditions.

B. Verify rough-in frames, anchors and supports are accurately placed.

3.02 PREPARATION

A. Coordinate rough-in frame and anchor placement by Section [03 10 00.]

B. INSTALLATION

C. Install in accordance with standards required by authority having jurisdiction.

D. Anchor equipment securely in place.

E. Sequence installation to accommodate required utility connections.

F. Touch-up minor damaged surfaces caused during installation. Replace damaged components.

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3.03 ADJUSTING

A. Section 01 70 00, Execution and Closeout Requirements: Testing, adjusting, and balancing.

B. Adjust operating equipment to efficient operation.

3.04 SCHEDULES

A. Fume Hood Manufacturers:

1. Teclab Model [TBD].
2. LabconcoModel [TBD].
3. Air Master Systems Corp. Model [TBD].
4. Features: Stainless steel cabinet interior, baked enamel cabinet exterior, stone work top surface, sliding framed glass sash, 75 cfm exhaust through open sash, adjustable baffles, 100 w incandescent lamp in vapor tight light fixture.
5. Working Surface of Fume Hood: Capable of supporting 75 psi live load.

B. Lab equipment schedule:

Item	**Description**	**Quantity**
Turbidity meter	2100Q turbidimeter kit	1
Vials	For turbiditimeter	1
pH/Conductivity meter	SensIon MM374 GLP Duel Channel kit	1
Colorimeter	DR890 Portable Colorimeter kit	1
Colorimeter	Ferrous Fe powder pillow	1
Colorimeter	Total Fe powder pillows	1
Colorimeter	Cr6 powder pillows	1
Colorimeter	CrT powder pillow kit (set)	1
Colorimeter	Arsenic Test kit	1
Breakers	100mL Poly pk12	1
Graduated cylinders	25 mL	2

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Item	Description	Quantity
Graduated cylinders	100 mL	2
Graduated cylinders	1000 mL	2

END OF SECTION

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SECTION 13 34 19
METAL BUILDING SYSTEMS

PART 1 - GENERAL

1.01 SUMMARY

A. Section includes pre-engineered, shop fabricated structural steel building frame; [insulated] metal wall and sloped roof system including [soffits,] [gutters and downspouts,] [roof mounted equipment curbs,] [and] [_____]; and exterior doors [windows,] [skylights,] [overhead doors,] [louvers,] [and] [_____].

B. Related Sections:

1. Section 03 10 00, Concrete Forming and Accessories: Execution requirements for placement of [anchor bolts] [base plates] [_____] specified in this section in concrete.
2. Section 07 90 00, Joint Protection.
3. Section 09 90 00, Painting and Coating: Finish painting [of exterior primed steel surfaces,] [inside surface of liner sheet,] [and] [_____].
4. Section [_____-_____]: Mechanical rough-in utilities.
5. Section [_____-_____]: Electrical rough-in utilities.
6. Section [_____-_____], Fire Protection Systems.

1.02 REFERENCES

A. American Institute of Steel Construction:

1. AISC S335, Specification for Structural Steel Buildings Allowable Stress Design, and Plastic Design.
2. AISC S342L, Load and Resistance Factor Design Specification for Structural Steel Buildings.
3. AISC S344L, Metric Load and Resistance Factor Design Specification for Structural Steel Buildings.

B. ASTM International:

1. ASTM A36/A36M, Standard Specification for Carbon Structural Steel.
2. ASTM A123/A123M, Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
3. ASTM A153/A153M, Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.

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4. ASTM A307, Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength.
5. ASTM A325, Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength.
6. ASTM A490, Standard Specification for Heat-Treated Steel Structural Bolts, 150 ksi Minimum Tensile Strength.
7. ASTM A500/A500M, Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes.
8. ASTM A501, Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing.
9. ASTM A529/A529M, Standard Specification for High-Strength Carbon-Manganese Steel of Structural Quality.
10. ASTM A572/A572M, Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel.
11. ASTM A653/A653M, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.
12. ASTM A792/A792M, Standard Specification for Steel Sheet, 55% Aluminum-Zinc Alloy-Coated by the Hot-Dip Process.
13. ASTM C665, Standard Specification for Mineral-Fiber Blanket Thermal Insulation for Light Frame Construction and Manufactured Housing.
14. ASTM C991, Standard Specification for Flexible Glass Fiber Insulation for Pre-Engineered Metal Buildings.
15. ASTM C1107/C1107M, Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink).
16. ASTM C1371, Standard Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers.
17. ASTM C1549, Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer.
18. ASTM E84, Standard Test Method for Surface Burning Characteristics of Building Materials.
19. ASTM E96/E96M, Standard Test Methods for Water Vapor Transmission of Materials.
20. ASTM E408, Standard Test Methods for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques.
21. ASTM E903, Standard Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres.
22. ASTM E1918, Standard Test Method for Measuring Solar Reflectance of Horizontal and Low-Sloped Surfaces in the Field.
23. ASTM E1980, Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces.

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24. ASTM E1996, Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors and Impact Protective Systems Impacted by Windborne Debris in Hurricanes.

C. American Welding Society:

1. AWS A2.4, Standard Symbols for Welding, Brazing, and Nondestructive Examination.
2. AWS D1.1, Structural Welding Code, Steel.

D. Green Seal: GC-03, Anti-Corrosive Paints.

E. Metal Building Manufacturers Association: MBMA, Low Rise Building Systems Manual.

F. SSPC: The Society for Protective Coatings:

1. SSPC, Steel Structures Painting Manual.
2. SSPC Paint 20, Zinc-Rich Primers (Type I - Inorganic and Type II - Organic).

G. Underwriters Laboratories Inc.: UL, Building Materials Directory.

H. U.S. Environmental Protection Agency: ENERGY STAR - ENERGY STAR Voluntary Labeling Program.

1.03 SYSTEM DESCRIPTION

A. [Single span rigid frame.] [Tapered beam.] [Continuous beam frame.] [Truss frame.] [Lean-to.] [_____.]

B. Bay Spacing: [_____] ft.

C. Primary Framing: Rigid frame of rafter beams and columns, [canopy beams,] [intermediate columns,] [braced end frames,] [end wall columns,] [_____,] and wind bracing.

D. Secondary Framing: [Purlins,] [girts,] [eave struts,] [flange bracing,] [sill supports,] [_____,] clips, and other items detailed.

E. Wall System: Preformed metal panels of [horizontal] [vertical] [_____] profile, [with sub-girt framing/anchorage assembly,] [insulation,] [liner sheets,] and accessory components.

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F. Roof System: Preformed metal panels of [upslope] [parallel to eave] [_____] profile, [with sub-girt framing/anchorage assembly,] [insulation,] [liner sheets,] and accessory components.

G. Roof Slope: [1/8] [1] [2] [4] [_____] inches in 12 inches.

1.04 DESIGN REQUIREMENTS

A. Thermal resistance of [Calculated] [Installed] Wall System: R-Value of [_____].

B. Thermal Resistance of [Calculated] [Installed] Roof System: R-Value of [_____].

C. Design members to withstand dead load, [applicable snow load,] [vertical and horizontal seismic loads,] and design loads due to pressure and suction of wind calculated in accordance with [[applicable] [_____] code.] [design load schedule.]

D. Design members to withstand [_____] psf dead load, [[_____] psf [nominal] [progressive] snow [and live] load], and [_____] psf design loads due to pressure and suction of wind.

E. Design members to withstand UL 580 - Uplift Resistance, Uplift Class [10.] [30.] [60.] [90.]

F. [Design members to support [mechanical] [and] [electrical] equipment [and] [fire sprinkler system piping] indicated.]

G. Maximum allowable deflection: [1/90] [1/180] [_____] of span with imposed loads for exterior wall and roof system.

H. Provide drainage to exterior for water entering or condensation occurring within wall or roof system.

I. Permit movement of components without buckling, failure of joint seals, undue stress on fasteners or other detrimental effects, when subject to temperature range of [_____] degrees F.

J. Size and fabricate wall and roof systems free of distortion or defects detrimental to appearance or performance.

K. Wind-Borne Debris Loads: Design louvers located within 30 feet of grade to withstand ASTM E1996; large missile impact test.

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1.05 PERFORMANCE REQUIREMENTS

A. Conform to [applicable] [_____] code for submission of [design calculations,] [reviewed shop and erection drawings,] [and] [_____] as required for acquiring permits.

B. Cooperate with regulatory agency or authority and provide data as requested authority having jurisdiction.

C. Provide components of each type from one manufacturer compatible with adjacent materials.

D. Vapor Retarder Permeance: Maximum [1 perm] [[_____] perms] when tested in accordance with ASTM E96/E96M, [desiccant method] [water method].

1.06 SUBMITTALS

A. Section 01 33 00, Submittal Procedures: Submittal procedures.

B. Shop Drawings: Indicate assembly dimensions, locations of structural members, [connections,] [attachments,] [openings,] [cambers,] [loads,] [and] [_____]; wall and roof system dimensions, panel layout, general construction details, anchorages and method of anchorage, method or installation [and] [_____]; framing anchor bolt settings, sizes, and locations from datum, [and foundation loads]; indicate welded connections with AWS A2.4 welding symbols; indicate net weld lengths; provide professional seal and signature.

C. Product Data: Submit data on profiles, component dimensions, [fasteners,] [performance characteristics] [and] [_____].

D. Samples: Submit [two] [_____] samples of precoated metal panels for each color selected, [_____] inch in size illustrating color and texture of finish.

E. Manufacturer's Instructions: Submit preparation requirements, anchor bolt placement, [and] [_____].

F. Erection Drawings: Indicate members by label, assembly sequence, and temporary erection bracing.

1.07 SUSTAINABLE DESIGN SUBMITTALS

A. Section 01 81 13, Sustainable Design Requirements: Requirements for sustainable design submittals.

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B. Manufacturer's Certificate: Certify products meet or exceed specified sustainable design requirements.

1. Sustainable Sites Certificates: Certify roofing materials solar reflectance index.
2. Materials Resources Certificates:
   a. Certify recycled material content for recycled content products.
   b. Certify source for local and regional materials and distance from Project site.
3. Indoor Air Quality Certificates: Certify volatile organic compound content for each interior paint and coating.

C. Product Cost Data: Submit cost of products to verify compliance with Project sustainable design requirements. Exclude cost of labor and equipment to install products.

1. Provide cost data for the following products:
   a. Products with recycled material content.
   b. Local and regional products.
   c. [_____.]

1.08 CLOSEOUT SUBMITTALS

A. Section 01 70 00, Execution and Closeout Requirements: Closeout procedures.

B. Project Record Documents: Record actual locations of concealed components and utilities.

1.09 QUALITY ASSURANCE

A. Perform Work in accordance with [AISC S335,] [AISC S342L,] [AISC S344L,] [and] [MBMA Low Rise Building Systems Manual.]

B. Insulation Installed in Concealed Locations Surface Burning Characteristics:

1. Batt Insulation: Maximum 25/450 flame spread/smoke developed index when tested in accordance with ASTM E84.

C. Insulation Installed in Exposed Locations Surface Burning Characteristics: 25/450 flame spread/smoke developed index when tested in accordance with ASTM E84.

D. Sustainable Design Requirements:

1. Recycled Content Materials: Furnish materials with recycled content [including:] [.]

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Material	Minimum Recycled Content (Percent)	
	Post Consumer	Pre Consumer

a. [_____.]

2. Regional Materials: Furnish materials extracted, processed, and manufactured within 500 miles of Project site [including:] [.]
   a. [_____.]

E. Perform Work in accordance with [[State] [Municipality] of [_____] [Highways] [Public Work's] standard.]

F. Maintain [one copy] [[_____] copies] of [each] document on site.

1.10 QUALIFICATIONS

A. Manufacturer: Company specializing in manufacturing products specified in this section with minimum three years documented experience.

B. Erector: Company specializing in performing Work of this section [with minimum [_____] years [documented] experience.] [approved by manufacturer.]

C. Design structural components, develop shop drawings, and perform shop and site work under direct supervision of Professional Engineer experienced in design of this Work and licensed [at Project location.] [in State of [_____].]

1.11 PRE-INSTALLATION MEETINGS

A. Section 01 30 00, Administrative Requirements: Pre-installation meeting.

B. Convene minimum [one] [_____] week prior to commencing work of this section.

1.12 WARRANTY

A. Section 01 70 00, Execution and Closeout Requirements: Product warranties and product bonds.

B. Furnish [five] [_____] year manufacturer warranty for pre-engineered building systems and components.

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C. Furnish [five] [_____] year warranty to include coverage for exterior pre-finished surfaces color coat against chipping, cracking or crazing, blistering, peeling, chalking, or fading. Include coverage for weather tightness of building enclosure elements after installation.

PART 1 - PRODUCTS

2.01 PRE-ENGINEERED BUILDINGS

A. Manufacturers:

1. [Butler Manufacturing Co.] Model [_____].
2. [Lester Building Systems] Model [_____].
3. [Trachte Building Systems, Inc.] Model [_____].
4. [Varco-Pruden Buildings] Model [_____].
5. [_____] Model [_____].
6. Substitutions: [Section 01 60 00, Product Requirements] [Not Permitted].

B. Furnish materials in accordance with [State] [Municipality] of [_____] [Highways] [Public Work's] standards.

2.02 COMPONENTS - FRAMING

A. Structural Steel Members: ASTM [A36/A36M.] [A529/A529M Grade 50.] [A572/A572M, Grade 50.] [_____.]

B. Structural Tubing: ASTM [A500/A500M, Grade [B] [_____].] [A501.]

C. Plate or Bar Stock: ASTM [A529/A529M Grade 50.] [_____.]

D. Anchor Bolts: ASTM A307 Grade A, [unprimed.] [galvanized.]

E. Bolts, Nuts, and Washers: [ASTM A325] [ASTM A490] [galvanized].

F. Welding Materials: AWS D1.1; type required for materials being welded.

G. Primer: [SSPC Paint 20, Red Oxide.] [_____.]

1. [Interior] Anti-Corrosive Paints: Maximum volatile organic compound content in accordance with GC-03.

H. Non-Shrink Grout: ASTM C1107/C1107M; premixed compound consisting of non-metallic aggregate, cement, water reducing and plasticizing agents; capable of developing minimum compressive strength of [2,400] [_____] psi in 48 hours and [7,000] [_____] psi in 28 days manufactured by [_____].

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2.03 COMPONENTS - WALL AND ROOF SYSTEM

A. Sheet Steel: [ASTM A653/A653M; [G90] [_____] zinc coating] [ASTM A792/A792M; [AZ50] [_____] aluminum-zinc alloy coating]; [0.030] [_____] inch thick.

B. Sheet Steel Stock: ASTM A792/A792M aluminum-zinc alloy Coating Designation [AZ50] [_____].

C. Insulation: [Semi-rigid] [Batt] [Roll] glass fiber type, [unfaced,] [faced with reinforced [foil] [white vinyl]], friction fit, [_____] inches thick.

D. Insulation: [ASTM C665 [Type I] [Type II Class [A] [B] [C]] [Type III Class [A] [B] [C]]] [ASTM C991 Type [I] [II]]; [_____] inches thick.

E. Joint Seal Gaskets: [Manufacturer's standard] [_____] type.

F. Fasteners: Manufacturer's standard type, [galvanized] [high performance organic coating], finish to match adjacent surfaces when exterior exposed.

G. Bituminous Paint: [Asphaltic] [_____] type.

H. Sealant: [Manufacturer's standard] [_____] type, [as specified in Section 07 90 00,] non-staining, elastomeric, skinning.

I. [Metal Mesh: Galvanized steel wire, woven.]

J. Roof Curbs: Insulated metal same as roofing, [_____] inch thick, designed for imposed equipment loads, anchor fasteners to equipment, counterflashed to metal roof system.

K. Trim, Closure Pieces, Caps, Flashings, [Rain Water Diverter,] [Facias] [Infills], [and] [_____]: Same material, thickness and finish as exterior sheets; brake formed to required profiles.

2.04 COMPONENTS - METAL DOORS AND FRAMES

A. Manufacturers:

1. [_____] Model [_____].
2. [_____] Model [_____].
3. [_____] Model [_____].
4. Substitutions: [Section 01 60 00, Product Requirements] [Not Permitted].

B. Doors: Specified in Section [08 13 15.] [_____.]

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C. Frames: Specified in Section [08 12 15.] [_____.]

D. Doors and Frames: Manufacturer's standard.

2.05 COMPONENTS - OVERHEAD DOORS

A. Manufacturers:

1. [_____] Model [_____].
2. [_____] Model [_____].
3. [_____] Model [_____].
4. Substitutions: [Section 01 60 00, Product Requirements] [Not Permitted].

B. Overhead Doors: Specified in Section [08 36 13.] [_____.]

C. Overhead Door Frame: Formed steel sections braced to building frame specified in Section 05 50 00.

D. Doors and Frames: Manufacturer's standard.

E. Glass and Glazing: Specified in Section [08 80 00.] [_____.]

2.06 COMPONENTS - WINDOWS

A. Manufacturers:

1. [_____] Model [_____].
2. [_____] Model [_____].
3. [_____] Model [_____].
4. Substitutions: [Section 01 60 00, Product Requirements] [Not Permitted].

B. Windows: Specified in Section [08 51 26.] [08 51 13.] [08 52 00.] [08 53 00.] [_____.]

C. Windows: Manufacturer's standard.

D. Glass and Glazing: Specified in Section [08 80 00.] [_____.]

2.07 PLASTIC SKYLIGHTS

A. Manufacturers:

1. [_____] Model [_____].
2. [_____] Model [_____].
3. [_____] Model [_____].

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4. Substitutions: [Section 01 60 00, Product Requirements] [Not Permitted].

B. Plastic Skylight: Specified in Section [08 62 00] [_____].

C. Plastic Skylight: Manufacturer's standard.

D. Single Dome: [Acrylic] [Polycarbonate] plastic, [_____] inch thick; [clear.] [white translucent.] [_____.]

E. Double Dome: [Acrylic] [Polycarbonate] plastic, [_____] inch thick; [air] [argon] seal space:

1. Outer Dome: [clear] [white translucent] [_____].
2. Inner Dome: [clear] [white translucent] [_____].

F. Nominal Size: [[____x____] inches single unit.] [as scheduled.]

G. Configuration: [Single] [Multiple] [_____] units.

H. Shape: [Convex] [Pyramidal] [_____].

I. Unit Frame: Extruded aluminum [thermally broken,] integral curb frame [and counterflashing,] with integral condensation drainage gutter.

J. Support Curb: Aluminum sandwich construction; [_____] inch thick, [_____] inch high, fiber glass insulated, with flange for anchorage to roof deck, counterflashed and formed to roofing metal.

2.08 FABRICATION - FRAMING

A. Fabricate members in accordance with AISC Specification for plate, bar, tube, or rolled structural shapes.

B. Anchor Bolts: Formed with [bent] [straight] shank, assembled with template for casting into concrete.

C. Provide framing for [door] [window] [louver] [skylight,] [ventilator,] [and] [_____] openings.

2.09 FABRICATION - WALL AND ROOF SYSTEMS

A. Siding: Minimum [_____] inch metal thickness, [_____] profile [indicated], [_____] inch deep, [lapped] [male/female] edges [fitted with continuous gaskets].

B. Roofing: Minimum [_____] inch metal thickness, [_____] profile, [lapped] [male/female] edges [fitted with continuous gaskets].

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1. Roof Surfaces: ENERGY STAR compliant with minimum solar reflectance index (SRI) of [78] [29] for 75 percent of roof area, calculated in accordance with ASTM E1980.
   a. Reflectance: Measured in accordance with ASTM E903, ASTM E1918, or ASTM C1549.
   b. Emittance: Measured in accordance with ASTM E408 or ASTM C1371.
2. Roof Surface: ENERGY STAR compliant with the following performance:
   a. Emissivity: Minimum 0.9 for 75 percent of roof area in accordance with ASTM E408.

C. Liner: Minimum [_____] inch metal thickness, [flat] [V crimped] [perforated] profile [indicated], [lapped V] [male/female] edges [fitted with continuous gaskets].

D. Soffit Panels: Minimum [_____] inch metal thickness, [flat] [V crimped] [_____] profile [indicated], [perforated for ventilation] [unperforated].

E. Girts/Purlins: Rolled formed structural shape to receive siding, roofing [and liner] sheet.

F. Internal and External Corners: Same material thickness and finish as adjacent material, profile [brake formed] [shop cut and factory mitered] to required angles. Back brace mitered internal corners with [_____] inch thick sheet.

G. Expansion Joints: Same material and finish as adjacent material [where exposed], [_____] inch thick, [manufacturer's standard brake formed] [infill] [_____] type, of profile [to suit system.] [formed as detailed.]

H. Flashings, Closure Pieces, [Fascia], [Infills], [Caps], and [_____]: Same material and finish as adjacent material, profile [to suit system.] [formed as detailed.]

I. Fasteners: To maintain load requirements and weather tight installation, same finish as cladding, non-corrosive [type.] [finish.]

J. Ventilator: [Sheet steel, galvanized, rotary design, [_____] inch nominal size.] [_____.]

K. Wall Louvers: [_____] type [Z] [Y] [_____] blade design, [same finish as adjacent material] [_____], with steel mesh [bird] [insect] screen and frame, [blank sheet metal] [_____] at unused portions.

2.10 FABRICATION - GUTTERS AND DOWNSPOUTS

A. Fabricate of same material and finish as roofing metal.

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B. Form gutters and downspouts [and scuppers] of [_____] profile and size [indicated] to collect and remove water. Fabricate with connection pieces.

C. Form sections in maximum possible lengths. Hem exposed edges. [Allow for expansion at joints.]

D. Fabricate support straps of same material and finish as roofing metal, color as selected.

2.11 FACTORY FINISHING

A. Framing Members: Clean, prepare, and [shop prime.] [prime to SSPC Manual requirements.] [galvanize to ASTM A123/A123M; galvanize after fabrication.] [Do not prime surfaces to be field welded.]

B. Galvanizing for Nuts, Bolts and Washers: ASTM A153/A153M.

C. Interior Surfaces of [Wall] [Roof] Components and Accessories: Precoated enamel on steel of [modified silicone] [_____] finish, [_____] color [as selected from manufacturer's standard range].

D. Exterior Surfaces of [Wall] [Roof] Components and Accessories: Precoated enamel on steel of [modified silicone] [fluoropolymer] [_____] finish, [_____] color [as selected from manufacturer's standard range].

E. Vapor Retarder at Interior Face of Insulation: Sheet vinyl, [_____] inch thick, [white.] [_____.]

PART 3 - EXECUTION

3.01 EXAMINATION

A. Section 01 30 00, Administrative Requirements: Coordination and project conditions.

B. Verify foundation, floor slab, mechanical and electrical utilities, and placed anchors are in correct position.

3.02 ERECTION - FRAMING

A. Erect framing in accordance with AISC Specification.

B. Provide for erection and wind loads. Provide temporary bracing to maintain structure plumb and in alignment until completion of erection and installation of permanent bracing. [Locate braced bays as indicated on Drawings.]

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C. Set column base plates with non-shrink grout to achieve full plate bearing.

D. Do not field cut or alter structural members without approval of Architect/Engineer.

E. After erection, prime welds, abrasions, and surfaces not [shop primed.] [galvanized.]

F. Install Work in accordance with [State] [Municipality] of [_____] [Highways] [Public Work's] standards.

3.03 ERECTION - WALL AND ROOFING SYSTEMS

A. Exercise care when cutting prefinished material to ensure cuttings do not remain on finish surface.

B. Fasten cladding system to structural supports, aligned level and plumb.

C. Locate end laps over supports. End laps minimum [2] [_____] inches. Place side laps over bearing.

D. Install expansion joints where indicated on Drawings.

E. Use [concealed] [exposed] fasteners.

F. Install insulation [and vapor retarder] utilizing [_____] for attachment. [Place wire mesh under vapor retarder for support between framing members.]

G. Install sealant and gaskets to prevent weather penetration.

H. Install Work in accordance with [State] [Municipality] of [_____] [Highways] [Public Work's] standards.

3.04 ERECTION - GUTTER AND DOWNSPOUTS

A. Rigidly support and secure components. Joint lengths with formed seams sealed watertight. Flash and seal gutters to downspouts.

B. Apply bituminous paint on surfaces in contact with cementitious materials.

C. Slope gutters minimum [_____] inch/ft.

D. Connect downspouts to [storm sewer system.] [_____.]

E. Install splash [pans] [pads] [_____] under each downspout.

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F. Install Work in accordance with [State] [Municipality] of [_____] [Highways] [Public Work's] standards.

3.05 ERECTION - SKYLIGHTS

A. Coordinate with installation of roofing system and related flashings.

B. Apply bituminous paint on aluminum surfaces of units in contact with dissimilar metals.

C. Provide weather tight installation.

D. Install Work in accordance with [State] [Municipality] of [_____] [Highways] [Public Work's] standards.

3.06 ERECTION - ACCESSORIES

A. Install [door frame,] [door,] [overhead door,] [window and glass,] [skylight,] [louvers,] [and] [_____].

B. Seal wall and roof accessories watertight [and weather tight] with sealant [in accordance with Section 07 90 00].

C. Install Work in accordance with [State] [Municipality] of [_____] [Highways] [Public Work's] standards.

3.07 ERECTION TOLERANCES

A. Section 01 40 00, Quality Requirements: Tolerances.

B. Framing Members: [1/4] [_____] inch from level; [1/8] [_____] inch from plumb.

C. Siding and Roofing: [1/8] [_____] inch from indicated position.

END OF SECTION

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SECTION 21 24 00
DRY-CHEMICAL FIRE-EXTINGUISHING SYSTEMS

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Society of Mechanical Engineers (ASME): B31.1, Power Piping.
2. ASTM International (ASTM):
   a. A53, Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless.
   b. A106, Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service.
   c. A197, Standard Specification for Cupola Malleable Iron.
3. National Electrical Manufacturer's Association (NEMA): 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
4. National Fire Protection Association (NFPA):
   a. 12A, Halon 1301 Fire Extinguishing Systems.
   b. 70, National Electrical Code.
   c. 72, National Fire Alarm Code.
   d. 75, Standard for the Protection of Electronic Computer/Data Processing Equipment.
   e. 2001, Standard on Clean Agent Fire Extinguishing Systems.

1.02 DEFINITIONS

A. Protected Area: The area of the building that the FM-200 system protects.

1.03 PERFORMANCE REQUIREMENTS

A. General: Design a system to detect and suppress by total flooding, fires originating in the following protected areas:

1. MW-20 Bench Building.
2. TW Bench Building.

B. Fire Detection System:

1. Engineered type suitable for interfacing with the FM-200 suppression system.

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2. Concept shall provide an alarm mode on the activation of any one fire detector and a predischarge mode on the activation of any two fire detectors located in the protected area.

C. Fire Suppression System:

1. System shall discharge the total calculated agent quantity into the protected space in a 10-second time period.
2. System shall provide sufficient FM-200 agent for a concentration of 7 percent by volume at 70 degrees F in the protected area. Adjust calculations as required for:
   a. Multiple protected areas served by a common FM-200 supply.
   b. Suspended ceiling space volume (if required).
   c. Volume of ductwork for HVAC system.

1.04 DESIGN REQUIREMENTS

A. General:

1. System shall include both automatic and manual operation, with control panel, fire detectors, alarm devices, manual discharge stations, abort stations, agent storage containers, piping, nozzles, wiring, conduit, and other auxiliary devices specified herein or required to provide a complete system.
2. System shall conform to the requirements of applicable codes, standards, and authorities including, but not limited to:
   a. National Fire Code-NFPA Nos. 12A, 70, 72, 75, and 2001, including appendages.
   b. Requirements of city, county, or state authorities having jurisdiction.
   c. Requirements of OWNER's insurance underwriter, if applicable.
   d. Equipment shall be Underwriters Laboratories (UL) listed and/or Factory Mutual (FM) approved for fire protection.
3. Obtain all permits, arrange all inspections, and perform all systems tests required by the applicable codes and the authorities having jurisdiction.

B. Protected Area Segregation:

1. System shall be based on the protected area enclosure being of sufficient tightness to guard against extinguishing agent exfiltration including, but not limited to exit doors and windows, piping, and electrical conduit.
2. Area segregation shall require HVAC system supply and return serving the protected space to shut down, and the air duct system motorized dampers to close.

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C. Hydraulic Calculations: Base on the unbalanced piping principle as defined in NFPA No. 12A., and include:

1. Agent quantity for each nozzle.
2. Nozzle type and size.
3. Nozzle pressure.
4. Number of agent storage cylinders, cylinder fill weight, and density.
5. Total FM-200 agent weight.
6. Pipe schedule including sizes, length, volume, and percent of agent in pipe after discharge.
7. Discharge time.
8. Pressure at beginning of pipe network.
9. Pressure at beginning and end of each pipe section.
10. Flow rate, density, and pressure drop per pipe section.

D. Pipe Supports: Design and fabrication shall conform to the requirements of ASME B31.1.

E. Discharge Nozzles:

1. Provide sufficient nozzles to assure a uniform agent concentration throughout protected area.
2. Space discharge nozzles as required by applicable codes and manufacturer's criteria.
3. Consider additional nozzles based on area conditions and manufacturer's recommendations.

F. Fire Detectors:

1. Ionization and photoelectric type.
2. Base spacing and installation on guidelines in NFPA 72 recommended practices for ceiling construction and airflow, and on manufacturer's recommendations.

G. Locate manual discharge and abort stations at all exit doors from the protected area.

H. Locate alarm devices within the protected area and above each exit door outside the protected area.

I. Control Panel:

1. Panel Locations:

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a. MW-20 Bench Building.
b. TW Bench Building.

2. Locate to provide control, supervision, annunciation, and power for the operation of the fire suppression zone and detection circuits.
3. Provide rechargeable battery supply to automatically operate each protected area system including detectors, control panel, manual stations, alarm sounding devices, and auxiliary equipment in the event of a loss of primary power.
4. Provide a common general alarm circuit for common area signaling.
5. Provide form "C" SPDT dry contacts for general alarm and trouble.
6. Provide a single switch that will silence active signals without affecting subsequent signals.
7. Provide diagnostic indicators to indicate, at a minimum, ac power loss, dc power fault, auxiliary power loss, system common ground fault, and trouble in the common general alarm circuit.
8. Control Circuitry: Provide each protected area with the following supervised circuits:
   a. Detection: Utilizing cross-zoned or counting zone.
   b. Individually Fused and Silenceable Audible Circuits:
      1) Three required.
      2) Individual diagnostic fault indicators.
      3) Minimum of 24V dc, at 350 mA available power.
      4) Program to operate on alarm, predischarge, and discharge.
   c. Manual Release: Programmable with the following options:
      1) Override time delay and abort circuit. Discharge will be immediate.
      2) Override abort circuit but not the time delay. Discharge occurs at the end of the time delay.
      3) Not override time delay or abort circuits.
   d. Time Delay:
      1) Field programmable in 1-second intervals from 0 to 60 seconds.
      2) Have the ability, through the abort circuit, of being recycled and held until the abort switch is released.
      3) Control panel-mounted digital countdown timer.
      4) Illuminated digital display when the system time delay is active and counting down.
   e. Agent Release:
      1) Parallel wired initiators or solenoids, fully supervised.
      2) Wired in a Class A configuration such that a trouble signal will occur if there is a break in the wiring.

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3) System shall function properly if a fire condition occurs with this abnormal condition.

f. Abort:
   1) Dedicated and supervised.
   2) Actuation shall recycle the time delay to its original setting, and begin counting after the abort station (momentary) pushbutton is released.

g. Container Low-Pressure: Dedicated and supervised.

h. Diagnostic Fault Indicators: Detection, alarm audible, predischarge audible, discharge audible, manual release, and abort circuits; discharge circuit wiring; discharge device; relay connection; and low pressure.

i. Area ALARM/DISABLED Switch:
   1) Switch to disable the FM-200 discharge circuit.
   2) Switch shall not interfere with the detection or audible circuits.
   3) Operation of this switch shall cause a distinctive trouble indication for the area involved.

j. Protected Area Control Panel:
   1) Six DPDT and two SPDT auxiliary relays rated at 10 amps at 120V ac/3V dc resistive.
   2) Programmable relays for operation in alarm, predischarge, discharge, or trouble modes.
   3) Programming of relays without the need to relocate wiring.
   4) Means to individually operate relays without the need to put the control panel into alarm condition.
   5) Means to prevent each relay from operating in event of system testing.

k. Capability to transmit a trouble indication from each area.

J. Control System:

1. Actuation of a fire detector in the protected area shall initiate the following control functions:
   a. Light the corresponding suppression zone light on control panel.
   b. Activate alarm.
   c. Shut down HVAC equipment and close motorized air duct dampers serving protected area.
   d. Transmit a signal (close a normally-open alarm contact) to the building fire alarm system.
2. Actuation of a second fire detector in the protected area shall initiate the following control functions:
   a. Light the corresponding suppression zone light on control panel.

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b. Activate strobe/horn combination signaling predischarge of FM-200.
c. Shut down control and electrical equipment in the protected area.
d. Start preset agent discharge time delay.
e. Transmit a signal (close a normally-open alarm contact) to the building fire alarm system.

3. If predischarge is not aborted, and time delay expires, system shall discharge and strobe lights shall be activated outside the protected area.
4. Actuation of manual discharge stations shall immediately discharge FM-200 into the protected area and initiate the following control functions:
   a. Light suppression zone light on control panel.
   b. Activate visual and audible alarm devices.
   c. Transmit a signal (close a normally-open alarm contact) to the building fire alarm system.
5. Trouble conditions caused by open fire detector, valve actuator circuit wiring, or loss of agent storage container pressure shall initiate the following control functions:
   a. Light the corresponding suppression zone light on control panel.
   b. Light system trouble light.
   c. Sound system trouble signal.
   d. Transmit a signal (close a normally-open trouble contact) to the building fire alarm system.
6. Trouble conditions caused by open bell wiring, open battery circuit wiring, silenced alarm sounding devices, or loss of primary power shall initiate the following control functions:
   a. Light system trouble light.
   b. Sound system trouble signal.
   c. Transmit a signal (close a normally-open trouble contact) to the building fire alarm system.

K. FM-200 Reserve Supply:

1. Provide a reserve supply of agent and storage containers equal to the main supply.
2. Include required piping, actuating devices, and miscellaneous components to provide a permanently connected reserve system.
3. Reserve containers may have a completely separate set of piping and nozzles, or be connected to the same piping as the main supply.
4. Provide a key operated selector switch to change from the main system to the reserve supply.
5. Provide isolation check valves in discharge piping to prevent loss of agent or injury to personnel in event of system actuation when an agent container is removed.

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6. Transfer to Connected Reserve shall be by means of an electrical switch mounted near the control panel.

L. Provide electrical intertie between building fire alarm system, HVAC equipment, and protected area FM-200 control panel as specified in Division 26, Electrical.

1.05 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. Data sheets, catalog cuts, and technical information describing system components and devices to be installed.
   b. Calculations for standby battery power.
   c. Wiring diagrams including elementary, electrical termination, and interconnection diagrams.
   d. One-line conduit diagrams showing equipment locations, conduit locations, wire size, number of conductors, equipment mounting and other construction details.
   e. Isometric piping diagrams showing location of agent storage containers, pipe sizes, pipe lengths, and fittings. Key to required piping and nozzle calculations, and cross reference all junctions with calculations.
   f. Complete details on support of agent storage containers.
   g. Seismic anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Seismic Anchorage and Bracing.

B. Informational Submittals:

1. Experience qualification listing of firm(s) proposed to design and install the system.
2. Design Calculations:
   a. Hydraulic flow from a UL listed computer program, including the manufacturer’s name and UL listing for verification.
   b. Include individual pipe lengths and fittings to be used.
   c. Verify that the design concentration of FM-200 is reached within specified time.
3. Seismic anchorage and bracing calculations as required by Section 01 88 15, Seismic Anchorage and Bracing.
4. Test Plan: Submit as specified in Article Field Quality Control, at least 30 days prior to beginning functional testing.

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5. Component and attachment testing seismic certificate of compliance as required by Section 01 45 33, Special Inspection and Testing.
6. Operation and Maintenance Data: As specified in Section 01 78 23, Operation and Maintenance Data.
7. Manufacturer's Certificate of Proper Installation, in accordance with Section 01 43 33, Manufacturers' Field Services.

1.06 QUALITY ASSURANCE

A. Qualifications: System design and installation shall be by licensed firm(s) having a minimum of 5 years of documented experience in the design, installation, and testing of similar types of suppression systems.

1.07 MAINTENANCE

A. Inspections During Warranty Period:

1. Provide two system inspections, at 6 months and at 12 months, during the 1-year Correction Period.
2. Conduct the inspections in accordance with the manufacturer's guidelines and in compliance with NFPA 2001.
3. Submit documentation to OWNER upon completion of each inspection certifying satisfactory system operation.

PART 2 - PRODUCTS

2.01 SYSTEM CONTROL PANEL

A. General: Panel shall contain required system operation lights, reset and silence switches, circuits, relays, a standby battery power and either an enclosed or adjacently-mounted battery charger, and all other devices necessary to provide a complete automatic control system.

B. Cabinet:

1. UL listed and FM approved as an alarm-releasing control unit.
2. NEMA 250, Type 1.
3. Surface-mounted, 18-gauge steel.
4. Door: Hinged, key lockable.
5. Finish: Manufacturer's standard color.

C. Standby Battery:

1. Minimum Capacity: 6 Ah.

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2. Sized to operate the system for a minimum of 24 hours in supervisory condition and 5 minutes in alarm control condition immediately after the time in supervisory condition.
3. Sealed, gelled electrolyte type, designed for fire alarm service.
4. Supervised to provide a trouble signal on low voltage, open, or shorted cell.

D. Battery Charger:

1. Automatic, solid state, capable of charging batteries from 75 to 100 percent of full charge within 24 hours.
2. Voltmeter or other means to display battery condition.
3. Enclosure: Manufacturer's standard.

2.02 FIRE DETECTION BASE AND DEVICES

A. Base:

1. Interchangeable with photoelectric or thermal type detectors.
2. LED that illuminates steadily upon detector sensing a fire condition and with ability to power a remote annunciator that will duplicate LED indication.

B. Detection Devices, General:

1. Equip with a means of securing head to base in a manner that head may not be readily tampered with or removed.
2. UL listed and FM approved.

C. Ionization Type Device:

1. Dual chamber type, utilizing solid state circuitry.
2. Unaffected by RF energy from 1 kHz through 100 MHz or air velocities up to 3,000 fpm.

D. Photoelectric Type Device:

1. Solid state circuitry, pulsed infrared LED light source, and silicon photodiode receiving element.
2. Incorporate means to discriminate between valid fire signals and nonfire signal.
3. Include a fine stainless steel mesh cover to prevent foreign objects from entering sensing chamber.
4. Dew-proof and unaffected by air velocities up to 3,000 fpm.

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2.03 MANUAL DISCHARGE STATION

A. Furnish to provide a means of manually discharging the fire suppression system in case of an emergency.

B. Stainless steel, with keyed red release button.

C. Cover shall include operating instructions and identify discharge station as a FM-200 discharge component.

D. Double-pole switch.

E. UL listed and FM approved.

2.04 DISCHARGE ABORT STATION

A. “Dead-man” type requiring constant pressure to transfer one set of normally open and one set of normally closed contacts on each contact block.

B. Digital countdown timer to indicate time remaining until system discharge.

C. Faceplate constructed of stainless steel, with abort button, operating instructions, and identification as a component of the FM-200 system.

D. Rated 6 amps at 120V ac and 1 amp at 120V dc, with ability to override shutdown of HVAC and control equipment.

E. UL listed and FM approved.

2.05 ALARM BELL

A. Vibrating type, approved for use with the control unit provided.

B. Polarized for full supervision, and rated at 24V dc, drawing no more than 0.063 amps.

C. Noise Level: 86 to 90 dB at 10 feet.

D. Finish: Baked red enamel.

E. UL listed and FM approved.

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2.06 STROBE LIGHT

A. Rating: 24V dc with amperage draw of 0.033 amps.

B. Lamp protected by a white translucent lens imprinted with the word FM-200 in red letters.

C. Polarized, powered from the control panel.

D. UL listed and FM approved.

2.07 AGENT STORAGE CONTAINERS

A. High-strength alloy steel, equipped with the following:

1. Integral lifting ring.
2. Automatic, remotely operated discharge valve assembly.
3. 0 to 600 psi pressure gauge.
4. Electrically supervised valve actuator.
5. Filling valve to allow recharging in place.
6. Supervisory pressure switch to sense loss of agent from the container.
7. Liquid level indicating device, UL listed.

B. Container and Valve: Conform to DOT Specification 4BW500 or 4BA500.

C. Automatic Pressure Relief: On overpressure condition of 810 to 1,000 psi.

D. Superpressurized with dry nitrogen to 360 psig at 70 degrees F.

2.08 PIPING

A. In accordance with Section 22 10 01, Plumbing Piping and Accessories:

1. Distribution Piping: Black or galvanized steel, ASTM A53, Grade A, or ASTM 106, Grade A, B, or C.
2. Fittings: Malleable iron, 300-pound class, ASTM A197.

2.09 ELECTRICAL

A. In accordance with Division 26, Electrical.

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PART 3 - EXECUTION

3.01 DETECTORS

A. Install ionization and photoelectric detectors such that spacing per detector does not exceed 250 square feet.

B. Do not install detectors closer than 3 feet from air supply diffusers and 1 foot from wall.

C. Conform to NFPA No. 72E, latest edition.

3.02 AGENT STORAGE CONTAINERS

A. Floor mount and securely support to wall with wall brackets.

B. Attach mounting brackets and piping to the structure in a manner capable of withstanding the thrust developed during discharge without displacement.

C. Connect the same size containers to a common manifold.

3.03 CONNECTED RESERVE

A. Provide complete connected reserve supply of FM-200 in agent containers, duplicating those in main supply.

3.04 PIPING

A. Install in accordance with Section 22 10 01, Plumbing Piping and Accessories.

B. Cap pipe ends immediately after installation. Maintain until nozzles are installed.

C. Provide escutcheon plates at all pipe penetrations through walls, floors, and ceilings.

D. Pipe Supports: Install in accordance with ASME B31.1.

3.05 ELECTRICAL

A. Install in accordance with Division 26, Electrical.

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3.06 SIGNS

A. In addition to the following, provide as required to comply with NFPA 2001 and the recommendations of the FM-200 equipment manufacturer:

1. Caution:
   a. Provide on all entry doors to FM-200 protected areas.
   b. Wording: Alert personnel that room is protected by FM-200 and all doors must be kept closed in event of fire.
   c. Size: 10 inches by 14 inches by 1/16 inch, constructed of plastic, with black face and yellow letters.
2. Manual Discharge:
   a. Provide adjacent to each manual discharge station.
   b. Identify the manual discharge station as the place where FM-200 can be manually discharged.
   c. Size: 4 inches by 4 inches by 1/16 inch, constructed of plastic, with red face and white letters.
3. Flashing Light:
   a. Provide adjacent to each strobe horn and light.
   b. Explain the presence of the flashing lights.
   c. Size: 7 inches by 4 inches by 1/16 inch, constructed of plastic, with red face and white letters.

3.07 FIELD FINISHING

A. As specified in Section 09 90 00, Painting and Coating.

B. Pipe Labeling:

1. Label with the legend FM-200 EXTINGUISHING AGENT in letters 1 inch high.
2. Maximum Intervals:
   a. Exposed Piping: 12 feet.
   b. Concealed Piping: 20 feet.

3.08 FIELD QUALITY CONTROL

A. General: System functional and performance testing shall be conducted by qualified, trained personnel in accordance with the manufacturer’s recommended procedures and NFPA 2001.

B. Test Plan:

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1. Prepare a plan of testing to include a step-by-step description of all tests to be performed and the type and location of test apparatus to be employed.
2. Testing shall not be conducted until the Test Plan has been approved.

C. Functional Tests:

1. Perform under supervision of equipment manufacturer and with the ENGINEER present.
2. All functional testing, including system and equipment interlocks, must be successfully completed at least 5days prior to beginning performance testing.
3. Check all containers and distribution piping for proper mounting and installation.
4. Test all electrical wiring for proper connection, continuity, and resistance to ground.
5. Verify that HVAC connections to the area have properly installed dampers, and HVAC equipment will shut down upon a signal from the FM-200 control panel.
6. Test each detector in accordance with the manufacturer's recommended procedures, and record test values.
7. Demonstrate that all system and equipment interlocks, such as door release devices, audible and visual devices, equipment shutdowns, and local and remote alarms function as designed.
8. Test each control panel circuit by inducing a trouble condition into the system.

D. Performance Test:

1. Perform under actual or approved simulated operating conditions to demonstrate that the entire control system functions as designed and intended.
2. Perform under supervision of equipment manufacturer.
3. Demonstrate to the ENGINEER and authorities having jurisdiction, operation of all components under simulated fire conditions.
4. Test in accordance with NFPA 2001.
5. Conduct using the Retro-Tec Corp. door fan system, or equivalent, with integrated computer program.
6. Room Pressurization:
   a. Conduct test, at room pressurization in each protected space, to determine the presence of openings that would affect the system concentration levels.
   b. Seal all protected spaces against agent loss or leakage.

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c. Conduct pressurization tests until protected space is shown to be successfully sealed.

7. Test the following circuits:
   a. Automatic actuation.
   b. A.R.M.
   c. Manual actuation.
   d. HVAC and power shutdowns.
   e. Audible and visual alarm devices.
   f. Manual override of abort functions and agent container pressure supervision.
   g. Supervision of all panel circuits, including ac power and battery power supplies.
8. Upon acceptance by OWNER, recharge system if required, and place the completed system into normal service.

3.09 MANUFACTURER'S SERVICES

A. Provide qualified manufacturer's representative(s) for the equipment specified herein at the Job Site and classroom designated by the OWNER for the following services:

1. Installation assistance, inspection, and certification of installation.
2. Functional and performance testing assistance.
3. Classroom or Job Site training of OWNER's operations and maintenance personnel.

END OF SECTION

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SECTION 22 10 01
PLUMBING PIPING AND ACCESSORIES

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Gas Association (AGA):
   a. B109.1, Diaphragm Type Gas Displacement Meters (under 500 Cubic Feet Per Hour Capacity).
   b. B109.2, Diaphragm Type Gas Displacement Meters (500 Cubic Feet Per Hour Capacity and Over).
2. American National Standards Institute (ANSI).
3. American Public Works Association (APWA): Uniform Color Code.
4. American Society of Sanitary Engineering (ASSE):
   a. 1010, Performance Requirements for Water Hammer Arresters.
   b. 1050, Performance Requirements for Stack Air Admittance Valves for Sanitary Drainage Systems.
5. ASTM International (ASTM):
   a. A47/A47M, Standard Specification for Ferritic Malleable Iron Castings.
   b. A53/A53M, Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless.
   c. A74, Standard Specification for Cast Iron Soil Pipe and Fittings.
   d. A105/A105M, Standard Specification for Carbon Steel Forgings for Piping Applications.
   e. A126, Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings.
   f. A179/A179M, Standard Specification for Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes.
   g. A181/A181M, Standard Specification for Carbon Steel Forgings, for General-Purpose Piping.
   h. A193/A193M, Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications.
   i. A194/A194M, Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both.
   j. A197/A197M, Standard Specification for Cupola Malleable Iron.

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k. A234/A234M, Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service.
l. A307, Standard Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength.
m. A351/A351M, Standard Specification for Castings, Austenitic, for Pressure-Containing Parts.
n. A518/A518M, Standard Specification for Corrosion-Resistant High-Silicon Iron Castings.
o. A536, Standard Specification for Ductile Iron Castings.
p. A563, Standard Specification for Carbon and Alloy Steel Nuts.
q. A861, Standard Specification for High-Silicon Iron Pipe and Fittings.
r. A888, Standard Specification for Hubless Cast Iron Soil Pipe and Fittings for Sanitary and Storm Drain, Waste, and Vent Piping Applications.
s. B32, Standard Specification for Solder Metal.
t. B61, Standard Specification for Steam or Valve Bronze Castings.
u. B62, Standard Specification for Composition Bronze or Ounce Metal Castings.
v. B75/B75M, Standard Specification for Seamless Copper Tube.
w. B88, Standard Specification for Seamless Copper Water Tube.
x. B98/B98M, Standard Specification for Copper-Silicon Alloy Rod, Bar, and Shapes.
y. B127, Standard Specification for Nickel-Copper Alloy (UNS N04400) Plate, Sheet, and Strip.
z. B139/B139M, Standard Specification for Phosphor Bronze Rod, Bar, and Shapes.
aa. B164, Standard Specification for Nickel-Copper Alloy Rod, Bar, and Wire.
bb. B194, Standard Specification for Copper-Beryllium Alloy Plate, Sheet, Strip, and Rolled Bar.
cc. B306, Standard Specification for Copper Drainage Tube (DWV).
dd. C564, Standard Specification for Rubber Gaskets for Cast Iron Soil Pipe and Fittings.
ee. C1277, Standard Specification for Shielded Couplings Joining Hubless Cast Iron Soil Pipe and Fittings.
ff. C1460, Standard Specification for Shielded Transition Couplings for use with Dissimilar DWV Pipe and Fittings Above Ground.
gg. C1540, Standard Specification for Heavy Duty Shielded Couplings Joining Hubless Cast Iron Soil Pipe and Fittings.

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hh. D1784, Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds.
ii. D1785, Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120.
jj. D2000, Standard Classification System for Rubber Products in Automotive Applications.
kk. D2239, Standard Specification for Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter.
ll. D2466, Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40.
mm. D2513, Standard Specification for Polyethylene (PE) Gas Pressure Pipe, Tubing, and Fittings.
nn. D2564, Standard Specification for Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems.
oo. D2683, Standard Specification for Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing.
pp. D2855, Standard Practice for Making Solvent-Cemented Joints with Poly(Vinyl Chloride) (PVC) Pipe and Fittings.
qq. D3035, Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter.
rr. D3261, Standard Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing.
ss. D3350, Standard Specification for Polyethylene Plastics Pipe and Fittings Materials.
tt. E438, Standard Specification for Glasses in Laboratory Apparatus.
uu. F656, Standard Specification for Primers for Use in Solvent Cement Joints of Poly(Vinyl Chloride) (PVC) Plastic Pipe and Fittings.
vv. F714, Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter.
ww. F1412, Standard Specification for Polyolefin Pipe and Fittings for Corrosive Waste Drainage Systems.
xx. F1924, Standard Specification for Plastic Mechanical Fittings for Use on Outside Diameter Controlled Polyethylene Gas Distribution Pipe and Tubing.
yy. F1973, Standard Specification for Factory Assembled Anodeless Risers and Transition Fittings in Polyethylene (PE) and Polyamide 11 (PA11) and Polyamide 12 (PA12) Fuel Gas Distribution Systems.

6. American Water Works Association (AWWA):
   a. C104/A21.4, Standard for Cement-Mortar Lining for Ductile-Iron Pipe and Fittings for Water.

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b. C110/A21.10, Standard for Ductile-Iron and Gray-Iron Fittings.
c. C111/A21.11, Standard for Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings.
d. C115/A21.15, Standard for Flanged Ductile-Iron Pipe with Ductile-Iron or Gray-Iron Threaded Flanges.
e. C151/A21.51, Standard for Ductile-Iron Pipe, Centrifugally Cast.
f. C203, Coal-Tar Protective Coatings and Linings for Steel Water Pipelines, Enamel and Tape, Hot-Applied.
g. C207, Steel Pipe Flanges for Waterworks Service - Sizes 4 In. Through 144 In. (100 mm Through 3,600 mm).
h. C606, Grooved and Shouldered Joints.
i. C651, Disinfecting Water Mains.

7. Cast Iron Soil Pipe Institute (CISPI):
   a. 301, Standard Specification for Hubless Cast Iron Pipe and Fittings for Sanitary and Storm Drain, Waste, and Vent Piping Applications.
   b. 310, Specification for Couplings for Use in Connection with Hubless Cast Iron Soil Pipe and Fittings for Sanitary and Strom Drain, Waste, and Vent Piping Applications.
8. Plumbing and Drainage Institute (PDI): WH 201, Water Hammer Arresters Standard.

1.02 DESIGN REQUIREMENTS

A. Where pipe diameter, thickness, pressure class, pressure rating, or thrust restraint is not shown or specified, design piping system in accordance with the following:

1. Sanitary Building Drainage and Vent Systems Local plumbing code.

1.03 SUBMITTALS

A. Action Submittals:

1. Product data sheets.
2. Shop Drawings:
   a. Show CONTRACTOR recommended changes in location of fixtures or equipment.
   b. Seismic anchorage and bracing drawings and data sheets, as required by Section 01 88 15, Seismic Anchorage and Bracing.
3. Isometric riser diagrams.

B. Informational Submittals:

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1. Seismic anchorage and bracing calculations as required by Section 01 88 15, Seismic Anchorage and Bracing.
2. Changes in location of equipment or piping that affect connecting or adjacent work, before proceeding with the work.
3. Complete list of products proposed for installation.
4. Test records produced during testing.

PART 2 - PRODUCTS

2.01 PIPING

A. Piping Schedule: Refer to Article Supplements.

B. Piping Material: Refer to Piping Data Sheet(s), Article Supplements

2.02 PIPE HANGERS AND SUPPORTS

A. Refer to Section 40 05 15, Piping Support Systems.

2.03 INSULATION

A. As specified in Section 22 07 00 Building Mechanical Thermal Insulation.

2.04 VALVES

A. General:

1. Furnish complete with necessary operating hand wheels, chain wheels, extension stems, floor stands, worm and gear operators, operating nuts, chains, and wrenches.
2. Renewable Parts Including Discs, Packing, and Seats: Types as recommended by valve manufacturer for intended service.
3. Units shall have name of manufacturer and size of valve cast on body or bonnet or shown on a permanently attached plate in raised letters.

B. Design Features:

1. Brass and bronze components, including appurtenances in contact with water.
2. Alloys containing less than 16 percent zinc and 2 percent aluminum.
3. Alloys are of the following ASTM designations:
   a. B61, B62, B98/B98M (Alloy A, B, or D), B139 (Alloy A), B164, B194, and B127.

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b. Stainless steel Alloy 18-8 may be substituted for bronze as an option with approval of ENGINEER.

4. Gland Bolts on Iron Body Valves: Bronze, fitted with brass nuts.

C. Valve Operators:

1. Open by turning counterclockwise.
2. Worm and Gear Operators On Manually Operated Valves: Totally enclosed design, proportioned as to permit operation of valve under full operating head with maximum pull of 40 pounds on handwheel or crank.
3. Self-locking type to prevent the disc or plug from creeping.
4. Self-Locking Worm Gears:
   a. One-piece design of gear bronze material, accurately machine cut.
   b. Worm: Hardened alloy steel, with thread ground and polished.
   c. Reduction gearing shall run in a proper lubricant.
5. Galvanize handwheels.

D. Gate Valves:

1. 3 Inches and Smaller for Water and Air Services:
   a. All-bronze with screwed bonnet, single solid wedge gate with nonrising stem, and handwheel operator.
   b. Rated 125-pound SWP, 200-pound WOG.
   c. Manufacturers and Products for Threaded Ends:
      1) Crane; No. 438.
      2) Nibco; Model No. T-113.
   d. Manufacturers and Products for Soldered Ends:
      1) Crane; No. 1701S.
      2) Nibco; Model No. S-113.
2. 4 Inches and Larger for Water and Air Services:
   a. Iron body, bronze mounted, with flanged ends, solid wedge gate with nonrising stem, and handwheel operator.
   b. Rated 125-pound SWP, 200-pound WOG.
   c. Manufacturers and Products:
      1) Crane; No. 461.
      2) Nibco; Model No. F-619.

E. Ball Valves:

1. 2 Inches and Smaller for General Water and Air Service:
   a. Three-piece body type, bronze body and end pieces, hard-chrome plated bronze or brass ball, full bore port, RTFE seats and packing,

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blowout-proof stem, zinc-plated steel hand lever operator with vinyl grip.

b. Rated 6-pound WOG, 150-psi SWP.
c. [For steam service, provide stainless steel ball and stem.]
d. Manufacturers and Products:
    1) Threaded Ends:
        a) Milwaukee; BA-300.
        b) Nibco; T-595-Y.
        c) Conbraco Apollo; 82-100.
    2) Soldered Ends:
        a) Milwaukee; BA-350.
        b) Nibco; S-595-Y.
        c) Conbraco Apollo; 82-200.

2. 3 Inches and Smaller for Vacuum Service:
    a. Brass body and trim, replaceable double TFE seals and seats.
    b. Furnish screwed ends and rate for service to 0.01 micron.
    c. Manufacturers and Products:
        1) Jamesbury; Style A.
        2) Worcester; Series 400.
3. Thermoplastic Ball Valves 2 Inches and Smaller for Water Service:
    a. Rated 150 psi at 105 degrees F, with ASTM D1784, Type I, Grade 1 polyvinyl chloride (PVC) body, ball, and stem.
    b. End entry, double union design, with replaceable Teflon seats and Viton or Teflon O-ring stem seals.
    c. Furnish with hand lever operator.
    d. Single union ball valves with flanged ends drilled to 150-pound ANSI Standard are acceptable.
    e. Manufacturers:
        1) Asahi/America.
        2) R&G Sloane Manufacturing Co., Inc.
4. Deionized Water Ball Valve (1/2 Inch to 2 Inches):
    a. True Union ball valve, size as shown on the Drawings.
    b. Manufactured from virgin polypropylene using no antioxidants, plasticizers, or pigments.
    c. Socket-weld type electrically fused. Factory sealed in a protective wrap.
    d. Minimum pressure rated of 140 psi at 70 degrees F.
    e. Manufacturers:
        1) R&G Sloane Manufacturing Co., Inc.
        2) Orion Fittings, Inc.
        3) Chemline Plastics Ltd.

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F. Globe Valves:

1. 3 Inches and Smaller:
   a. Bronze body, replaceable composition disc, screwed ends, union bonnet, inside screw rising stem, and TFE disc.
   b. Rated 150-pound SWP, 300-pound WOG.
   c. Manufacturers and Products:
      1) Crane; No. 7TF.
      2) Nibco; No. T-235-Y.

G. Plug Valve:

1. 2 Inches and Smaller for Natural Gas and Propane Gas Service:
   a. Eccentric type, nonlubricated, cast iron body, and bronze plug with Buna N elastomer O-ring seal.
   b. UL listed and CSA (AGA-CGA) approved.
   c. Pressure Rating: ANSI 125, 175 psi.
   d. Threaded end connections.
   e. Manufacturers and Products:
      1) Milliken Valve Company, Inc.; Series 625.
      2) Key Port Valve; Series 400.
2. 2-1/2 Inches to 4 Inches for Natural Gas and Propane Gas Service:
   a. Eccentric type, nonlubricated, cast iron body and nickel plated cast iron plug with Buna N elastomer O-ring seal.
   b. UL listed and CSA (AGA-CGA) approved.
   c. Pressure Rating: ANSI 125, 175 psi.
   d. End Connections:
      1) 2-1/2 Inches to 3 Inches: Threaded.
      2) 4 Inches: Flanged, ASME B16.1, Class 125/150.
   e. Manufacturers and Products:
      1) Milliken Valve Company, Inc.; Series 625.
      2) Key Port Valve; Series 400.

H. Angle Valves 3 Inches and Smaller:

1. Bronze body, threaded ends, union bonnet, and rising stem.
   a. Rated 150-pound SWP and 300-pound WOG.
   b. Manufacturers and Products for Threaded End:
      1) Crane; No. 17TF.
      2) Nibco; No. T-335-Y.

I. Check Valves 3 Inches and Smaller:

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1. Bronze body, wye pattern, threaded ends and cap, regrinding seat, and swing type disc.
2. Rated 125-pound SWP, 200-pound WOG.
3. Manufacturers and Products:
   a. Crane; No. 37.
   b. Walworth Co.; Figure 406.

J. Backwater Check Valve 2 Inches to 8 Inches:

1. Coated cast iron backwater check valve, integral offset type swing-check assembly, [gasketed bolted access cover] [threaded, ferrule, and cover].
2. Manufacturers and Products:
   a. J. R. Smith; Figure 7012.
   b. Josam; Series 67500.
   c. Zurn; Model Z-1095.

K. Balancing Valves (Recirculating Hot Water):

1. Bronze, calibrated balancing type with provisions for connecting a portable differential pressure meter. Meter connections shall have built-in check valves.
2. An integral pointer shall register degree of valve opening.
3. Construct with internal seals to prevent leakage around rotating element.
4. Rated for 125 psig working pressure at maximum temperature of 250 degrees F.
5. Furnish one pressure gauge type readout meter in carrying case.
6. Furnish with preformed polyurethane insulation valve enclosure, suitable for use on hot water systems.
7. Manufacturers and Products:
   a. Bell & Gossett; No. CB circuit setter.
   b. TACO; Series 790.

L. Water Pressure Reducing Valves 1/2 Inch Through 2-1/2 Inches:

1. Spring controlled, with a neoprene diaphragm.
2. Sizes and Ratings:
   a. PRV-[_____]: [_____]-inch IPS, maximum [_____] gpm, with inlet pressure [_____] psig; outlet pressure [_____] psig.
3. Manufacturers and Products:
   a. Fisher; Type 75.
   b. Watts; No. 223.

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M. Gauge Cock Valves 1/8 Inch to 3/8 Inch:

1. Bronze body, hexagon male and female ends, and tee head.
2. Rated for 125-pound SWP.
3. Manufacturers and Products:
   a. Ernst Gage Co.; [_____]
   b. Lunkenheimer.

N. Manual Air Vent Valves:

1. With coin-operated air vent.
2. Manufacturers and Products:
   a. Bell & Gossett; No. 4V.
   b. Dole; No. 9.

O. Solenoid Valves:

1. Two-way, full line size, normally [closed,] [open,] [_____] psig body pressure, [_____] psig operating differential, for use with cold water.
2. Suitable for 115-volt, 60-Hz, ac power supply.
3. Manufacturers:
   a. Automatic Switch Co.
   b. Skinner.

2.05 MISCELLANEOUS PIPING SPECIALTIES

A. Strainers for Water Service:

1. Iron body, Y-pattern, 125-pound rated, with screwed bronze or bolted iron cap.
2. Screen: Heavy-gauge stainless steel or monel, 30 mesh.
3. Manufacturers and Products:
   a. Crane; No. 988-1/2.
   b. Mueller; No. 758.

B. Flexible Connectors for Stainless Steel Gas Lines:

1. Corrugated, Type 316 stainless steel hose, with 10-inch live length and Type 316 stainless steel male NPT pipe connectors at each end.
2. Manufacturers:
   a. Flexonics Braided Rex-Weld.
   b. Kin-Line.

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C. Vacuum Breakers 2 Inches and Smaller:

1. Angle type, as required.
2. Manufacturers:
   a. Febco.
   b. Watts.

D. Water Hammer Arresters:

1. Materials: ASSE 1010 certified, Type L copper tube, HHPP piston with two lubricated EPDM O-rings, FDA approved lubricant, rolled piston stop, wrought copper male thread adapter.
2. Manufacturers and Products:
   a. Sioux Chief Mfg. Co., Inc.; Series 650 and 660.
   b. Precision Plumbing Products, Inc.

E. Sleeves:

1. Manufacturers and Products:
   a. J. R. Smith; Figure 1720.
   b. Josam; No. 26400.

F. Flashing Sleeves for Roof Penetrations:

1. Built-Up Bituminous Roofing: Fabricate of lead as specified in Section 07 62 00, Sheet Metal Flashing and Trim.
2. Single-Ply Membrane Roofing: Pipe seals as specified in Section 07 70 01, Roof Specialties and Accessories.

G. Insulating Dielectric Unions and Flanges:

1. Galvanically compatible with piping to which attached and pressure ratings suitable for system working pressures.
2. Unions 2 Inches and Smaller: Screwed or solder-joint type.
3. Unions 2-1/2 Inches and Larger: Flanged type, complete with bolt insulators, dielectric gasket, bolts, and nuts.
4. Manufacturers:
   a. Epco Sales, Inc., Cleveland, OH.
   b. Capitol Insulation Unions.

H. Air Admittance Valve (AAV):

1. PVC construction with internal air check valve and insect screen.

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2. Unit shall meet ASSE 1051 for fixture and branch air admittance valves.
3. Unit shall bear seal of ASSE approval.
4. Manufacturer and Product: Studor, Inc., Dunedin, Florida; Maxi-Vent (2 inches to 4 inches).

I. Joint Solder: 95-5 wire solder, ASTM B32, Grade 95 TA. Do not use cored solder.

J. Pipe Joint Sealer: Compound insoluble in water or Teflon tape; approved by NFS for use in potable water.

K. Rubber Gaskets: ASTM C564.

2.06 MEASURING DEVICES

A. Thermometers:

1. Adjustable angle, organic spirit type, blue in color, with 9-inch case and scale range in degrees F, as shown.
2. Furnish with 3-1/2-inch stem length and separable NPT brass thermowell.
3. Manufacturers:
   a. Trerice Co.; Model A005.
   b. Weksler.

B. Pressure Gauges:

1. Construction: 3-1/2-inch gauge size, 0 to 690 kPa, 0 to 160 psi range, steel case, glass crystal, brass movement, and 1/4-inch NPT lower connection.
2. Furnish with 1/4-inch brass gauge cock.
3. Manufacturers and Products:
   a. Ashcroft; Type 1008.
   b. Marsh; J80.
   c. Marshalltown.

C. Natural Gas Meters:

PART 3 - EXECUTION

3.01 GENERAL

A. Install plumbing systems to meet applicable plumbing code.

B. Field Obstructions:

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1. Drawings do not attempt to show exact details of piping. Provide offsets around obstructions.
2. Do not modify structural components, unless approved by ENGINEER.

C. Sleeves:

1. Pipe sizes shown are nominal sizes, unless shown or specified otherwise.
2. Provide piping passing through walls, floors, or ceilings with standard-weight pipe sleeves.
3. Provide pipes passing through finished walls with chrome-plated canopy flanges.
4. Dry pack sleeves in existing work in-place and provide finished appearance.
5. Pack holes left by removal of existing piping with grout and finish to match adjacent surface.

D. Provide unions in piping systems at connections to equipment.

E. Provide shielded transition couplings, insulating dielectric unions and flanges between ferrous and nonferrous piping and where otherwise required for electrically insulated connection.

F. Pipe air release valves, water-lubricated bearings, and other appurtenances having water effluent with copper tubing to nearest drain.

3.02 INSTALLATION

A. Steel Pipe:

1. Ream, clean, and remove burrs and mill scale from piping before making up.
2. Seal joints with pipe joint sealer or Teflon tape.

B. Copper Tubing:

1. Cut tubing square and remove burrs.
2. Clean both inside of fittings and outside of tubing with steel wool and hydrochloric acid before soldering.
3. Prevent annealing of fittings and hard-drawn tubing when making connections.
4. Do not use mitered joints for elbows or notching of straight runs of pipe for tees.

C. Rigid PVC or CPVC:

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1. Cut, make up, and install in accordance with pipe manufacturer's recommendations.
2. Ream, clean, and remove burrs from cut ends before joining pipe.
3. Lay in trench by snaking pipe from one side to other.
4. Offset: As recommended by manufacturer for maximum temperature variation between time of solvent welding and final use.
5. Do not lay pipe when temperature is below 40 degrees F or above 90 degrees F when exposed to direct sunlight.
6. Shield ends to be joined from direct sunlight prior to and during laying operation.
7. Use strap wrenches only for tightening threaded plastic joints. Do not over tighten fittings.

D. Water System Balancing: Provide a qualified registered engineer or firm specializing in testing and balancing to adjust domestic water system. Balance system for required water flows at each plumbing fixture, terminal device, and recirculating hot water loop.

E. Water Hammer Arresters:

1. Install in piping systems where shown on Drawings and adjacent to pieces of equipment where quick closing valves are installed.
2. Install at all emergency safety showers and eyewashes.
3. Size and install in accordance with PDI-WH201.
4. Shock arresters to have access panels or to be otherwise accessible.

F. Valves: Install in accordance with manufacturer's recommendations.

G. Miscellaneous Piping Specialties: Install in accordance with manufacturer's recommendations.

H. Measuring Devices: Install in accordance with manufacturer's recommendations.

3.03 SANITARY AND WASTE DRAINS AND VENTS PIPING

A. Installation:

1. Set piping above floor slab true and plumb.
2. Set exposed risers as close to walls as possible.
3. Where vent stacks pass through roof slab, fit with flashing sleeve secured to roof.
4. Extend vents minimum 1 foot above roof.
5. Provide cleanouts where shown and where required by code.

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3.04 ACID-RESISTANT DRAINS AND VENTS

A. Install in accordance with manufacturer's recommendations.

B. Drainage Vents: Same piping system as used for acid-resistant drains.

C. Make connections between polypropylene piping systems and other acid-resistant drainage systems with adapters recommended by manufacturer.

D. Buried Polypropylene Pipe:

1. Heat join and test for leakage before placing in trench.
2. Snake slightly on long runs placed in trench.
3. When installed in extremely hot or cold weather, make proper allowance for expansion or contraction.

E. Buried Acid-Resistant Cast Iron Pipe With Teflon-Lined Couplings:

1. Install in accordance with manufacturer's instructions.
2. Do not allow acid waste to contact pipe and Teflon until installation is complete and tested.

F. Buried Polypropylene Drain and Vent Pipe:

1. Install in accordance with manufacturer's recommendations.
2. Trench shall have a clean sand bed graded to proper pitch.
3. Completely cover pipe with clean sand prior to backfilling.
4. Compact sand by flooding with water.
5. Do not permit sharp stones in backfill surrounding pipe.

3.05 HVAC CONDENSATE PIPING

A. Set piping true and plumb.

B. Slope piping 1/8 inch per foot minimum.

3.06 WATER SUPPLY PIPING

A. Water supply piping includes potable W1systems.

B. Flush water piping systems clean of internal debris, clean faucet aerators, and adjust plumbing fixture valves for manufacturer's recommended flow.

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C. Do not run water piping through electrical rooms, stairwells, or immediately over or within a 3-foot horizontal clearance of electrical panels, motor starters, or environmental control panels.

D. Provide valve operators with position indicators, where indicated, to show position of valve disc or plug.

E. Provide bypass with globe valve for emergency throttling around each reducing valve.

F. Vacuum Breakers 2 Inches and Smaller: Install minimum 6 inches above flood line of equipment they serve.

3.07 INSULATION

A. As specified in Section 22 07 00, Building Mechanical Thermal Insulation.

3.08 HANGERS AND SUPPORTS

A. Install pre-engineered support equipment in accordance with manufacturer's recommendations.

B. Hanger Rod Sizing and Spacing for:

1. Steel Pipe:

Pipe Size	Max. Hanger Spacing (feet)	Min. Rod Size (inches)
1 inch and smaller	6	1/4
1-1/4 through 2-1/2 inches	8	1/4
3 and 4 inches	10	3/8
6 inches	12	3/8
8 inches	12	1/2

2. Copper Pipe:
   a. Rod Size: Same as for steel pipe.
   b. Spacing: 2 feet less per size than for steel pipe, except pipe 1-1/4 inches and smaller shall be supported every 6 feet.
3. Cast Iron Pipe:

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a. Rod Size: Same as for steel pipe.
b. Spacing: Locate hanger rods at each pipe joint and change of direction, 10-foot maximum spacing.

4. Plastic Pipe:
   a. Rod Size: Same as for steel pipe.
   b. Spacing: As recommended by manufacturer and required by applicable plumbing code for flow and temperature in pipe.
   c. No metal portion of hanger shall contact pipe directly.

C. Attach Support Rods For Horizontal Piping:

1. To steel beams with I-clamps.
2. To concrete with inserts or with flanges fastened with flush shells.
3. To wood with thickness of 2-1/2 inches or more with bolts or angle clips.

D. Trapeze Hangers:

1. Trapeze hangers may be used in lieu of individual hangers where horizontal piping is arranged with two or more parallel lines.
2. Attach lines to horizontal with U-bolts or one-hole clamps.

E. Vertical Piping:

1. Support by channel type support system and pipe clamps on 10-foot maximum centers.
2. Copper, and Plastic Piping: Isolate from channels and pipe clamps with pipe isolators.

F. Insulated Piping: Furnish galvanized protection shield and oversized hangers under insulated piping.

3.09 INTERIM CLEANING

A. Prevent accumulation of weld rod, weld spatter, pipe cuttings and filings, gravel, cleaning rags, and other foreign material within piping during fabrication and assembly.

B. Examine piping to assure removal of foreign objects prior to assembly.

C. Shop cleaning may employ conventional commercial cleaning method if it does not corrode, deform, swell, or otherwise alter physical properties of material being cleaned.

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3.10 TESTING

A. [As specified in Section 40 80 01, Process Piping Leakage Testing.]

B. General:

1. Conduct pressure and leakage tests on newly installed pipelines.
2. Provide necessary equipment and material, and make taps in pipe, as required.
3. [ENGINEER] [_____] will monitor tests. Provide 24-hour advance notice of start of testing.
4. Test Pressures: As specified herein and in Piping Schedule.
5. Test Records: Make records of each piping system installation during test to document the following:
   a. Date of test.
   b. Description and identification of piping tested.
   c. Test fluid.
   d. Test pressure.
   e. Remarks, including:
      1) Leaks (type, location).
      2) Repairs made on leaks.
   f. Certification by CONTRACTOR and signed acknowledgment by [ENGINEER] [_____] that tests have been satisfactorily completed.

C. Testing New Pipe Connected to Existing Pipe: Isolate new pipe with grooved end pipe caps, spectacle blinds, or blind flanges.

D. Preparation and Execution:

1. Buried Pressure Piping:
   a. An initial service leak test may be conducted with a partially backfilled trench and the joints left open for inspection, if field conditions permit, as determined by ENGINEER.
   b. Expose joints for the acceptance test on buried pressure piping to be pneumatically tested or subjected to an initial service leak test.
   c. Conduct final hydrostatic acceptance tests after trench has been completely backfilled.
2. Exposed Piping: Conduct tests after piping has been completely installed including supports, hangers, and anchors, but prior to insulation.

E. Hydrostatic Leak Tests:

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1. Equipment: Provide the following:

Amount	Description
2	Graduated containers
2	Pressure gauges
1	Hydraulic force pump
	Suitable hose and suction pipe as required

2. Procedure:
   a. Use water as the hydrostatic test fluid.
   b. Provide clean test water of such quality as to minimize corrosion of the materials in the piping system.
   c. Open vents at high points of the piping system to purge air pockets while the piping system is filling.
   d. Venting during filling of system may also be provided by loosening flanges with a minimum of four bolts or by the use of equipment vents.
   e. Test piping systems at test pressure specified in Piping Schedule.
   f. Maintain hydrostatic test pressure continuously for 30 minutes minimum and for such additional time as necessary to conduct examinations for leakage.
   g. Examine joints and connections for leakage.
   h. Piping system, exclusive of possible localized instances at pump or valve packing, shall show no visual evidence of weeping or leaking.
   i. Correct visible leakage and retest to satisfaction of [ENGINEER] [_____].
3. Gravity Sewers and Drains:
   a. Test by water or air exfiltration tests as prescribed by local or state plumbing codes and visually examine for leaks.
   b. Repair leaks and retest system until no further leakage is evident.

F. Pneumatic Leak Tests:

1. Perform on compressed air, natural gas, and vacuum piping.
2. Equipment: Provide the following:

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Amount	Description
1	Pneumatic compressor separator-dryer system capable of providing oil-free dry air and equipped with one or more full capacity safety relief valves set at a pressure of not more than 105 percent of the required primary test pressure
1	Calibrated test gauge

3. Procedure:
   a. Perform pneumatic testing using accurately calibrated instruments and oil-free, dry air.
   b. Perform tests only on exposed piping, after piping has been completely installed, including supports, hangers and anchors, and inspected for proper installation.
   c. Test piping system at test pressure specified in Piping Schedule.
   d. Take necessary precautions to protect test personnel [and OWNER's operating personnel] from hazards associated with air testing.
   e. Secure piping to be tested to prevent damage to adjacent piping and equipment in event of a joint failure.
   f. Prior to test, remove or suitably isolate appurtenant instruments or devices that could be damaged by test.
   g. Apply maximum 25 psig preliminary pneumatic test to piping system prior to final leak testing, to locate major leaks.
   h. Examine joints and connections for leakage with soap bubbles.
   i. Correct visible leaks and retest to satisfaction of [ENGINEER] [_____].
   j. Gradually increase pressure in system to not more than one-half of test pressure.
   k. Thereafter increase pressure in steps of approximately 1/10 of maximum test pressure until required test pressure is reached.
   l. Maintain pneumatic test pressure continuously for minimum 10 minutes and for such additional time as necessary to conduct a soap bubble examination for leakage.
   m. Piping system, exclusive of possible localized instances at pump or valve packing, shall show no evidence of leakage.
   n. Correct visible leakage retest to satisfaction of [ENGINEER] [_____].
   o. Following pneumatic testing, thoroughly purge lines that are to carry flammable gases with nitrogen to assure no explosive mixtures will be present in system during filling process.

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3.11 CLEANING AND DISINFECTION

A. Prior to final acceptance, following assembly and testing, flush pipelines with water, except for plant process air lines and instrument air lines, and remove accumulated construction debris and other foreign matter.

B. Minimum Flushing Velocity: 5 feet per second.

C. Insert cone strainers in the connections to attached equipment and leave until cleaning has been accomplished.

D. Remove accumulated debris through drains 2 inches and larger or by dropping spools and valves.

E. Immediately following drainage of flushed lines, dry piping with compressed air.

F. Plant process air and instrument air piping shall be blown clean of loose debris with compressed air.

G. Disinfect pipelines intended to carry potable water before placing in service:

1. Meet the requirements of AWWA C651, unless otherwise specified.
2. Disinfecting Mixture:
    a. A chlorine-water solution having a free chlorine residual of 40 ppm to 50 ppm.
    b. Prepare by injecting one of the following:
        1) Liquid chlorine gas-water mixture.
        2) Dry chlorine gas.
        3) Calcium or sodium hypochlorite and water mixture.
    c. Inject mixture into pipeline at a measured rate while freshwater is allowed to flow through the pipeline at a measured rate so the combined mixture of freshwater and chlorine solution or gas is of the specified strength.
    d. Apply liquid chlorine gas-water mixture by means of a chlorinating device.
    e. Feed dry chlorine gas through proper devices for regulating the rate of flow and providing effective diffusion of gas into water within pipe being treated.
    f. Chlorinating devices for feeding solutions of chlorine gas or gas itself must prevent backflow of water into chlorine cylinder.
    g. Calcium Hypochlorite: If this procedure is used, first mix dry powder with water to make a thick paste, then thin to approximately a 1 percent solution (10,000 ppm chlorine).

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h. Sodium Hypochlorite: If this procedure is used, dilute liquid with water to obtain a 1 percent solution.

i. The following proportions of hypochlorite to water will be required:

Product	Quantity	Water
Calcium Hypochlorite[1] (65 - 70 percent C1)	1 lb	7.5 gal
Sodium Hypochlorite[2] (5.25 percent C1)	1 gal	4.25 gal
[1]Comparable to commercial products known as HTH, Perchloron, and Pittchlor. [2] Known as liquid laundry bleach, Clorox, and Purex.		

H. Point of Application:

1. Inject chlorine mixture into pipeline to be treated at the beginning of the line through a corporation stop or suitable tap in the top of pipeline.
2. Control clean water from existing system or another source so it flows slowly into newly installed piping during chlorine application.
3. Manipulate valves so the strong chlorine solution in the line being treated will not flow back into line supplying the water. Use check valves, if necessary.

I. Retention Period:

1. Retain treated water in pipeline for a minimum of 24 hours or long enough to destroy nonspore-forming bacteria.
2. At the end of the retention period, the disinfecting mixture shall have strength of at least 10 ppm of chlorine.
3. Operate valves, hydrants, and other appurtenances during disinfection to assure disinfecting mixture is dispersed into all parts of the pipeline including dead ends, new services, and similar areas that otherwise may not receive the disinfecting solution.
4. Do not place concentrated quantities of commercial disinfectants in pipeline before filling with water.
5. After chlorination, flush water from permanent source of supply until water through pipeline is equal chemically and bacteriologically to permanent source of supply.

J. Disposal of Disinfecting Water:

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1. Dispose of disinfecting water in an acceptable manner that will protect the public and receiving waters from harmful or toxic concentrations of chlorine.
2. Do not allow disinfecting water to flow into a waterway without adequate dilution or other satisfactory method of reducing chlorine concentrations to a safe level.

3.12 PROTECTION OF INSTALLED WORK

A. Protective Covers:

1. Provide over floor and shower drains during construction, to prevent damage to drain strainers and keep foreign material from entering drainage system.
2. Cover roof drains and emergency overflow drains during roofing process so roofing material and gravel do not enter drain piping.
3. Remove at time of Substantial Completion.

3.13 FIELD FINISHING

A. In accordance with Section 40 27 00, Processing Piping—General.

3.14 PIPING IDENTIFICATION

A. Refer to Section 40 27 00, Process Piping—General and Pipe Schedule.

3.15 SUPPLEMENTS

1. The supplements listed below, following "End of Section," are part of this specification.
   a. 22 10 01.01, Plumbing Piping Schedule.
   b. Plumbing Piping Data Sheets.

Section Number	Title
22 10 01.02	Polyvinyl Chloride Drain Waste and Vent (PVC-DWV) Pipe and Fittings
22 10 01.04	Acid-Resistant Cast Iron Pipe and Fittings
22 10 01.06	Acid-Resistant Polypropylene Waste and Vent Pipe and Fittings

END OF SECTION

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Section 22 10 01.02 POLYVINYL CHLORIDE DRAIN WASTE AND VENT (PVC-DWV) PIPE AND FITTINGS		
Item	Size	Description
Pipe and Fittings	All	PVC-DWV Schedule 40 nonpressure application, Class 12454B conforming to ASTM D2665 and ANSI/NSF Standard 14 system.
Joints	All	Solvent cemented conforming to ASTM D2855 except where connection to equipment may require future removal.
Solvent Cement	All	As recommended by the pipe and fitting manufacturer conforming to ASTM D2564.

END OF SECTION

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SECTION 22 10 01.04
ACID-RESISTANT CAST IRON PIPE AND FITTINGS

Item	Size	Description
Pipe and Fittings	All	High silicone cast iron, no-hub ends, extra heavy grade, conforming to ASTM A518/A518M and ASTM A861.
Joints	All	No-hub type compression coupling, with Teflon inner sleeve, neoprene outer sleeve, and stainless steel shield and clamp assembly.

END OF SECTION

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SECTION 22 10 01.08
DOUBLE CONTAINED PIPE AND FITTINGS
HIGH-DENSITY POLYETHYLENE (HDPE)

Item	Size	Description
General	All	Pipe lengths, fittings, and flanged connections to be joined by thermal butt-fusion; shall be of the same type, grade, and class of polyethylene compound and supplied from same raw material supplier. Pipe tubing and fittings manufactured in accordance with ASTM D2239. Preferred SDR 11

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SECTION 22 10 01.08
DOUBLE CONTAINED PIPE AND FITTINGS
HIGH-DENSITY POLYETHYLENE (HDPE)

Item	Size	Description
Pipe	1/2" to 4"	Cell class ASTM D3350 high-density polyethylene, maximum allowable hoop stress 1,600 psi at 73.4 degrees F. Polyethylene Resin: Conform to Type PE 3408 or better. Provide protection against ultraviolet light degradation using carbon black, not less than 2 percent, well dispersed in resin. Pipe wall thickness shall reflect required SDR* and diameter, as shown in Table 8, ASTM F714. For 3" and larger sizes, ASTM D3035. The containment pipe sizes (corresponding to carrier pipe sizes would be as follows (carrier pipe size first and containment pipe size second): • 2"/4" • 3"/6" • 4"/8" • 6"/10" • 8"/12" Design Stress Rating: 1600 psi hydrostatic. Pressure Rating (psi) at 100 degrees F SDR* 128 13.5 100 17.0 90 19.0 Identification: Colored [stripes extruded into pipe outside surface] [marking tape] for identification of type of service, in accordance with APWA Uniform Color Code. *SDR: standard dimension ratio = OD/thickness

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SECTION 22 10 01.08
DOUBLE CONTAINED PIPE AND FITTINGS
HIGH-DENSITY POLYETHYLENE (HDPE)

Item	Size	Description
Fittings	4" & smaller	Molded fittings, butt fusion joined, conforming to ASTM D3261.
Flanges	All	Van Stone type, cast ASTM A351/A351M, Type 316 stainless steel backing ring, IPP Deltaflex convoluted design or equal for bolting to ANSI B16.1, Class 125; ANSI B16.5, Class 150; and AWWA C207, Class E. Pressure performance of backing ring equal to SDR rating of pipe with safety factor of two. Stub ends same grade HDPE and pressure rating as pipe.
Bolting		Stainless steel, ASTM A193/A193M Grade B8M studs and ASTM A194/A194M Grade 8M hex head nuts. Washers shall be same material as bolts.
Gaskets		Flat ring, 1/8" ethylene propylene rubber (EPR).
Manufacturer		Option to purchase already assembled. For steel pipe, purchase each pipe separately and contractor to install centralizers. JM Eagle PE 3408; Driscoplex 4000/4100 PE 3408.

Note: manufacturer to use standard steel pipe and weld in the field.

END OF SECTION

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SECTION 22 30 00
PLUMBING EQUIPMENT

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Gas Association (AGA).
2. American Society of Heating, Refrigerating & Air-Conditioning Engineers, Inc. (ASHRAE): 90.1, Energy Standard for Buildings Except Low-Rise Residential Buildings.
3. American Society of Mechanical Engineer's (ASME).
4. American Society of Sanitary Engineering (ASSE):
   a. 1013, Performance Requirements for Reduced Pressure Principle Backflow Preventers and Reduced Pressure Fire Protection Backflow Preventers.
   b. 1015, Performance Requirements for Double Check Backflow Prevention Assemblies and Double Check Backflow Fire Protection Assemblies.
   c. American Water Works Association (AWWA):
   d. C510, Double Check Valve Backflow Prevention Assembly.
   e. C511, Reduced-Pressure Principle Backflow Prevention Assembly.
   f. C550, Protective Interior Coatings for Valves and Hydrants.
5. ASTM International (ASTM):
   a. A48/A48M, Standard Specification for Gray Iron Castings.
   b. D4101, Standard Specification for Polypropylene Injection and Extrusion Materials.
   c. FM Global (FM).
   d. Food and Drug Administration (FDA).
   e. Foundation for Cross-Connection Control and Hydraulic Research at University of Southern California (FCCHR): Manual of Cross-Connection Control.
   f. International Code Council (ICC): International Plumbing Code (IPC).
   g. National Electrical Code (NEC).
   h. National Electrical Manufacturers Association, (NEMA): MG 1, Motors and Generators.
   i. NSF International (NSF).
   j. Underwriters Laboratories Inc. (UL).

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1.02 SUBMITTALS

A. Action Submittals:

1. Manufacturer's product data.
2. Seismic anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Seismic Anchorage and Bracing.

B. Informational Submittals:

1. Seismic anchorage and bracing calculations as required by Section 01 88 15, Seismic Anchorage and Bracing.
2. Component and attachment testing seismic certificate of compliance as required by Section 01 45 33, Special Inspection[, Observation, and Testing.

1.03 SPECIAL GUARANTEE

A. Where note below, provide manufacturer's extended guarantee in writing with Owner named as beneficiary. Special guarantee shall provide for correction, or at the option of the Owner, removal and replacement of products found defective during the stated period after date of Substantial Completion.

PART 2 - PRODUCTS

2.01 WATER HEATERS

A. Instantaneous Electric Water Heater:

1. Description: UL listed, tankless with removable cover, replaceable heating element, immersion-type thermostat, replaceable inlet filter, and flow regulator.
2. Capacity: See data sheet at end of section.
3. Manufacturers:
   a. Chronomite Laboratories, Inc.
   b. EEMAX, Inc.
   c. Weben-Jarco Inc.

2.02 SUBMERSIBLE CENTRIFUGAL SUMP PUMPS

A. Simplex, Submersible Sump Pump:

1. Description:

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a. Type: Simplex, heavy-duty, nonclog, close-coupled submersible centrifugal sewage ejector pump.
b. Volute: Cast iron, foot mounted.
c. Impeller: Cast iron, double shroud, fully enclosed
d. Wear Plates: Brass.
e. Motor Enclosure: Cast iron, Buna-N O-ring seals with corrosion-resistant exterior finish.
f. Motor: Continuous-duty, built-in thermal overload protection.
g. Shaft Seals: Tandem, mechanical type.
h. Shaft: Stainless steel.
i. Bearings: Permanently lubricated, ball bearing with B-10 bearing life of 17,500 hours.
j. Electrical: Inner seal chamber with 2 moisture sensing probes and attached power and control cables, with length, voltage, and power requirements as indicated on data sheet at end of section.
k. Controls:
1) Circuit Breakers: Motor rated.
2) Motor Starters: Magnetic with thermal overload protection device.
3) Level Control: Polypropylene-encapsulated mechanical float switch.
4) Leak Detection: Pump seal alarm circuit.

2. Capacity: See data sheet at end of section.
3. Manufacturers:
a. Hydromatic Pumps.
b. Paco Pump.
c. Weil Pump Company, Inc.

B. Duplex, Submersible Sump Pump:

1. Construction:
a. Impeller and Volute: Nonclog design, ASTM A48/A48M, Class 30, cast iron capable of passing 2-inch spherical solid.
b. Electrical: Water-resistant, UL listed and CSA approved electrical power cord.
c. Motor: Sealed, oil-filled, NEMA B design with winding thermal sensors.
d. Bearings and Shaft: Upper and lower thrust bearings, solid Type 303 stainless steel shaft.
e. Seals: Two mechanical seals, carbon rotating seal face and ceramic stationary seal face, and lower seal failure sensor and warning device.
2. Controller:

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3. Control Panel: Fabricated steel, NEMA 4 enclosure, door disconnect switch, and bear UL listing mark. Components shall bear UL recognized marking. Wiring, schematics, and workmanship shall comply with NEC and UL.
4. Wiring and Conduit: Minimum of MTH, 600V rated, 18-gauge with 90 degrees C rating, in accordance with NEC standards. Wire sized in accordance with NEC standards.
5. Motor Protection: Magnetic motor starter, across the line type, UL listing mark, under voltage and over voltage protection with manual reset button mounted in panel door.
6. Level Sensors (Duplex): Automatic pump cycle and alternation. Polypropylene encapsulated mechanical level sensors for pump on, pump off, and override (standby pump on). Additional level sensor shall activate audible-visual panel mounted light and horn. Panel mount, push-to-silence button for deactivating audible alarm.

C. Duplex, Column Type, Sump Pump (Acid-Resistant):

1. Construction:
   a. Impeller and Volute: PVC construction with stainless steel inserts.
   b. Motor Support Bracket: Cast iron, epoxy coated.
   c. Shaft: Stainless steel with PVC sleeve.
   d. Bearings: Lower and intermediate ceramic bearings with vapor seals. Upper bearing shall be external and allow shaft adjustment.
   e. Column: Ribbed PVC construction.
   f. Strainer: PVC construction with 1/4-inch diameter holes.
   g. Motor: Vertical mounted, C-face, open drip-proof (ODP), premium-efficiency, ball bearing design.
2. Sump and Cover Plate: Cylindrical design, PVC construction, vaportight with subplates and openings.
3. Controller:
   a. Float: Adjustable, rising rod, PVC construction, fume-tight design. High-level indicator light, dry contacts for remote alarm, alarm horn, and alarm acknowledge.
   b. Control Panel: NEMA 4 enclosure with fusible disconnect switch, HOA (HAND/OFF/AUTO) selector switch. Panel mounted indicator lights for “power on” and “pump off.”
   c. Motor Protection: Magnetic motor starter with overload protection.
4. Capacity: See data sheet at end of section.
5. Manufacturer: Vanton.

2.03 BACKFLOW PREVENTERS

A. Double Check Backflow Preventer (3/4 Inch Through 2 Inches):

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1. Description:
    a. Regulatory Compliance: AWWA C510, CSA B64.5, FCCHR of USC Section 10, ASSE 1015, ICC (IPC).
    b. Valve Body: Bronze.
    c. End Connections: Threaded, NPT.
    d. Maximum Working Pressure: 175 psi (350 psi test).
    e. Temperature Range: 32 degrees to 140 degrees F.
    f. Shutoff Valve: Full port, resilient seated, bronze ball valve with bronze ball valve test cock.
    g. [Inlet Strainer: bronze wye strainer, 40-mesh perforated, Type 304 stainless steel.]
2. Sizes: See data sheet at end of section.
3. Manufacturers and Products:
    a. Febco; Model 850.
    b. Watts Regulator Company; Model 709.

B. Double Check Backflow Preventer (2-1/2 Inches Through 10 Inches):

1. Description:
    a. Regulatory Compliance: AWWA C510, CSA B64.5, FCCHR of USC Section 10, ASSE 1015, ICC (IPC).
    b. Valve Body: Ductile or cast iron, Class 125, epoxy-coated (FDA approved).
    c. End Connections: Flanged.
    d. Maximum Working Pressure: 175 psi (350 psi test).
    e. Temperature Range: 32 degrees to 140 degrees F.
    f. Shutoff Valve: Nonrising stem, resilient seated gate valve with bronze ball valve test cock.
    g. [Inlet Strainer: cast-iron wye strainer, Class 125 flanged, fusion epoxy AWWA C550 coated, perforated stainless steel screen (1/16-inch perforations on 2-1/2 inches to 4 inches; 1/8-inch perforation on 6 inches to 10 inches), threaded cap plug blowout opening.]
2. Sizes: See data sheet at end of section.
2. Manufacturers and Products:
    a. Febco; Model 850.
    b. Watts Regulator Company; Model 709.

C. Reduced Pressure Backflow Preventers (1/4 Inch Through 1/2 Inch):

1. Description:
    a. Regulatory Compliance: AWWA C511, CSA B64.4, ASSE 1013, ICC (IPC), FM, USC-UL.

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b. Valve Body: Bronze.
c. End Connections: Threaded, NPT.
d. Maximum Working Pressure: 175 psi (350 psi test).
e. Temperature Range: 32 degrees to 140 degrees F.
f. Shutoff Valve: Full port, resilient seated, bronze ball valve with bronze ball valve test cock.
g. Accessories: Drainline air gap fitting.

2. Sizes: See data sheet at end of section.
3. Manufacturer and Product: Conbraco Industries; Series 20-400.

D. Reduced-Pressure Backflow Preventers (3/4 Inch Through 2 Inches):

1. Description:
a. Regulatory Compliance: AWWA C511, CSA B64.4, FCCHR of USC Section 10, ASSE 1013, ICC (IPC).
b. Valve Body: Bronze.
c. End Connections: Threaded, NPT.
d. Maximum Working Pressure: 175 psi (350 psi test).
e. Temperature Range: 32 degrees F to 140 degrees F.
f. Shutoff Valve: Full port, resilient seated, bronze ball valve with bronze ball valve test cock.
g. [Inlet Strainer: Bronze wye strainer, 40-mesh perforated, Type 304 stainless steel.]
h. Accessories: Drainline air gap fitting.

2. Sizes: See data sheet at end of section.
3. Manufacturers and Products:
a. Febco; Model 860.
b. Watts; Model 909.

E. Reduced Pressure Backflow Preventers (2-1/2 Inches Through 10 Inches):

1. Description:
a. Regulatory Compliance: AWWA C511, CSA B64.4, FCCHR of USC Section 10, ASSE 1013, IAPMO (UPC), SBCCI.
b. Valve Body: Ductile or cast iron, Class 125, epoxy-coated (FDA approved).
c. End Connections: Flanged.
d. Maximum Working Pressure: 175 psi (350 psi test).
e. Temperature Range: 32 degrees F to 140 degrees F.
f. Shutoff Valve: Nonrising stem, resilient seated gate valve with bronze ball valve test cock.
g. [Inlet Strainer: cast-iron wye strainer, Class 125 flanged, fusion epoxy AWWA C550 coated, perforated stainless steel screen (1/16-inch

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perforations on 2-1/2 inches to 4 inches; 1/8-inch perforation on 6 inches to 10 inches), threaded cap plug blowout opening.]

h. Accessories: Drainline air gap fitting.

2. Sizes: See data sheet at end of section.
3. Manufacturers and Products:
   a. Febco; Model 860.
   b. Watts; Model 909.

F. Water Meter and Meter Boxes: Refer to Section 33 12 13, Water Service Connections.

2.04 ENVIRONMENTAL ENCLOSURES

A. For Backflow Preventers 3/4 Inch to 3 Inches:

1. Description:
   a. Enclosure shall be factory-assembled unit providing heat and accessibility to the system backflow preventers. Unit shall meet the requirements of NFPA and ASSE for testing of the backflow preventer. Design to protect to minus 30 degrees F. Unit shall be suitable for concrete pad mounting.
   b. Adjustable thermostat shall control electric heaters/cables. Set thermostat to maintain 40 degrees F.
   c. Fiberglass construction, 1-inch-thick, factory applied unicellular nonwicking insulation, minimum R-value of 8, hinged and lockable access doors. Designed for exterior installation.
2. Heating Capacity:
   a. 3/4-Inch to 1-1/2-Inch: 60-watt heater, 120 volt, single-phase.
   b. 2-Inch: 90-watt heater, 120 volt, single-phase.
   c. 3-Inch: 1500-watt heaters, 120 volt, single-phase.
3. Manufacturers and Products:
   a. Hot Box; Series HB, Model [_____].
   b. Watts; Model [_____].

B. For Backflow Preventers 4 inches to 10 Inches:

1. Description:
   a. Enclosure shall be factory-assembled unit providing heat and accessibility to the system backflow preventers. Unit shall meet the requirements of NFPA and ASSE for testing of the backflow preventer. Design to protect to minus 30 degrees F. Unit shall be suitable for concrete pad mounting.

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b. Adjustable thermostat shall control electric heaters. Set thermostat to maintain 40 degrees F.
c. Reinforced 18-gauge aluminum construction, factory applied unicellular nonwicking insulation, minimum R-value of 8, hinged and lockable access doors. Designed for exterior installation.
d. Verify unit length, width, and height with manufacturer based on actual backflow preventer provided.

2. Heating Capacity:
   a. 4 Inches: One 2.0-kW heater, 120 volt, single-phase.
   b. 6 Inches and 8 Inches: Two 1.5-kW heaters, 120 volt, single-phase.
   c. 10 Inches: Two 2.0-kW heaters, 120 volt, single-phase.
3. Manufacturers and Products:
   a. Hot Box; Series HB, Model [_____].
   b. Watts; Model [_____].

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install, arrange, and connect equipment as shown on Drawings and in accordance with manufacturer's recommendations.

3.02 FIELD QUALITY CONTROL

A. Pumps: Do not hydrostatic test pumps with mechanical seals.

B. Startup:

1. In accordance with Section 01 91 14, Equipment Testing and Facility Startup, and Section 23 05 93, Testing, Adjusting, and Balancing for HVAC.
2. Piping Systems: Verify that flushing, cleaning, and testing has been completed prior to startup.

3.03 SUPPLEMENTS

A. Supplements listed below, following "End of Section," are a part of this Specification.

1. Data Sheet: Instantaneous Water Heater.
2. Data Sheet: Simplex, Submersible Sump Pump.
3. Data Sheet: Duplex, Submersible Sump Pump.
4. Data Sheet: Duplex, Column Type, Sump Pump (Acid Resistant).

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3. Data Sheet: Backflow Preventers.

END OF SECTION

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Instantaneous Water Heater					
Tag Number	**Flow Rate (gpm)**	**Temperature Rise (Degrees F)**	**Power (kW)**	**Voltage**	**Manufacturer and Model Number**
XX-WH-01	0.5	40	3.0	120V/1ph	Chronomite, Model S-30L
XX-WH-02	0.5	63	4.6	208V/1ph	Chronomite, Model S-46L
XX-WH-03	1.0	41	6.0	208V/1ph	Chronomite, Model S-60I
XX-WH-04	1.0	48	7.0	208V/1ph	Chronomite, Model S-70I
XX-WH-05	1.0	54	8.0	208V/1ph	Chronomite, Model S-80I
XX-WH-06	1.0	61	9.0	208V/1ph	Chronomite, Model S-90I

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Simplex, Submersible Sump Pump						
Tag Number	**Flow Rate (gpm)**	**Pressure (feet head)**	**Motor (hp)**	**Motor Speed (rpm)**	**Power (volts/phase)**	**Manufacturer, Model No.**
XX-SP-01	30	21	1/3	1750	120V/1ph	Weil, 1-1/4” Series 1400
XX-SP-02	50	25	1/2	1750	120V/1ph	Weil, 1-1/2” Series 1410
XX-SP-03	35	10	1/4	1550	120V/1ph	Hydromatic, Model SHEF25
XX-SP-04	30	14	1/3	1550	120V/1ph	Hydromatic, Model SHEF33

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Duplex, Submersible Sump Pump						
Sump Pump:						
Tag Number	**Flow Rate (gpm)**	**Pressure (feet head)**	**Motor (hp)**	**Motor Speed (rpm)**	**Power (volts/phase)**	**Manufacturer, Model No.**
XX-SP-01				1750	120V/1ph	
XX-SP-02				1750	120V/1ph	
XX-SP-03				1750	120V/1ph	
XX-SP-04				1750	120V/1ph	
Sump:						

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Tag Number	Sump Config (sq/rd)	Sump Size (L x W/dia)	Finished Floor (feet)	Inlet Pipe (feet)	Water Alarm (feet)	Override (feet)	Pump On (feet)	Pump Off (feet)	Bottom of Sump (feet)
XX-SP-01	round	4'-0"	100.00	97.00	96.50	96.00	95.50	92.50	92.00
XX-SP-02	round	5'-0"							
XX-SP-03	square	4'-0" x 4'-0"							
XX-SP-04	square	5'-0" x 5'-0"							

Brake Horsepower Calculator:	
Flow =	10 gpm
Pressure =	35 feet head
Fluid Specific Gravity =	1.00
Pump Efficiency =	70%
Motor Efficiency =	90%
Brake Horsepower =	0.14 bhp
Note: Brake horsepower calculator should be deleted from the final equipment schedule.	

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Duplex, Column Type, Sump Pump (Acid Resistant)								
Sump Pump:								
Tag Number	**Flow Rate (gpm)**	**Pressure (feet head)**	**Motor (hp)**	**Motor Speed (rpm)**	**Power (volts/phase)**	**Manufacturer, Model No.**		
XX-SP-01	20	15	1/4	1750	120V/1ph	Vanton, Model SG-200		
XX-SP-02	60	30	1	1750	120V/1ph	Vanton, Model SG-300		
XX-SP-03	100	10	1/2	1750	120V/1ph	Vanton, Model SG-500		
XX-SP-04	100	30	1-1/2	1750	120V/1ph	Vanton, Model SG-800		
Sump:								
Tag Number	**Sump Config (sq/rd)**	**Sump Size (L x W/dia)**	**Finished Floor (feet)**	**Inlet Pipe (feet)**	**High Water Alarm (feet)**	**Pump On (feet)**	**Pump Off (feet)**	**Bottom of Sump (feet)**
XX-SP-01	round	4'-0"	100.00	97.00	96.50	95.50	92.50	92.00
XX-SP-02	round	5'-0"						
XX-SP-03	square	4'-0" x 4'-0"						
XX-SP-04	square	5'-0" x 5'-0"						
Brake Horsepower Calculator:								
Flow =	100 gpm							
Pressure =	30 feet head							
Fluid Specific Gravity =	1.00							

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Duplex, Column Type, Sump Pump (Acid Resistant)	
Pump Efficiency =	70%
Motor Efficiency =	90%
Brake Horsepower =	1.20 bhp
Note: 1. Brake horsepower calculator should be deleted from the final equipment schedule. 2. Add a Pump Override column to the Sump Schedule is a duplex system is used.	

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Backflow Preventers						
Tag Number	**Valve Type[1]**	**Size (inches)**	**Flow Stream**	**Maximum Operating Flow (gpm)**	**Maximum Pressure Drop (psi)**	**Manufacturer, Model No.**
XX-BFP-01	DC	1/2	W1	3	5	Febco, Model 850
XX-BFP-02	DC	3/4	W1	8	6	Febco, Model 850
XX-BFP-03	DC	1	W1	17	7	Febco, Model 850
XX-BFP-04	DC	1-1/2	W1	45	6	Febco, Model 850
XX-BFP-05	DC	2	W1	75	6	Febco, Model 850
XX-BFP-06	DC	2-1/2	W1	120	5	Febco, Model 850
XX-BFP-07	DC	3	W1	175	5	Febco, Model 850
XX-BFP-08	DC	4	W1	320	3	Febco, Model 850
XX-BFP-09	DC	6	W1	700	3	Febco, Model 850
XX-BFP-10	DC	8	W1	1200	3	Febco, Model 850
XX-BFP-11	DC	10	W1	1900	5	Febco, Model 850
XX-BFP-01	RP	1/4	W1	0.75	10	Conbraco, Series 20-400
XX-BFP-02	RP	3/8	W1	1.5	10	Conbraco, Series 20-400
XX-BFP-03	RP	1/2	W1	3	10	Conbraco, Series 20-400
XX-BFP-01	RP	1/2	W1	3	11	Febco, Model 825Y
XX-BFP-02	RP	3/4	W1	8	14	Febco, Model 825Y
XX-BFP-03	RP	1	W1	17	14	Febco, Model 825Y
XX-BFP-04	RP	1-1/2	W1	45	12	Febco, Model 825Y

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Backflow Preventers						
Tag Number	**Valve Type[1]**	**Size (inches)**	**Flow Stream**	**Maximum Operating Flow (gpm)**	**Maximum Pressure Drop (psi)**	**Manufacturer, Model No.**
XX-BFP-05	RP	2	W1	75	12	Febco, Model 825Y
XX-BFP-06	RP	2-1/2	W1	120	11	Febco, Model 825Y
XX-BFP-07	RP	3	W1	175	12	Febco, Model 825Y
XX-BFP-08	RP	4	W1	320	9	Febco, Model 825Y
XX-BFP-09	RP	6	W1	700	10	Febco, Model 825Y
XX-BFP-10	RP	8	W1	1200	11	Febco, Model 825Y
XX-BFP-11	RP	10	W1	1900	12	Febco, Model 825Y

Notes:

1. Valve Type: RP - Reduced Pressure, DC - Double Check.

2. Flow Streams: DIW - Deionized Water, FP - Fire Protection, IRR - Irrigation Water, LCW - Laboratory Cold Water, TWS - Tempered Water Supply, W1 - Potable Water, W2 - Nonpotable Water, W3 - Plant Water.

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SECTION 22 40 00
PLUMBING FIXTURES

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. Americans with Disabilities Act (ADA).
2. American Gas Association (AGA).
3. American Society of Mechanical Engineers (ASME).
4. American Society of Sanitary Engineering (ASSE): 1010, Performance Requirements for Water Hammer Arresters.
5. ASTM International (ASTM): D4101, Standard Specification for Polypropylene Injection and Extrusion Materials.
6. Food and Drug Administration (FDA).
7. Plumbing and Drainage Institute (PDI):
   a. Code Guide 302 and Glossary of Industry Terms.
   b. WH-201, Water Hammer Arrester Standard.
8. Underwriters Laboratories Inc. (UL).

1.02 SUBMITTALS

A. Action Submittals: Catalog information and rough-in dimensions for plumbing fixtures, products, and specialties.

1.03 REGULATORY REQUIREMENTS

A. Comply with the Americans with Disabilities Act (ADA), and local and state requirements.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Fixture Trim:

1. Supply Stops and Traps:
   a. McGuire.
   b. American Standard.
   c. Kohler.

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2. Flush Valves: Sloan.
3. Water Closet Seats:
   a. Bemis.
   b. Church.
   c. Olsonite.
4. Lavatory Supply, Tailpiece, and Trap Insulation:
   a. McGuire.
   b. Trap Wrap.
   c. Truebro.

B. Plumbing Fixtures:

1. Water Closets, Lavatories, and Urinals:
   a. American Standard.
   b. Kohler.
   c. Eljer.
2. Service Sinks:
   a. Kohler.
   b. Eljer.
3. Faucet Fittings:
   a. Sinks:
      1) Chicago.
      2) T&S Brass.
   b. Lavatories:
      1) Chicago.
      2) Symmons.
4. Shower Trim:
   a. Symmons.
   b. Powers.
5. Shower Stalls:
   a. Aqua Glass.
   b. Fixture Manufacturers.
6. Stainless Steel Sinks:
   a. Elkay.
   b. Just.
7. Mop Sinks:
   a. Stern-Williams.
   b. Fiat Products Inc.
   c. Fixture Manufacturers.
8. Drinking Fountains and Electric Water Coolers:
   a. Elkay.
   b. Haws.

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c. Western.

9. Wash Fountains:
   a. Bradly.
   b. Acorn.
   c. Intersan.
   d. Willoughby.

C. Emergency Showers and Eyewashes:

1. Haws.
2. Western.
3. Guardian.

D. Drainage Products:

1. General:
   a. Smith.
   b. Wade.
   c. Zurn.
2. Acid Resistant:
   a. Enfield.
   b. R&G Sloane.
   c. T&C Plastic Drain Co.

E. Plumbing Specialties:

1. Shock Arresters:
   a. Smith.
   b. Sioux Chief.
   c. Precision Plumbing Products.
2. Trap Primers:
   c. Precision Plumbing Products.
   d. Smith.
   e. Wade.
2. Pressure/Temperature Relief Valves:
   a. Cash-Acme.
   b. Kunkle Valve.
   c. Watts.
3. Pressure Gauges:
   a. Ashcroft.
   b. Marsh.
   c. Marshalltown.

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4. Thermometers:
   a. Trerice.
   b. Weksler.
5. Automatic Washer Supplies:
   a. Guy Gray.
   b. Symmons.

2.02 GENERAL

A. Fixture Trim: Provide plumbing fixture trim where applicable on fixtures.

B. Plumbing Fixtures: Indicated by fixture number as shown on Drawings.

C. Drainage Products: Indicated by fixture number as shown on Drawings.

D. Plumbing Specialties: Indicated by fixture number as shown on Drawings.

E. Exposed fixture connections and piping shall be polished chrome-plated.

2.03 MATERIALS

A. Fixture Trim:

1. Supply Stop:
   a. Flexible supply with heavy cast brass, loose key, 1/2-inch IPS by 3/8-inch outside diameter tubing angle stop to wall with escutcheon plate; chrome-plated finish.
   b. Provide stop with stuffing box.
   c. Manufacturer: McGuire Manufacturing Company, Inc.
2. Trap:
   a. Chrome-plated, 17-gauge, semicast P-trap with compression ring cast brass waste and vent connection and cleanout.
   b. 1-1/2 inches for lavatories and drinking fountains.
   c. 1-1/2 inches for sinks.
   d. Manufacturer: McGuire Manufacturing Company, Inc.
3. Water Closet and Urinal Flush Valves: Sloan Valve Co., Royal Continental, low flush, quiet action with screwdriver stop and vacuum breaker.

B. Plumbing Fixtures:

1. LAV-1, Lavatory (Wall-Hung Type, ADA Compliant):
   a. Fixture: 20 inches by 18 inches, vitreous china, for floor-mounted concealed arm carrier, three-hole punched on 4-inch centers for faucet

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[; additional hole for soap dispenser]. American Standard Companies, Inc.; Lucerne, Model 0355.012.

b. Faucet: Chicago Faucet Co.; Model 2200-4CP with 0.5-gpm flow restricter.

c. Trim: 3/8-inch supply stop with loose key, 17-gauge chrome-plated cast brass P-trap.

d. Insulation: McGuire Manufacturing Company, Inc., Prowrap antimicrobial PVC resin seamless insulation for trap, tailpiece, and hot and cold water supply piping.

e. Strainer: McGuire Manufacturing Company, Inc.; Model 155A chrome-plated grid strainer with tailpiece.

f. Carrier: Jay R. Smith Mfg. Co.; 700 series concealed arm.

2. LAV-3, Lavatory (Counter Set, Oval):

a. Fixture: 20 inches by 17 inches, vitreous china, self-rimming. American Standard Companies, Inc.; Aqualyn, Model 0476.028.

b. Faucet: Chicago Faucet Co.; Model 2200-4CP with 0.5-gpm flow restricter.

c. Trim: 3/8-inch supply stop with loose key, 17-gauge chrome-plated cast brass P-trap.

d. Insulation: McGuire Manufacturing Company, Inc.; Prowrap antimicrobial PVC resin seamless insulation for trap, tailpiece, and hot and cold water supply piping.

e. Strainer: McGuire Manufacturing Company, Inc.; Model 155A chrome-plated grid strainer with tailpiece.

3. LAV-4, Lavatory (Under Counter Set, Oval):

a. Fixture: 17 inches by 14 inches, vitreous china, unglazed rim for underdeck mounting, rear overflow with mounting kit. American Standard Companies, Inc.; Ovalyn II, Model 0496.221.

b. Faucet: Chicago Faucet Co.; Model 2200-4CP with 0.5-gpm flow restricter.

c. Trim: 3/8-inch supply stop with loose key, 17-gauge chrome-plated cast brass P-trap.

d. Insulation: McGuire Manufacturing Company, Inc.; Prowrap antimicrobial PVC resin seamless insulation for trap, tailpiece, and hot and cold water supply piping.

e. Strainer: McGuire Manufacturing Company, Inc.; Model 155A chrome-plated grid strainer with tailpiece.

4. LAV-5, Lavatory (Wall Hung Type, Stainless Steel):

a. Fixture: 23 inches by 20 inches, 18-gauge Type 304 stainless steel, seamless welded construction with integral backsplash and apron,

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underside sound deadened, wall clip with integral flange, three-hole punched on 4-inch centers for faucet. Just; Model A-33338.

b. Faucet: Chicago Faucet Co.; Model 2200-4CP with 0.5-gpm flow restricter.
c. Trim: 3/8-inch supply stop with loose key, 17-gauge, chrome-plated cast brass P-trap.
d. Strainer: McGuire Manufacturing Company, Inc.; Model 155A chrome-plated grid strainer with tailpiece.

5. WF-1, Wash Fountain (ADA Compliant):
   a. 54-inch diameter wash fountain, [semi-circular] [circular]. Type 304 stainless steel, 14-gauge, one-piece polished to a No. 4 finish. Straight pedestal panels, same material as bowl. Thermostatic mixing valve, check valves, internal pipe assembly, distribution header, isolation valve s, and multiple station soap dispensers.
   b. Supply Header Operation: Infrared; furnish 24V ac transformer.
   c. Drain: 2-inch grid drain and trap assembly.
   d. Service Configuration: Refer to Drawings.
   e. Manufacturer and Product: [Semi-circular, Sentry Model SN2004.] [Circular, Sentry Model SN2008.]
6. S-1, Sink (Counter, Stainless Steel, Single Compartment):
   a. Fixture: 21 inches by 25 inches overall by 8 inches deep, 18-gauge, Type 304 stainless steel, three-hole punch, self-rimming, undercoated, ledge-type. Just Mfg. Co.; Model SL-2125-A-GR.
   b. Faucet: [Chicago Faucet Co.; Model 2300-8 single handle with 8-inch cover plate.] [Chicago Faucet Co.; Model 1201 double handle.]
   c. Trim: 1-1/2-inch outside diameter, 17-gauge chrome-plated cast tailpiece and cast brass P-trap with cleanout, and 1/2-inch wall supply stop with loose key.
   d. Strainer: Just Mfg. Co.; Model J-35, stainless steel crumb-type.
   e. [Disposer: IES (In-Sink-Erator); Model 77, 3/4 horsepower, stainless steel.]
   f. [Hot Water Dispenser: ISE (In-Sink-Erator); Model GN, 190 degrees.]
7. S-2, Sink (Counter, Stainless Steel, Double Compartment):
   a. Fixture: 21 inches by 33 inches overall by 8 inches deep, 18-gauge, Type 304 stainless steel, three-hole punch, self-rimming, undercoated, ledge-type. Just Mfg. Co.; Model DL-2133-A-GR.
   b. Faucet: [Chicago Faucet Co.; Model 2300-8; single handle with 8-inch cover plate.] [Chicago Faucet Co.; Model 1201A, double handle.]

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c. Trim: 1-1/2-inch outside diameter, 17-gauge chrome-plated cast tailpiece and cast brass P-trap with cleanout, and 1/2-inch wall supply stop with loose key.
d. Strainer: Just Mfg. Co.; Model J-35, stainless steel crumb-type.
e. [Disposer: IES (In-Sink-Erator); Model 77, 3/4 horsepower, stainless steel.]
f. [Hot Water Dispenser: ISE (In-Sink-Erator); Model GN, 190 degrees.]

8. S-4, Sample Sink (Single Compartment, Free Standing):
   a. Fixture: 24 inches by 24 inches by 14 inches deep, 14-gauge, Type 304 stainless steel, 8-inch backsplash, adjustable stainless steel tubular legs. Elkay Mfg. Co.; Model SS-8124.
   b. Faucet: Short spout with vacuum breaker, 3/4-inch hose thread outlet, pail hook, H supply arms, 4-inch to 8-3/8-inch adjustable centers, lever handles. Faucet mounted on backsplash. Chicago Faucet Co.; Model 305-VB.
   c. Trim: 1-1/2-inch outside diameter, 17-gauge chrome-plated flat strainer, tailpiece, and cast brass P-trap with cleanout, and 1/2-inch wall supply stop with loose key. Elkay Mfg. Co.; Model LK-18.
9. ES-1, Emergency Shower (Freestanding):
   a. Model: Haws Drinking Faucet Co.; Model 8100.
   b. Shower: ABS plastic deluge.
   c. Valve: Stay-open, chrome-plated brass ball valve.
   d. Support: 1-1/4-inch galvanized pipe standard with 9-inch-diameter floor flange.
   e. Alarm: Magnetically operated proximity switch.
   f. Factory applied CRP (corrosive atmospheres coating).
10. ES-2, Emergency Shower (Freeze Resistant):
    a. Model: Haws Drinking Faucet Co.; Model 8111FP.
    b. Shower: ABS plastic deluge.
    c. Valve: Stay-open, chrome-plated brass ball valve with special extension shaft for location inside of building.
    d. Support: Shower support brace to wall.
    e. Alarm: Magnetically operated proximity switch.
    f. Factory applied CRP (corrosive atmospheres coating).
11. ES-3, Emergency Shower:
    a. Model: Haws Drinking Faucet Co.; Model [8122H] [8122V].
    b. Shower: ABS plastic deluge.
12. Valve: Stay-open, chrome-plated brass ball valve.
    a. Alarm: Magnetically operated proximity switch.
13. Factory applied CRP (corrosive atmospheres coating).
    a. ES-4, Emergency Shower (All Stainless Steel):

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b. Model: Haws Drinking Faucet Co.; Model [8133H] [8133V].
c. Shower: Stainless steel deluge.
d. Valve: Stay-open, stainless steel ball valve activated by pulling stainless steel pull rod.
e. Alarm: Magnetically operated proximity switch.

14. EE-1, Emergency Eyewash (Deck-Mounted):
    a. Model: Haws Drinking Faucet Co.; Model 7612.
    b. Eyewash: Polished dual chrome-plated brass heads, swing-away design and automatic stream control.
    c. Valve: Stay-open, polished chrome-plated brass ball valve.
15. EE-2, Emergency Eyewash (Freestanding):
    a. Model: Haws Drinking Faucet Co.; Model 7720.
    b. Eyewash: ABS plastic receptor, dual PVC-covered anti-surge spray heads and automatic stream control.
    c. Valve: Stay-open, polished chrome-plated brass ball valve.
    d. Support: Galvanized steel pedestal with 9-inch-diameter floor flange.
    e. Alarm: Magnetically operated proximity switch.
    f. Factory applied CRP (corrosive atmospheres coating).
16. EE-3, Emergency Eyewash (Stainless Steel, Freestanding):
    a. Model: Haws Drinking Faucet Co.; Model 7777.
    b. Eyewash: Dual stainless steel heads and 16-inch-diameter face spray ring with stainless steel receptor.
    c. Valv5e: Stay-open, stainless steel ball valve.
    d. Support: Stainless steel pipe pedestal with 9-inch-diameter stainless steel floor flange.
    e. Alarm: Magnetically operated proximity switch.
17. EE-4, Emergency Eyewash (Stainless Steel, Wall Mount):
    a. Model: Haws Drinking Faucet Co.; Model 7778B.
    b. Eyewash: Dual stainless steel heads and 16-inch-diameter face spray ring with stainless steel receptor.
    c. Valve: Stay-open, stainless steel ball valve.
    d. Support: Stainless steel wall bracket.
    e. Alarm: Magnetically operated proximity switch.
18. EE-5, Emergency Eyewash (Wall Mount, Pull Down):
    a. Model: Haws Drinking Faucet Co.; Model [7651.] [7655.]
    b. Eyewash: Dual stainless steel heads.
    c. Valve: Stay-open, chrome-plated valve activated by pulling down on spray arm.
    d. Mount: [To wall face with lock nut.] [Mount: recessed 18-gauge, Type 304 stainless steel No. 4 finish cabinet.]
19. EE-6, Emergency Eyewash (Self-Contained, Heated):

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a. Model: Haws Drinking Faucet Co.; Model 7500EB.
b. Tank: 16-gallon, FDA high-density polyethylene material with fitted insulated protective cover.
c. Heating System: 1,000-watt heater, thermostatic control to maintain 75 degrees F water temperature.
d. Temperature and Safety Control: Two thermostats with safety override thermostat with warning light and manual reset button.
e. Electrical: UL listed components, 110-volt plug, grounded and weather tight, three lighted indicators for power is on, heater is activated, and malfunction.
f. Hydrosep: Haws Drinking Faucet Co.; Model 9081, bacteriostatic additive to permit storage of water for several months.

20. SSH-1, Safety Shower/Eyewash Combination:
    a. Model: Haws Drinking Faucet Co.; Model 8346.
    b. Shower: ABS plastic deluge.
    c. Eyewash: Stainless steel bowl with aerated eye/face wash.
    d. Valve: Stay open.
    e. Support: Freestanding, 1-1/4-inch galvanized pipe standard, stanchion, and floor flange.
    f. Alarms: Magnetically operated proximity switches.
    g. Factory applied CRP (corrosive atmospheres coating).
21. SSH-2, Safety Shower/Eyewash Combination (Freeze-proof):
    a. Model: Haws Drinking Faucet Co.; Model 8317CTFPT.
    b. Shower: ABS plastic deluge.
    c. Eyewash: Stainless steel bowl with aerated eye/face wash.
    d. Valve: Stay open.
    e. Support: Freestanding, 1-1/4-inch galvanized pipe standard, stanchion, and floor flange, cable heated and insulated.
    f. Alarms: Magnetically operated proximity switches.
22. SSH-3, Safety Shower/Eyewash Combination (Frost-proof):
    a. Model: Haws Drinking Faucet Co.; Model 8330FP.
    b. Shower: Stainless steel deluge.
    c. Eyewash: Stainless steel aerated eye/face wash, dust cover, and stainless steel bowl.
    d. Valve: Stainless steel, freeze-proof, stay open with stainless steel push-plates and rods.
    e. Bury Depth: [24 inches.] [42 inches.] [66 inches.]
    f. Support: Freestanding, 1-1/4-inch stainless steel pipe standard, stanchion, and floor flange.
    c. Alarms: Magnetically operated proximity switches.
23. SSH-4, Safety Shower/Eyewash Combination (All Stainless Steel):

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a. Model: Haws Drinking Faucet Co.; Model 8330.
b. Shower: Stainless steel deluge.
c. Eyewash: Stainless steel aerated eye/face wash and stainless steel bowl.
d. Valve: Stay open.
e. Support: Freestanding, 1-1/4-inch stainless steel pipe standard, stanchion, and floor flange.
f. Alarms: Magnetically operated proximity switches.

24. SSH-5, Safety Shower/Eyewash Combination (All PVC):
a. Model: Haws Drinking Faucet Co.; Model 8336.
b. Shower: PVC deluge.
c. Eyewash: PVC aerated eye/face wash and PVC bowl.
d. Valve: Stay open.
e. Support: Freestanding, 2-1/2 inches, Schedule 80, PVC pipe standard, stanchion, and floor flange.
f. Alarms: Magnetically operated proximity switches.

25. SSH-6, Safety Shower/Eyewash Combination (Enclosed):
a. Model: Haws Drinking Faucet Co.; Model 8605.
b. Shower: ABS plastic deludge.
c. Eyewash: Chrome-plated brass spray nozzles.
d. Valve: Stay open.
e. Enclosure: Molded fiberglass on three sides, top, and bottom with 3-inch drain.
d. Alarms: Magnetically operated proximity switches.

C. Drainage Products:

1. AD-1, Area Drain:
a. Material: Cast-iron body and grate.
b. Options: Hinged grate, sediment bucket, and vandalproof screws.
c. Manufacturer and Product: Jay R. Smith Mfg. Co.; Model 2210Y-H-U.

2. AD-2, Area Drain (Deck Drain):
a. Material: Cast-iron body and polished bronze strainer.
b. Options: Sump receiver, underdeck clamp, vandalproof screws, and seepage openings.
c. Manufacturer and Product: Jay R. Smith Mfg. Co.; Model 1470Y-R-C-PB-U.

3. CO-1, Cleanout (Exterior):
a. Material: Taper thread, bronze plug, heavy-duty, scoriated cast-iron top.
b. Manufacturer and Product: Jay R. Smith Mfg. Co.; Model 4263.

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4. CO-2, Cleanout:
   a. Material: Taper thread, bronze plug, scoriated nickel bronze top.
   b. Manufacturer and Product: Jay R. Smith Mfg. Co.; Model 4023.
5. FCO-1, Floor Cleanout (Finished Areas):
   a. Material: Tapered thread, bronze plug with round adjustable scoriated secured nickel bronze top.
   b. Manufacturer and Product: Jay R. Smith Mfg. Co.; Model 4103S.
6. FCO-2, Floor Cleanout (Unfinished Areas):
   a. Material: Tapered thread, bronze plug with round adjustable scoriated secured cast-iron top.
   b. Manufacturer and Product: Jay R. Smith Mfg. Co.; Model 4243S.
7. FCO-3, Floor Cleanout (Acid Resistant):
   a. Material: Polypropylene conforming to ASTM D4101.
   b. Ferrule supplied with countersunk plug and adjustable top with round cover, with Acid Waste Cleanout (AWCO) cast in the cover.
   c. Manufacturer and Product: Orion Fittings Inc.; Model FCO-RD.
8. FD-1, Floor Drain (Finished Areas):
   a. Materials: Cast-iron body, adjustable nickel bronze strainer.
   b. Options: Jay R. Smith Mfg. Co.; Model 2696, trap primer connection, vandalproof screws.
   c. Manufacturer and Product: Jay R. Smith Mfg. Co.; Model 2005T-U-[round] [square].
9. FD-2, Floor Drain (Unfinished Areas, General Drainage):
   a. Materials: Cast-iron body and grate.
   b. Options: Sediment bucket, Jay R. Smith Mfg. Co.; Model 2696, trap primer connection, vandalproof screws.
   c. Manufacturer and Product: Jay R. Smith Mfg. Co.; Model 2210T-U.
10. FD-3, Floor Drain (Unfinished Areas, Heavy Drainage):
    a. Materials: Cast-iron body and grate.
    b. Options: Sediment bucket, Jay R. Smith Mfg. Co.; Model 2696, trap primer connection, vandalproof screws.
    c. Manufacturer and Product: Jay R. Smith Mfg. Co.; Model 2233T-U.
    d. FD-4, Floor Drain (Gutter Drain):
    e. Materials: Rectangular cast-iron body and grate.
    f. Manufacturer and Product: Jay R. Smith Mfg. Co.; Model 2585T-U.
11. FD-5, Floor Drain (Indirect Receptor):
    a. Materials: Cast-iron body and strainer.
    b. Options: Round top, antiflood rim strainer, Jay R. Smith Mfg. Co.; with integral trap primer connection, vandalproof screws.
    c. Manufacturer and Product: Jay R. Smith Mfg. Co.; Model 2010T-U-F37.

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12. FD-6, Floor Drain (Acid Resistant):
    a. Materials: Acid-resistant polypropylene with flame-retardant body, integral flange with clamping collar, basket strainer, and top grate.
    b. Model: T & C Plastic Drain Co., Inc.; Model PP-7749 (2 inches), PP-7750 (3 inches), PP-7751 (4 inches).
13. GD-1, Gutter Drain:
    a. Material: Rough bronze flashing clamp and bronze top secured high dome.
    b. Manufacturer and Product: Jay R. Smith Mfg. Co.; Model [1630-RBB, bottom outlet] [1690-RBB, side outlet].

D. Hose Valves: Refer to Section 22 10 01, Plumbing Piping and Accessories.

E. Plumbing Specialties:

1. Water Hammer Arresters:
    a. Materials: ASSE 1010 certified, Type L copper tube, HHPP piston with two lubricated EPDM O-rings, FDA approved lubricant, rolled piston stop, wrought copper male thread adapter.
    b. Manufacturer and Product: Sioux Chief Mfg. Co., Inc.; Series 650 and 660.

PART 3 - EXECUTION

3.01 PREPARATION

A. Drawings do not attempt to show exact details of fixtures. Changes in locations of fixtures, advisable in opinion of CONTRACTOR, shall be submitted to ENGINEER for review before proceeding with the Work.

3.02 INSTALLATION

A. Fixture Trim: Install fixture trim where applicable on fixtures.

B. Plumbing Fixtures, Mounting Heights:

1. Standard rough-in catalogued heights, unless shown otherwise on Drawings.
2. Caulk fixtures in contact with finished walls with waterproof, white, nonhardening sealant which will not crack, shrink, or change color with age. See Section 07 92 00, Joint Sealants.

C. Exact fixture location and mounting arrangement shall be as indicated on toilet room elevations and details as shown on Drawings.

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D. Unless noted otherwise and as a minimum, fixtures shall be supported as indicated in PDI Code Guide 302.

E. Safety Equipment:

1. System Shutoff Valves:
   a. Shutoff valves shall give visual indication of position (open or closed).
   b. Shutoff valves shall be lockable valves and locked in open position.
2. Each safety shower, eyewash, combination safety shower/eyewash shall have red safety signoff tag. After completing requirements listed below, CONTRACTOR and OWNER shall sign red safety signoff tag. Requirements are as follows:
   a. Visually check safety shower/eyewash piping for leaks.
   b. Verify that upon operation, stay-open valves remain open.
   c. Showerheads to be between 82 inches and 96 inches above standing surface.
   d. Shower spray pattern, when valve is full open, shall be a minimum 20 inches in diameter at 60 inches above standing surface.
   e. Water arcs from eyewash spray heads must cross. Test with eyewash gauge; Haws Drinking Faucet Co., Model 9015.
   f. Minimum flow rates for safety showers shall be 20 gpm.
   g. Minimum flow rates for eyewashes shall be 3 gpm.
   h. Tempered water shall be temperature indicated on Drawings.

F. Drainage Products:

1. Floor Drains: Set top flush with floor. Provide membrane clamps where required.
2. Cleanouts: Install where shown or required for purposes intended. Set cover flush with finished floor.
3. Hub Drains: Set top of hub 2 inches above finished floor.

G. Plumbing Specialties:

1. Shock Arresters:
   a. Install PDI-certified and rated shock arresters, sized and located in accordance with PDI WH-201 and as shown on Drawings.
   b. Install adjacent to equipment wherein quick closing valves are installed.
   c. Install at each emergency safety shower.
   d. Shock arresters to have access panels or to be otherwise accessible.

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2. Drain P-Trap Priming:
   a. Pipe: Type K, soft copper.
   b. Trap and prime floor drains and hub drains, unless shown otherwise on the Drawings. No attempt has been made to show trap primer valve locations or trap primer pipe routing.
   c. Field route trap primer piping during installation of floor drains and hub drains, and install trap primer valves in mechanical rooms, janitor rooms, or other locations acceptable to ENGINEER.
   d. Priming System: Complete with connection to serving [W1] [W2] [W3] cold water system.
3. Trap Priming Valves:
   a. Floor drain traps primed with priming valves, 1/2-inch copper to floor drain.
   b. Two traps maximum primed from one priming valve or as recommended by manufacturer. Locate in mechanical spaces or janitor's rooms and as indicated on Drawings.
   c. Provide shutoff valve ahead of priming valves.
4. Thermometers and Pressure Gauges:
   a. Arrange devices to facilitate use and observation.
   b. Install in orientation that will allow clear observation from ground level.
   c. Provide pressure gauges with block valves.
   d. Install thermometers in thermowells.

H. Caulk penetrations of exterior walls with weatherproof sealant in accordance with Section 07 92 00, Joint Sealants.

I. Adjust water flows in domestic water systems for reasonable water flows at each plumbing fixture, terminal device, and recirculation loop. Flush valve fixtures shall be adjusted for proper flush cycle time and water quantity.

3.03 FIELD QUALITY CONTROL

A. Perform visual inspection for physical damage, blocked access, cleanliness, and missing items.

B. Notify OWNER and ENGINEER 48 hours prior to shower testing. OWNER and ENGINEER reserve the right to witness all tempered water and safety shower testing.

C. Test safety shower and eyewash units. Water flow must be tested at both showerhead and eyewash/face ring.

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1. Shower Flow:
   a. Test with tube-type water gauge (Haws Drinking Faucet Co., Model 9010) and 5-gallon container.
   b. Container shall fill in 10 seconds or less, with a minimum 20-gpm flow.
2. Eyewash Flow:
   a. Test with tube-type water gauge (Haws Drinking Faucet Co., Model 9010) and 1-gallon container.
   b. Container shall fill in 20 seconds or less.
   c. CONTRACTOR shall log, date, and initial inspection upon passing flow tests.

D. Verify alarm operation both locally and systemwide. Notify security prior to test if alarm is connected systemwide.

END OF SECTION

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SECTION 23 05 93
TESTING, ADJUSTING, AND BALANCING FOR HVAC

PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes:

1. Testing adjusting, and balancing of air systems.
2. Testing adjusting, and balancing of hydronic [steam] [and] [refrigerating] systems.
3. Measurement of final operating condition of HVAC systems.
4. Sound measurement of equipment operating conditions.
5. Vibration measurement of equipment operating conditions.

B. Related Sections:

1. Section 23 09 23, Direct-Digital Control System for HVAC: Requirements for coordination between DDC system and testing, adjusting, and balancing work.
2. Section 23 09 93, Sequence of Operations for HVAC Controls: Sequences of operation for HVAC equipment.

1.02 REFERENCES

A. Associated Air Balance Council: AABC MN-1, National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems.

B. American Society of Heating, Refrigerating and Air-Conditioning Engineers: ASHRAE 11, Practices for Measurement, Testing, Adjusting and Balancing of Building Heating, Ventilation, Air-Conditioning and Refrigeration Systems.

C. Natural Environmental Balancing Bureau: NEBB, Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems.

1.03 SUBMITTALS

A. Section 01 33 00, Submittal Procedures: Submittal procedures.

B. Prior to commencing Work, submit proof of latest calibration date of each instrument.

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C. Test Reports: Indicate data on [AABC MN-1 National Standards for Total System Balance forms] [forms prepared following ASHRAE 111] [NEBB Report forms] [forms containing information indicated in Schedules]. [Submit data in S.I. units.]

D. Field Reports: Indicate deficiencies preventing proper testing, adjusting, and balancing of systems and equipment to achieve specified performance.

E. Prior to commencing Work, submit report forms or outlines indicating adjusting, balancing, and equipment data required. Include detailed procedures, agenda, sample report forms [and copy of AABC National Project Performance Guaranty] [and Copy of NEBB Certificate of Conformance Certification] [_____].

F. Submit draft copies of report for review prior to final acceptance of Project.

G. Furnish reports in [soft cover, letter size, 3-ring] [_____] binder manuals, complete with table of contents page and indexing tabs, with cover identification at front and side. Include set of reduced drawings with air outlets and equipment identified to correspond with data sheets, and indicating thermostat locations.

1.04 CLOSEOUT SUBMITTALS

A. Section 01 70 00, Execution and Closeout Requirements: Closeout procedures.

B. Project Record Documents: Record actual locations of [flow measuring stations] [balancing valves and rough setting].

C. Operation and Maintenance Data: Furnish final copy of testing, adjusting, and balancing report inclusion in operating and maintenance manuals.

1.05 QUALITY ASSURANCE

A. Perform Work in accordance with [[State] [Municipality] of [_____] [Highways] [Public Work's] standard.]

B. Perform Work in accordance with [AABC MN-1 National Standards for Field Measurement and Instrumentation, Total System Balance] [ASHRAE 111] [NEBB Procedural Standards for Testing, Balancing and Adjusting of Environmental Systems].

C. Maintain one copy of each document on site.

D. Prior to commencing Work, calibrate each instrument to be used. [Upon completing Work, recalibrate each instrument to assure reliability.]

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1.06 QUALIFICATIONS

A. Agency: Company specializing in testing, adjusting, and balancing of systems specified in this section with minimum [three] [_____] years [documented] experience [certified by AABC] [Certified by NEBB].

B. Perform Work under supervision of [AABC Certified Test and Balance Engineer] [NEBB Certified Testing, Balancing and Adjusting Supervisor] [registered professional engineer experienced in performance of this Work and licensed [at place where Project is located] [in State of [_____]]].

1.07 PRE-INSTALLATION MEETINGS

A. Section 01 30 00, Administrative Requirements: Pre-installation meeting.

B. Convene minimum [one] [_____] week prior to commencing work of this section.

1.08 SEQUENCING

A. Section 01 10 00, Summary: Work sequence.

B. Sequence balancing between completion of systems tested and Date of Substantial Completion.

1.09 SCHEDULING

A. Section 01 30 00, Administrative Requirements: Coordination and project conditions.

B. Schedule and provide assistance in final adjustment and test of [life safety] [smoke evacuation] [smoke control] [_____] system with Fire Authority.

PART 2 – PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.01 EXAMINATION

A. Section 01 30 00, Administrative Requirements: Coordination and project conditions.

B. Verify systems are complete and operable before commencing work. Verify the following:

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1. Systems are started and operating in safe and normal condition.
2. Temperature control systems are installed complete and operable.
3. Proper thermal overload protection is in place for electrical equipment.
4. Final filters are clean and in place. If required, install temporary media in addition to final filters.
5. Duct systems are clean of debris.
6. Fans are rotating correctly.
7. Fire and volume dampers are in place and open.
8. Air coil fins are cleaned and combed.
9. Access doors are closed and duct end caps are in place.
10. Air outlets are installed and connected.
11. Duct system leakage is minimized.
12. Hydronic systems are flushed, filled, and vented.
13. Pumps are rotating correctly.
14. Proper strainer baskets are clean and in place or in normal position.
15. Service and balancing valves are open.

3.02 PREPARATION

A. Furnish instruments required for testing, adjusting, and balancing operations.

B. Make instruments available to Architect/ENGINEER to facilitate spot checks during testing.

3.03 INSTALLATION TOLERANCES

A. Air Handling Systems: Adjust to within plus or minus [10] [_____] percent of design.

B. Air Outlets and Inlets: Adjust total to within plus [10] [_____] percent and minus [5] [_____] percent of design to space. Adjust outlets and inlets in space to within plus or minus [10] [_____] percent of design.

C. Hydronic Systems: Adjust to within plus or minus 10 percent of design.

3.04 ADJUSTING

A. Section 01 70 00, Execution and Closeout Requirements: Testing, adjusting, and balancing.

B. Verify recorded data represents actual measured or observed conditions.

C. Permanently mark settings of valves, dampers, and other adjustment devices allowing settings to be restored. Set and lock memory stops.

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D. After adjustment, take measurements to verify balance has not been disrupted. If disrupted, verify correcting adjustments have been made.

E. Report defects and deficiencies noted during performance of services, preventing system balance.

F. Leave systems in proper working order, replacing belt guards, closing access doors, closing doors to electrical switch boxes, and restoring thermostats to specified settings.

G. At final inspection, recheck random selections of data recorded in report. Recheck points or areas as selected and witnessed by OWNER.

H. Check and adjust systems approximately six months after final acceptance and submit report.

3.05 AIR SYSTEM PROCEDURE

A. Adjust air handling and distribution systems to obtain required or design supply, return, and exhaust air quantities [at site altitude].

B. Make air quantity measurements in main ducts by Pitot tube traverse of entire cross sectional area of duct.

C. Measure air quantities at air inlets and outlets.

D. Adjust distribution system to obtain uniform space temperatures free from objectionable drafts.

E. Use volume control devices to regulate air quantities only to extent adjustments do not create objectionable air motion or sound levels. Effect volume control by using volume dampers located in ducts.

F. Vary total system air quantities by adjustment of fan speeds. Provide sheave drive changes to vary fan speed. Vary branch air quantities by damper regulation.

G. Provide system schematic with required and actual air quantities recorded at each outlet or inlet.

H. Measure static air pressure conditions on air supply units, including filter and coil pressure drops, and total pressure across fan. Make allowances for 50 percent loading of filters.

I. Adjust outside air automatic dampers, outside air, return air, and exhaust dampers for design conditions.

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J. Measure temperature conditions across outside air, return air, and exhaust dampers to check leakage.

K. At modulating damper locations, take measurements and balance at extreme conditions. [Balance variable volume systems at maximum airflow rate, full cooling, and at minimum airflow rate, full heating.]

L. Measure building static pressure and adjust supply, return, and exhaust air systems to obtain required relationship between each to maintain approximately 0.05 inches positive static pressure [near building entries] [in clean rooms] [_____].

M. Check multi-zone units for motorized damper leakage. Adjust air quantities with mixing dampers set first for cooling, then heating, then modulating.

N. For variable air volume system powered units set volume controller to airflow setting indicated. Confirm connections properly made and confirm proper operation for automatic variable-air-volume temperature control.

O. On fan powered VAV boxes, adjust airflow switches for proper operation.

3.06 WATER SYSTEM PROCEDURE

A. Adjust water systems, after air balancing, to obtain design quantities.

B. Use calibrated [Venturi tubes, orifices, or other metered] fittings and pressure gauges to determine flow rates for system balance. Where flow-metering devices are not installed, base flow balance on temperature difference across various heat transfer elements in system.

C. Adjust systems to obtain specified pressure drops and flows through heat transfer elements prior to thermal testing. Perform balancing by measurement of temperature differential in conjunction with air balancing.

D. Effect system balance with automatic control valves fully open or in normal position to heat transfer elements.

E. Effect adjustment of water distribution systems by means of balancing cocks, valves, and fittings. Do not use service or shut-off valves for balancing unless indexed for balance point.

F. Where available pump capacity is less than total flow requirements or individual system parts, simulate full flow in one part by temporary restriction of flow to other parts.

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3.07 SCHEDULES

A. Equipment Requiring Testing, Adjusting, and Balancing:

1. Fire Pumps.
2. Plumbing Pumps.
3. Steam Condensate Pumps.
4. Boiler Feedwater Pumps.
5. HVAC Pumps.
6. Water Tube Boilers.
7. Packaged Steel Water Tube Boilers.
8. Packaged Steel Fire Tube Boilers.
9. Forced Air Furnaces.
10. Direct Fired Furnaces.
11. Reciprocating Water Chillers.
12. Air Cooled Water Chillers.
13. Centrifugal Water Chillers.
14. Absorption Water Chillers.
15. Induced Draft Cooling Tower.
16. Blow Through Cooling Tower.
17. Air Cooled Refrigerant Condensers.
18. Packaged Roof Top Heating/Cooling Units.
19. Packaged Terminal Air Conditioning Units.
20. Unit Air Conditioners.
21. Computer Room Air Conditioning Units.
22. Air Coils.
23. Evaporative Humidifier.
24. Sprayed Coil Dehumidifier.
25. Terminal Heat Transfer Units.
26. Induction Units.
27. Unit Ventilators.
28. Fan Coil Units.
29. Air Handling Units.
30. Fans.
31. Air Filters.
32. Air Terminal Units.
33. Air Inlets and Outlets.
34. Heat Exchangers.

B. Report Forms

1. Title Page:
    a. Name of Testing, Adjusting, and Balancing Agency

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b. Address of Testing, Adjusting, and Balancing Agency
c. Telephone and facsimile numbers of Testing, Adjusting, and Balancing Agency
d. Project name
e. Project location
f. Project Architect
g. Project Engineer
h. Project Contractor
i. Project altitude
j. Report date

2. Summary Comments:
   a. Design versus final performance
   b. Notable characteristics of system
   c. Description of systems operation sequence
   d. Summary of outdoor and exhaust flows to indicate building pressurization
   e. Nomenclature used throughout report
   f. Test conditions
3. Instrument List:
   a. Instrument
   b. Manufacturer
   c. Model number
   d. Serial number
   e. Range
   f. Calibration date
4. Electric Motors:
   a. Manufacturer
   b. Model/Frame
   c. HP/BHP and kW
   d. Phase, voltage, amperage; nameplate, actual, no load
   e. RPM
   f. Service factor
   g. Starter size, rating, heater elements
   h. Sheave Make/Size/Bore
5. V-Belt Drive:
   a. Identification/location
   b. Required driven RPM
   c. Driven sheave, diameter and RPM
   d. Belt, size and quantity
   e. Motor sheave diameter and RPM
   f. Center to center distance, maximum, minimum, and actual
6. Pump Data:
   a. Identification/number

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b. Manufacturer
c. Size/model
d. Impeller
e. Service
f. Design flow rate, pressure drop, BHP and kW
g. Actual flow rate, pressure drop, BHP and kW
h. Discharge pressure
i. Suction pressure
j. Total operating head pressure
k. Shut off, discharge and suction pressures
l. Shut off, total head pressure

7. Combustion Test:
   a. Manufacturer
   b. Model number
   c. Serial number
   d. Firing rate
   e. Overfire draft
   f. Gas meter timing dial size
   g. Gas meter time per revolution
   h. Gas pressure at meter outlet
   i. Gas flow rate
   j. Heat input
   k. Burner manifold gas pressure
   l. Percent carbon monoxide (CO)
   m. Percent carbon dioxide (CO2)
   n. Percent oxygen (O2)
   o. Percent excess air
   p. Flue gas temperature at outlet
   q. Ambient temperature
   r. Net stack temperature
   s. Percent stack loss
   t. Percent combustion efficiency
   u. Heat output
8. Air Cooled Condenser:
   a. Identification/number
   b. Location
   c. Manufacturer
   d. Model number
   e. Serial number
   f. Entering DB air temperature, design and actual
   g. Leaving DB air temperature, design and actual
   h. Number of compressors
9. Chillers:

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a. Identification/number
b. Manufacturer
c. Capacity
d. Model number
e. Serial number
f. Evaporator entering water temperature, design and actual
g. Evaporator leaving water temperature, design and actual
h. Evaporator pressure drop, design and actual
i. Evaporator water flow rate, design and actual
j. Condenser entering water temperature, design and actual
k. Condenser pressure drop, design and actual
l. Condenser water flow rate, design and actual

10. Cooling Tower:
    a. Tower identification/number
    b. Manufacturer
    c. Model number
    d. Serial number
    e. Rated capacity
    f. Entering air WB temperature, specified and actual
    g. Leaving air WB temperature, specified and actual
    h. Ambient air DB temperature
    i. Condenser water entering temperature
    j. Condenser water leaving temperature
    k. Condenser water flow rate
    l. Fan RPM
11. Heat Exchanger:
    a. Identification/number
    b. Location
    c. Service
    d. Manufacturer
    e. Model number
    f. Serial number
    g. Steam pressure, design and actual
    h. Primary water entering temperature, design and actual
    i. Primary water leaving temperature, design and actual
    j. Primary water flow, design and actual
    k. Primary water pressure drop, design and actual
    l. Secondary water leaving temperature, design and actual
    m. Secondary water leaving temperature, design and actual
    n. Secondary water flow, design and actual
    o. Secondary water pressure drop, design and actual
12. Cooling Coil Data:
    a. Identification/number

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b. Location
c. Service
d. Manufacturer
e. Air flow, design and actual
f. Entering air DB temperature, design and actual
g. Entering air WB temperature, design and actual
h. Leaving air DB temperature, design and actual
i. Leaving air WB temperature, design and actual
j. Water flow, design and actual
k. Water pressure drop, design and actual
l. Entering water temperature, design and actual
m. Leaving water temperature, design and actual
n. Saturated suction temperature, design and actual
o. Air pressure drop, design and actual

13. Heating Coil Data:
    a. Identification/number
    b. Location
    c. Service
    d. Manufacturer
    e. Air flow, design and actual
    f. Water flow, design and actual
    g. Water pressure drop, design and actual
    h. Entering water temperature, design and actual
    i. Leaving water temperature, design and actual
    j. Entering air temperature, design and actual
    k. Leaving air temperature, design and actual
    l. Air pressure drop, design and actual
14. Electric Duct Heater:
    a. Manufacturer
    b. Identification/number
    c. Location
    d. Model number
    e. Design kW
    f. Number of stages
    g. Phase, voltage, amperage
    h. Test voltage (each phase)
    i. Test amperage (each phase)
    j. Air flow, specified and actual
    k. Temperature rise, specified and actual
15. Induction Unit Data:
    a. Manufacturer
    b. Identification/number
    c. Location

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d. Model number
e. Size
f. Design air flow
g. Design nozzle pressure drop
h. Final nozzle pressure drop
i. Final air flow

16. Unit Ventilator and Fan Coil Data:
    a. Manufacturer
    b. Identification/number
    c. Location
    d. Model number
    e. Size
    f. Air flow, design and actual
    g. Water flow, design and actual
    h. Water pressure drop, design and actual
    i. Entering water temperature, design and actual
    j. Leaving water temperature, design and actual
    k. Entering air temperature, design and actual
    l. Leaving air temperature, design and actual
17. Air Moving Equipment:
    a. Location
    b. Manufacturer
    c. Model number
    d. Serial number
    e. Arrangement/Class/Discharge
    f. Air flow, specified and actual
    g. Return air flow, specified and actual
    h. Outside air flow, specified and actual
    i. Total static pressure (total external), specified and actual
    j. Inlet pressure
    k. Discharge pressure
    l. Sheave Make/Size/Bore
    m. Number of Belts/Make/Size
    n. Fan RPM
18. Return Air/Outside Air Data:
    a. Identification/location
    b. Design air flow
    c. Actual air flow
    d. Design return air flow
    e. Actual return air flow
    f. Design outside air flow
    g. Actual outside air flow
    h. Return air temperature

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i. Outside air temperature
j. Required mixed air temperature
k. Actual mixed air temperature
l. Design outside/return air ratio
m. Actual outside/return air ratio

19. Exhaust Fan Data:
    a. Location
    b. Manufacturer
    c. Model number
    d. Serial number
    e. Air flow, specified and actual
    f. Total static pressure (total external), specified and actual
    g. Inlet pressure
    h. Discharge pressure
    i. Sheave Make/Size/Bore
    j. Number of Belts/Make/Size
    k. Fan RPM
20. Duct Traverse:
    a. System zone/branch
    b. Duct size
    c. Area
    d. Design velocity
    e. Design air flow
    f. Test velocity
    g. Test air flow
    h. Duct static pressure
    i. Air temperature
    j. Air correction factor
21. Duct Leak Test:
    a. Description of ductwork under test
    b. Duct design operating pressure
    c. Duct design test static pressure
    d. Duct capacity, air flow
    e. Maximum allowable leakage duct capacity times leak factor
    f. Test apparatus
        1) Blower
        2) Orifice, tube size
        3) Orifice size
        4) Calibrated
    g. Test static pressure
    h. Test orifice differential pressure
    i. Leakage
22. Air Monitoring Station Data:

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a. Identification/location
b. System
c. Size
d. Area
e. Design velocity
f. Design air flow
g. Test velocity
h. Test air flow

23. Flow Measuring Station:
    a. Identification/number
    b. Location
    c. Size
    d. Manufacturer
    e. Model number
    f. Serial number
    g. Design Flow rate
    h. Design pressure drop
    i. Actual/final pressure drop
    j. Actual/final flow rate
    k. Station calibrated setting
24. Terminal Unit Data:
    a. Manufacturer
    b. Type, constant, variable, single, dual duct
    c. Identification/number
    d. Location
    e. Model number
    f. Size
        1) Minimum static pressure
        2) Minimum design air flow
        3) Maximum design air flow
        4) Maximum actual air flow
    g. Inlet static pressure
    h. Air Distribution Test Sheet:
    i. Air terminal number
        1) Room number/location
        2) Terminal type
        3) Terminal size
        4) Area factor
        5) Design velocity
        6) Design air flow
        7) Test (final) velocity
        8) Test (final) air flow
        9) Percent of design air flow

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25. Sound Level Report:
    a. Location
    b. Octave bands - equipment off
    c. Octave bands - equipment on
    d. RC level - equipment on
26. Vibration Test:
    a. Location of points:
        1) Fan bearing, drive end
        2) Fan bearing, opposite end
        3) Motor bearing, center (when applicable)
        4) Motor bearing, drive end
        5) Motor bearing, opposite end
        6) Casing (bottom or top)
        7) Casing (side)
        8) Duct after flexible connection (discharge)
        9) Duct after flexible connection (suction)
    b. Test readings:
        1) Horizontal, velocity and displacement
        2) Vertical, velocity and displacement
        3) Axial, velocity and displacement
    c. Normally acceptable readings, velocity and acceleration
    d. Unusual conditions at time of test
    e. Vibration source (when non-complying)

END OF SECTION

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SECTION 23 34 00
HVAC FANS

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. Acoustical Society of America (ASA): S2.19, Mechanical Vibration—Balance Quality Requirements of Rigid Rotors—Part 1, Determination of Permissible Residual Unbalance.
2. Air Movement and Control Association International (AMCA):
   a. 99, Standards Handbook.
   b. 201, Fans and Systems.
   c. 203, Field Performance Measurement of Fan Systems.
   d. 204, Balance Quality and Vibration Levels for Fans.
   e. 210, Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating.
   f. 300, Reverberant Room Method for Sound Testing of Fans.
   g. 301, Methods for Calculating Fan Sound Ratings from Laboratory Test Data.
3. American Bearing Manufacturers Association (ABMA): 9, Load Ratings and Fatigue Life for Ball Bearings.
4. American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE): 52.2, Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size.
5. ASTM International (ASTM):
   a. B117, Standard Practice for Operating Salt Spray (Fog) Apparatus.
   b. D2247, Standard Practice for Testing Water Resistance of Coatings in 100% Relative Humidity.
   c. D2794, Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact).
   d. D3363, Standard Test Method for Film Hardness by Pencil Test.
   e. D4167, Standard Specification for Fiber-Reinforced Plastic Fans and Blowers.
   f. E84, Standard Test Method for Surface Burning Characteristics of Building Materials.
6. National Electrical Manufacturers Association (NEMA).
7. National Fire Protection Association (NFPA): 45, Standard on Fire Protection for Laboratories Using Chemicals.

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8. Occupational Safety and Health Act (OSHA).
9. Society for Protective Coatings (SSPC):
    a. SP 3, Power Tool Cleaning.
    b. SP 5, White Metal Blast Cleaning.
    c. SP 6, Commercial Blast Cleaning.
    d. SP 10, Near-White Blast Cleaning.
10. Underwriters Laboratories Inc. (UL): 507, Safety Standard for Electric Fans.

1.02 DEFINITIONS

A. The following is a list of abbreviations which may be used in this section:

1. AC: Alternating Current.
2. CISD: Chemical Industry, Severe-Duty.
3. dB: Decibel.
4. DWDI: Double Width, Double Inlet.
5. FRP: Fiberglass Reinforced Plastic.
6. hp: Horsepower.
7. ODP: Open Drip Proof.
8. SWSI: Single Width, Single Inlet.
9. TEFC: Totally Enclosed, Fan Cooled.
10. UV: Ultra Violet
11. XP: Explosion Proof.

1.03 SUBMITTALS

A. Action Submittals:

1. Provide following for specified products:
    a. Identification as referenced in Contract Documents.
    b. Manufacturer’s name and model number.
    c. Descriptive specifications, literature, and drawings.
    d. Dimensions and weights.
    e. Fan sound power level data (reference 10 to power minus 12 watts) at design operating point.
    f. Fan Curves:
        1) Performance Curves Indicating:
            a) Relationship of flow rate to static pressure for various fan speeds.
            b) Brake horsepower curves.
            c) Acceptable selection range (surge curves, maximum revolutions per minute).

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d) Static pressure, capacity, horsepower demand and overall efficiency required at duty point, including drive losses.

2) For variable air volume applications, indicate operating points at 100, 80, 60 and 40 percent of design capacity on fan curves including data to indicate effect of capacity control devices such as inlet vanes on flow, pressure, and brake horsepower.

g. Capacities and ratings.

h. Construction materials.

i. Fan type, size, class, drive arrangement, discharge, rotation, and bearings.

j. Wheel type, diameter, maximum revolutions per minute for fan class, operating revolutions per minute, and tip speed.

2. Motor data, including service factor and operating horsepower, as specified in Section 26 20 00, Low-Voltage AC Induction Motors.

a. Fan shaft first critical speed.

b. Belt service factor.

c. Drive assembly horsepower rating.

d. Sheave horsepower rating.

e. Power and control wiring diagrams, including terminals and numbers.

f. Factory run test and vibration test reports.

g. Vibration isolation.

h. Factory finish system.

i. Color selection charts where applicable.

j. [Corrosion protection coating product data.]

k. [Fiberglass Material: Statement of resins and reinforcing proposed for use.]

3. Seismic anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Seismic Anchorage and Bracing.

4. "Or Equal" Equipment:

a. Where submitted equipment results in change to fan inlet or outlet ductwork configuration shown on Drawings, submit system effect factor calculations indicating increased static pressure requirements as described in AMCA 201.

b. Where submitted equipment results in change to ductwork and equipment configuration shown on Drawings, submit detailed information on structural, mechanical, electrical, or other modifications necessary to adapt arrangement to equipment furnished.

B. Informational Submittals:

1. Seismic anchorage and bracing calculations as required by Section 01 88 15, Seismic Anchorage and Bracing.

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2. Recommended procedures for protection and handling of products prior to installation.
3. Manufacturer's installation instructions.
4. Manufacturer's Certificate of Compliance in accordance with Section 01 43 33, Manufacturers' Field Services, for the following:
   a. Motors specified to be premium efficient type.
   b. FRP fans.
5. Component and attachment testing seismic certificate of compliance as required by Section 01 45 33, Special Inspection [, Observation,] and Testing.
6. Test reports.
7. Operation and maintenance data in conformance with Section 01 78 23, Operation and Maintenance Data. Include as-built version of equipment schedules.

C. LEED Submittals:

1. Equipment and materials for [_____] [Administration Building] [Maintenance Building].
2. Refer to Section 01 81 13, Sustainable Design Requirements, for information regarding LEED submission requirements.
3. Engineer reserves right to reject products and assemblies based on incomplete or noncompliance with LEED certification requirements.
4. Documentation required indicating compliance with Optimize Energy Performance—EA Credit 1.
5. Documentation required indicating compliance with Minimum IAQ Performance—EQ Prerequisite 1.
6. Documentation required indicating compliance with Low-Emitting Materials, Adhesives and Sealants—EQ Credit 4.1.

1.04 QUALITY ASSURANCE

A. Performance Ratings: Tested in accordance with AMCA 210.

B. Sound Ratings: Tested in accordance with AMCA 300.

C. Fabrication: In accordance with AMCA 99.

1.05 EXTRA MATERIALS

A. Furnish, tag, and box for shipment and storage the following [spare parts,] [special tools,] [and] [materials:]

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Item	Quantity
Vee Belts	[One] [_____] complete set per unit
[_____]	[One] [_____] complete sets [per unit]
[Special tools required to maintain or dismantle]	[One] [_____] complete set [for each different size unit]

B. Delivery: In accordance with Section 01 61 00, Common Product Requirements.

PART 2 - PRODUCTS

2.01 EQUIPMENT SCHEDULES

A. Some specific equipment requirements are listed in Equipment Schedule. Refer to [Drawings] [Article Supplements].

2.02 GENERAL

A. Spark Resistant Construction: Fans required to be spark resistant shall comply with requirements of AMCA 99-0401.

B. Operating Limits: Fans designated to meet a specified fan class shall comply with requirements of AMCA 99-2408.

C. Acoustical Levels: Equipment selections shall produce sound power levels in each octave band no greater than shown in Equipment Schedule.

D. Fan Drives:

1. Drive assembly shall be sized for a minimum 140 percent of fan motor horsepower rating.
2. Furnish multiple drive belts where motor horsepower is 2 hp or larger.
3. Sheaves:
   a. Capable of providing 150 percent of motor horsepower.
   b. Unless otherwise noted, furnish belt-driven fans with cast iron or flanged steel sheaves.
4. Drive Adjustment:
   a. When fixed-pitch sheaves are furnished, accomplish system air balancing by either trial of different fixed-pitch sheaves or use of temporary adjustable-pitch sheaves.
   b. Provide trial and final sheaves, as well as drive belts, as required.

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5. Fan Shafts: First critical speed of at least 125 percent of fan maximum operating speed.
6. Provide speed test openings at shaft locations.
7. Belts: Oil and heat resistant, nonstatic type.
8. Motors:
    a. Motors 20 hp or Smaller:
        1) Variable pitch V-belt sheaves allowing at least 20 percent speed variation.
        2) Final operating point shall be at approximate sheave midpoint.
    b. Motors Larger than 20 hp: Fixed-pitch sheaves.
    c. Furnish motors for V-belt drives with adjustable rails or bases.
9. Weather Cover: For outdoor applications, factory fabricated drive assembly of same material as fan housing, unless specified otherwise.
10. Belt and Shaft Guards:
    a. Easily removable and to enclose entire drive assembly, meeting federal, OSHA [, and State of _____] requirements.
    b. Guard faces of expanded metal having minimum 60 percent free area for ventilation.
    c. Bright yellow finish.

E. Finishes:

1. Carbon Steel Parts: Factory finish as follows, unless indicated otherwise.
    a. Parts cleaned and chemically pretreated with phosphatizing process.
    b. Alkyd enamel primer.
    c. Air dry enamel topcoat.
2. Aluminum Parts: Finished smooth and left unpainted, unless stated otherwise.
3. Stainless Steel Parts: Finished smooth and left unpainted.
4. Fiberglass Parts: Finished in accordance with Paragraph Fiberglass Material.

2.03 CABINET FAN

A. General:

1. Factory-assembled, ceiling, wall or inline mounted, centrifugal cabinet fan; including housing, fan wheel, drive assembly, motor and accessories.
2. Bearing AMCA Certified Ratings Seal for sound and air performance.

B. Housing:

1. Material: Minimum 20-gauge galvanized steel.
2. Construction:

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a. Minimum 14-gauge blower and motor support frame.
b. Lined with minimum 1/2-inch acoustical insulation.
c. Outlet duct collar with integral reinforced aluminum backdraft damper, with nylon bushings.
d. Motor mounted on resilient vibration isolators.
e. Motor and blower removable from unit without cabinet disassembly.
f. Removable cabinet access panels.
g. Air Inlet: Field convertible for bottom or end air inlet configuration.
h. Predrilled universal mounting brackets, adjustable.

C. Wheel: Centrifugal forward curved type, galvanized steel or plastic construction.

D. Shaft, Bearings, Drive:

1. Shafts: Turned, ground and polished carbon steel.
2. Bearings: Grease lubricated, precision antifriction ball, sealed type.
3. Drives:
   a. In accordance with Paragraph on Fan Drives.
   b. Factory set to specified fan revolutions per minute.
   c. Type: Direct.

E. Electrical:

1. Integral wiring box.
2. Factory-installed disconnect receptacle.

F. Accessories: Provide [as scheduled in Equipment Schedule.] [as follows:]

1. Ceiling Grille: Factory fabricated, [steel] [aluminum] construction, white baked enamel finish.
2. Speed Controller:
   a. Wall mount.
   b. Solid state electronics.
   c. Dial type combination ON/OFF switch and SPEED selector.
   d. Filter Box:
   e. [Refer to Article Filter Housing.]
   f. [Attached to fan inlet.
   g. Box construction to match fan housing.
   h. Integral duct collars.]
   i. [Access Doors: Hinged and latched.]
   j. [Filter Media: 1-inch [aluminum wire mesh] [pleated disposable type].]
3. Wall Cap:

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a. Aluminum construction, mill finish.
b. Built-in backdraft damper.
c. Bird screen.
d. Round duct connection.

G. Manufacturers and Products:

1. Loren Cook; Gemini Series.
2. Greenheck; SP Series.
3. ACME; Model VQ Series.
4. Twin City Fan; T Series.

2.04 CEILING FAN, INDUSTRIAL

A. General:

1. Factory-assembled paddle-type ceiling fan, propeller, motor, and accessories.
2. Fans with motor speed control labeled in accordance with UL 507.
3. Warranty: 3-year duration, full coverage against manufacturer's defects.

B. Construction:

1. Industrial grade construction, with cast-iron yoke and cast-iron motor housing.
2. Blades: Aerodynamically curved, aluminum.
3. Finish: Baked white enamel.
4. Downrod:
   a. Minimum 10-inch length, other lengths as required to provide specified installation height; use factory provided extender kit where necessary.
   b. 3/4-inch nominal diameter.
5. Secondary Support: Factory-installed, minimum 6-foot-long, 1/8-inch-diameter galvanized steel cable, minimum 1,700-pound breaking strength.
6. Motor:
   a. Direct drive, permanent split-capacitor type, reversible.
   b. Permanently sealed ball bearings.
   c. Moisture and dust resistant.
   d. Thermal-overload: Built-in, self-resetting.

C. Accessories: Provide [as scheduled in Equipment Schedule.] [as follows:]

1. Speed Controller:
   a. Wall mount.
   b. Solid state electronics.
   c. Suitable for single and multiple fan operation.

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d. Dial type combination ON/OFF switch and SPEED selector.

2. Fan Blade Guard:
   a. Factory fabricated, spiral wire configuration, chrome plated steel.
   b. Full blade coverage.

D. Manufacturers and Products:

1. Leading Edge. Industrial Ceiling Fan.
2. Northwest Envirofan; Industrial Ceiling Fan.
3. Canarm; Model CP.

2.05 INLINE FAN, CENTRIFUGAL, SQUARE

A. General:

1. Factory-assembled, centrifugal, inline fan, square housing configuration; including housing, fan wheel, drive assembly, motor and accessories.
2. Bearing AMCA Certified Ratings Seal for sound and air performance.

B. Housing:

1. Construction: [Minimum 18-gauge galvanized steel.] [All aluminum.]
2. Integral duct collars.
3. Removable side panels, for ease of service.
4. Field convertible for side air discharge configuration.
5. Predrilled universal mounting brackets for vertical or horizontal installation.
6. Inlets: Aerodynamic aluminum venturi.
7. Corrosion-resistant fasteners.
8. Drive belt and bearings separated from air steam by enclosure.

C. Wheel:

1. Centrifugal backward inclined, 100 percent aluminum construction.
2. Precision machined cast aluminum hub.
3. Die-formed airfoil or backward inclined blades.
4. Matched to inlet venturi.
5. Attached to fan shaft with split taper lock bushing.

D. Shaft, Bearings, Drive:

1. Shafts:
   a. Turned, ground and polished carbon steel.
   b. Keyed for sheave installation.

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2. Bearings:
    a. Grease lubricated, precision antifriction ball, self-aligning, pillow block style, relubricatable or sealed type.
    b. Selected for average life (ABMA 9 L_{50}) of not less than 200,000 hours operation at maximum cataloged operating speed.
3. Drives:
    a. In accordance with Paragraph Fan Drives.
    b. Factory set to specified fan revolutions per minute.
    c. Type: [Belt or Direct, as indicated in Equipment Schedule.] [Belt.] [Direct.]
    d. Arrangement: [As scheduled in Equipment Schedule.] [Arrangement 9.] [Arrangement 10.] [Arrangement 4.]

E. Accessories: Provide [as scheduled in Equipment Schedule.] [as follows:]

1. Belt Guard: Sheet metal construction, OSHA type.
2. Motor and Drive Cover:
    a. Factory fabricated, OSHA type.
    b. Sheet metal construction, same material as fan housing.
    c. Vented, openings sufficient size for proper motor cooling.
    d. Fan speed controller.
3. Gravity Backdraft Damper: Galvanized steel frame, aluminum blades, brass pivot pins, neoprene seals on damper blade edges, gravity operation, and adjustable counterweight.
4. Motorized Damper: Galvanized steel frame, aluminum blades, neoprene seals on damper blade edges, [120V] [24V] operator.
5. Insulated Housing: Fiberglass insulation, 1-inch thick, [neoprene coated,] [foil faced,] on interior of housing.
6. Filter Box:
    a. [Refer to Article Filter Housings.]
    b. [Attached to fan inlet.
    c. Box construction to match fan housing.
    d. Integral duct collars.]
    e. [Access Doors: Hinged and latched.]
    f. [Filter Media: 1-inch [aluminum wire mesh] [pleated disposable type].]
7. Inlet Screen: Removable 1-inch mesh screen, aluminum construction, overexposed inlets.
8. Disconnect: Factory installed, nonfused, NEMA Type [1] [4X] [as scheduled].
9. Single Side Discharge: Package consisting of side duct connection collar and rear-discharge blank-off panel.
10. Dual Side Discharge: Package consisting of side duct connection collars and rear-discharge blank-off panel.

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11. Bearing Lubrication Lines:
    a. Extended to outside of fan housing.
    b. Terminate with zerk fittings.
12. Spark Resistant Construction Classification: AMCA 99-0401 Type [A] [B] [C] [as scheduled].
13. Corrosion Protection Coating:
    a. Provide factory-applied corrosion protection coating on the following:
        1) Wheel.
        2) Housing.
        3) Accessories.
        4) Interior surfaces in contact with airstream.
    b. [Coating system shall be [baked enamel] [baked polyester] [air-dry epoxy] [baked epoxy] [air-dry phenolic] [baked phenolic] [baked epoxy phenolic] [as scheduled in fan Equipment Schedule], and shall be in accordance with Article Corrosion Protection Coating.]
    c. [Coating system shall be in accordance with Section 09 90 00, Painting and Coating.]

F. Manufacturers and Products:

1. Greenheck; Model BSQ (Belt); SQ (Direct).
2. Loren Cook; Model SQNB (Belt); SQND (Direct).
3. ACME; Centri-Master Model XB Series (Belt); XD (Direct).
4. Twin City Fan (Aerovent); Model BSI (Belt); Model ISD (Direct).

2.06 INLINE FAN, TUBULAR CENTRIFUGAL

A. General:

1. Factory-assembled tubular centrifugal fan, belt drive; including housing, fan wheel, drive assembly, motor, and accessories.
2. Fan Performance: AMCA 99-2408 Class [I] [II] [III] [as scheduled].
3. Bearing AMCA Certified Ratings Seal for sound and air performance.

B. Housings:

1. Material: [Steel.] [Aluminum.] [Type 304 stainless steel.] [Type 316 stainless steel.]
2. Construction:
    a. Heavy-gauge rolled metal casing, with continuous seam welding.
    b. Air straightening vanes at fan outlet, integral with shaft, bearing support, and outer casing, fully welded.

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c. Bearing and drive components isolated from air stream within continuously welded tunnel.
d. Lifting lugs welded to housing.
e. Mounting brackets, welded to housing, as required for indicated fan arrangement.

3. Bearing Lubrication Lines:
   a. Extended to outside of fan housing.
   b. Type 316 stainless steel construction.
   c. Terminate with zerk fittings.
4. Inlets: Die-formed bell mouth, matched to fan wheel inlet shroud.
5. Motor Base Plate: Minimum of 3/16-inch metal plate, welded to fan housing, to provide belt tensioning and adjustment.
6. Duct Flanges: Angle ring flanges, same diameter as housing, at fan inlet and outlet, heavy construction, factory drilled.

C. Wheel:

1. Material: [Steel] [Aluminum] construction.
2. Centrifugal, one-piece, nonoverloading, backwardly inclined blades.
3. Blades continuously welded to inlet shroud and backplate.
4. Attached to fan shaft with split taper lock bushing.

D. Shaft, Bearings, Drive:

1. Shafts:
   a. Turned, ground and polished hot-rolled carbon steel.
   b. Keyed for sheave installation.
   c. Corrosion protection coating.
2. Bearings:
   a. Grease lubricated, precision antifriction ball, self-aligning type.
   b. Mounted in cast iron pillow block housing.
   c. Selected for average life (ABMA 9 L_{50}) of not less than 200,000 hours operation at maximum cataloged operating speed.
   d. Suitable for fan operation in vertical configuration.
3. Drives:
   a. In accordance with Paragraph Fan Drives.
   b. Factory set to the specified fan revolutions per minute.
   c. Type: Belt.
   d. Arrangement: [As scheduled in Equipment Schedule.] [Arrangement 1.] [Arrangement 4.] [Arrangement 9.] [Vertical.]

E. Roof Mount Accessories:

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1. Motor and Drive Cover:
   a. Factory fabricated; OSHA type.
   b. Sheet metal construction, same material as fan housing.
   c. Vented, openings sufficient size for proper motor cooling.
2. Stack Cap:
   a. Factory fabricated.
   b. Same material as fan housing.
   c. Integral backdraft dampers.
3. Curb Base:
   a. Factory fabricated.
   b. Sized to adapt fan inlet to roof curb.
   c. Same material as fan housing.

F. Accessories: Provide [as scheduled in Equipment Schedule.] [as follows:]

1. Roof Curb:
   a. Factory fabricated.
   b. [With] [Without] damper tray.
   c. Sloped to match roof pitch and to provide level top.
   d. Height Above Finished Roof: [12 inches.] [As scheduled.]
   e. [Galvanized steel] [Aluminum] construction.
   f. Mitered continuous welded corner seams.
   g. Pressure-treated wood nailer.
   h. Insulation: Minimum 1-1/2 inches thick, 3 pounds per cubic foot density, rigid mineral fiberboard insulation with metal liner.
2. Housing Access Doors: Bolted and gasketed.
3. Disconnect: Factory installed, nonfused, NEMA Type [3R] [4X].
4. Motor and Drive Cover:
   a. Factory fabricated; OSHA type.
   b. Sheet metal construction, same material as fan housing.
   c. Vented, openings sufficient size for proper motor cooling.
5. Belt Guard: Sheet metal construction, OSHA type.
6. Inlet Vanes: Variable position, for manual or automatic operation.
7. Housing Access Doors: Bolted and gasketed.
8. Shaft Seal: [Elastomeric.] [Ceramic felt.] [Lubricated.] [Stuffing box.] [Type as scheduled.]
9. Inlet Screen: Metal, spiral wire type, OSHA approved, removable.
10. Outlet Screen: Metal, spiral wire type, OSHA approved, removable.
11. Support Base: Welded metal, for standard platform or floor mounting.
12. Spark Resistant Construction: AMCA 99-0401 Type [A] [B] [C] [as scheduled].
13. Corrosion Protection Coating:

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a. Provide factory-applied corrosion protection coating on these fan components:
   1) Wheel.
   2) Housing.
   3) Accessories.
   4) Interior surfaces in contact with airstream.
b. [Coating system shall be [baked enamel] [baked polyester] [air-dry epoxy] [baked epoxy] [air-dry phenolic] [baked phenolic] [baked epoxy phenolic] [as scheduled in Equipment Schedule], and shall be in accordance with Article Corrosion Protection Coating.]
c. [Coating system shall be in accordance with Section 09 90 00, Painting and Coating.]

G. Manufacturers and Products:

1. Aerovent; Model CBD.
2. Cook; Model TCNH-B.
3. Greenheck; Model TCB.

2.07 INLINE FAN, TUBULAR CENTRIFUGAL, FIBERGLASS

A. General:

1. Factory-assembled tubular centrifugal fan, fiberglass construction, belt drive; including housing, fan wheel, drive assembly, motor and accessories.
2. Fiberglass Construction: In accordance with ASTM D4167.
3. Fan Performance: AMCA 99-2408 Class [I] [II] [III] [as scheduled].
4. Air Stream Hardware: Type 316 stainless steel.

B. Fiberglass Material:

1. Construction: Resin reinforced fiber cloth and mat.
2. Resin:
   a. [Polyester] [Vinyl ester] thermosetting resin.
   b. Selected by fabricator, subject to approval by Engineer.
   c. Suitable for intended service with no fillers or thixotropic agents.
   d. Premium grade and corrosion resistant.
   e. Structural wall resin may be of different chemical resistance, subject to conditions of service and approval by Engineer.
   f. [Flame Spread Index:
   g. ASTM E84, less than 25; fire retardant additives used only in structural layer.

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1) Structural wall resin shall contain a minimum of 3 percent antimony trioxide to achieve required flame spread index.]

h. For outdoor locations, add ultraviolet absorbers to surfacing resin to improve weather resistance.

i. For interior locations, final coat shall be factory applied intumescent coating to achieve designated results for low smoke development.

j. Color:

1) Use no dyes, pigments, or colorants [, except in exterior gel coat].

2) Exterior gel coat shall be [white] [_____].

3. Reinforcement:

4. Veil: Chemical surfacing mat, [Type C (chemical) glass veil] [Nexus Surface Veil] [carbon veil].

5. Chopped Strand Mat: Type E glass, minimum 1-1/2 ounces per square foot, with silane finish and styrene soluble binder.

a. Continuous Roving for Chopper Gun Spray-Up: Type E glass.

b. Woven Roving: Type E glass, nominal 24 ounces per square yard, 4 by 5 weave, with silane type finish.

6. Laminate:

a. Inner Surface (Veil):

1) Resin rich, veil reinforced, 10 mils to 20 mils thick.

2) Use no additives.

3) Finish and binder compatible with lay-up resin.

4) Reinforcement Content: Not more than 20 percent.

b. Interior (Corrosion) Layer:

1) Resin rich, at least two plies of chopped strand mat, nominal 100 mils to 120 mils thick.

2) Use no additives.

3) Construct interior layer of resin reinforced with at least two plies of chopped strand mat backing the veil.

4) Reinforcement Content: 25 plus or minus 5 percent.

c. Exterior (Structural) Layer:

1) Resin with mat, cloth, woven roving or chopped strand glass reinforcement.

2) Enough resin present to prevent surface fiber show.

3) Exterior surface relatively smooth, with no exposed fibers or sharp projections.

d. Wall Thickness: As required for equipment structural integrity, but not less than 3/16 inch.

C. Housing:

1. Material: Fiberglass construction.

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2. Construction:
    a. Tubular housing shell.
    b. Integral predrilled duct connection flanges to ensure housing concentricity and housing strength.
    c. Air straightening vanes, fiberglass construction, at fan outlet, interconnected with inner and outer shell.
    d. Bearing Base and Drive Enclosure:
        1) Bearings and belts enclosed in air insulated fiberglass housing for protection from air stream gases, fumes, and vapors.
        2) Supported by tapered gussets interlocked into outer housing.
        3) Constructed of laminated glass and resin.
        4) Bearing housing furnished with a bolted, removable Teflon shaft closure plate to facilitate bearing access.
        5) Viton shaft seal.
    e. Lifting lugs, steel, bolted to fan housing flanges.
    f. Mounting brackets, steel, bolted to fan housing flanges, as required for indicated fan arrangement.
3. Inlet:
    a. Bolted, removable.
    b. Streamlined, bell mouth type.
    c. Fiberglass construction.
    d. Matched to fan wheel inlet shroud.
4. Bearing Lubrication Lines:
    a. Extended to outside of fan housing.
    b. Type 316 stainless steel construction.
    c. Terminated with zerk fittings.
5. Motor Base Plate:
    a. Minimum 3/16-inch steel plate.
    b. Bolted between gussets integral to fan housing flanges.
    c. Provision for belt tensioning and adjustment.

D. Wheel:

1. Material: Fiberglass construction.
2. Centrifugal, one-piece, nonoverloading, backwardly inclined airfoil blades.
3. Mechanically fastened to end of fan shaft by Type 316 stainless steel bolt.

E. Shaft, Bearings, Drive:

1. Shafts:
    a. Turned, ground and polished Type 316 stainless steel.
    b. Keyed for sheave installation.

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2. Bearings:
   a. Grease lubricated, precision antifriction, ball self-aligning type.
   b. Mounted in cast iron pillow block housing.
   c. Selected for average life (ABMA 9 L_{50}) of not less than 200,000 hours operation at maximum cataloged operating speed.
   d. Suitable for fan operation in vertical configuration.
3. Drives:
   a. In accordance with Paragraph Fan Drives.
   b. Factory set to specified fan revolutions per minute.
   c. Type: Belt.
4. Arrangement: [As scheduled in Equipment Schedule.] [Arrangement 1.] [Arrangement 4.] [Arrangement 9.] [Vertical.]

F. Accessories: Provide [as scheduled in Equipment Schedule.] [as follows:]

1. Housing Access Doors: Fiberglass construction, bolted, and gasketed.
2. Disconnect: Factory installed, nonfused, NEMA Type [3R] [4X].
3. Motor and Drive Cover:
   a. Factory fabricated; OSHA type.
   b. Fiberglass construction, same material as fan housing.
   c. Vented, openings sufficient size for proper motor cooling.
4. Belt Guard: Sheet metal construction, OSHA type.
5. Inlet Vanes: Variable position, for manual or automatic operation.
6. Housing Access Doors: Bolted and gasketed.
7. Shaft Seal: [Elastomeric.] [Ceramic felt.] [Lubricated.] [Stuffing box.] [Type as scheduled.]
8. Inlet Screen: Metal, spiral wire type, OSHA approved, removable.
9. Outlet Screen: Metal, spiral wire type, OSHA approved, removable.
10. Nameplates: Type 316 stainless steel manufacturer's nameplates.
11. Support Base: Welded metal, for standard platform or floor mounting.
12. Spark Resistant Construction: AMCA 99-0401 Type [A] [B] [C] [as scheduled].
13. Corrosive Service Metal Components:
    a. Metal components including fan shaft, motor pedestal, motor slide base, lube lines, accessories, hardware shall be Type 316 stainless steel.
    b. Coated steel components will not be accepted.

1. Corrosion Protection Coating:
   a. Provide factory-applied corrosion protection coating on steel fan components.
   b. [Coating system shall be [baked enamel] [baked polyester] [air-dry epoxy] [baked epoxy] [air-dry phenolic] [baked phenolic] [baked epoxy phenolic] [as scheduled in fan Equipment Schedule], and shall be in accordance with Article Corrosion Protection Coating.]

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c. [Coating system shall be in accordance with Section 09 90 00, Painting and Coating.]

B. Manufacturers and Products:
1. Aerovent; Model CBDF.
2. Hartzell; Model 40.

2.08 INLINE FAN, TUBE AXIAL

A. General:

1. Factory-assembled tube-axial fan; including housing, fixed pitch fan wheel, drive assembly, motor and accessories.
2. Bearing AMCA Certified Ratings Seal for sound and air performance.

B. Housings:

1. Material: [Steel.] [Aluminum.] [Type 304 stainless steel.] [Type 316 stainless steel.]
2. Construction:
   a. Heavy-gauge rolled metal casing, with continuous seam welding.
   b. Bearing and drive components isolated from air stream within continuously welded tunnel.
   c. Lifting lugs welded to housing.
   d. Mounting brackets, welded to housing, as required for indicated fan arrangement.
3. Bearing Lubrication Lines:
   a. Extended to outside of fan housing.
   b. Type 316 stainless steel construction.
   c. Terminate with zerk fittings.
4. Motor Base Plate: Minimum of 3/16-inch metal plate, welded to fan housing, to provide belt tensioning and adjustment.
   a. Duct Flanges: Angle ring flanges, same diameter as housing, at fan inlet and outlet, heavy construction, factory drilled.

C. Wheel:

1. Hub: Cast aluminum.
2. Blades: Cast aluminum airfoil design.
3. Wheel assembly attached to fan shaft with split taper lock bushing.

D. Shaft, Bearings, Drive:

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1. Shafts:
   a. Turned, ground, and polished hot-rolled carbon steel.
   b. Keyed for sheave installation.
   c. Corrosion protection coating.

2. Bearings:
   a. Grease lubricated, precision antifriction ball, self-aligning type.
   b. Mounted in cast iron pillow block housing.
   c. Selected for average life (ABMA 9 L_{50}) of not less than 200,000 hours operation at maximum cataloged operating speed.
   d. Suitable for fan operation in vertical configuration.
3. Drives:
   a. In accordance with Paragraph Fan Drives.
   b. Factory set to specified fan revolutions per minute.
   c. Type: [Belt or direct, as indicated in Equipment Schedule.] [Belt.] [Direct.]
   d. Arrangement: [As scheduled in Equipment Schedule.] [Arrangement 1.] [Arrangement 4.] [Arrangement 9.] [Vertical.]

E. Roof Mount Accessories:

1. Motor and Drive Cover:
   a. Factory fabricated; OSHA type.
   b. Sheet metal construction, same material as fan housing.
   c. Vented, openings sufficient size for proper motor cooling.
2. Stack Cap:
   a. Factory fabricated.
   b. Same material as fan housing.
   c. Integral backdraft dampers.
3. Curb Base:
   a. Factory fabricated.
   b. Sized to adapt fan inlet to roof curb.
   c. Same material as fan housing.

F. Accessories: Provide [as scheduled in Equipment Schedule.] [as follows:]

1. Roof Curb:
   a. Factory fabricated.
   b. [With] [Without] damper tray.
   c. Sloped to match roof pitch and to provide level top.
   d. Height Above Finished Roof: [12 inches.] [As scheduled.]
   e. [Galvanized steel] [Aluminum] construction.

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f. Mitered continuous welded corner seams.
g. Pressure-treated wood nailer.
h. Insulation: Minimum 1-1/2 inches thick, 3 pounds per cubic foot density, rigid mineral fiberboard insulation with metal liner.

2. Housing Access Doors: Bolted and gasketed.
3. Disconnect: Factory installed, nonfused, NEMA Type [3R] [4X].
4. Motor and Drive Cover:
   a. Factory fabricated; OSHA type.
   b. Sheet metal construction, same material as fan housing.
   c. Vented, openings sufficient size for proper motor cooling.
5. Belt Guard: Sheet metal construction, OSHA type.
6. Inlet Vanes: Variable position, for manual or automatic operation.
7. Shaft Seal: Elastomeric.
8. Inlet Screen: Metal, spiral wire type, OSHA approved, removable.
9. Outlet Screen: Metal, spiral wire type, OSHA approved, removable.
10. Inlet Bell: Factory fabricated aerodynamic bell, bolted to fan inlet, same material as fan housing.
11. Inlet Cone: Factory fabricated, conical fan to duct transition, bolted to housing flange, same material as fan housing.
12. Outlet Cone: Factory fabricated, conical fan to duct transition, bolted to housing flange, same material as fan housing.
13. Support Base: Welded metal, for standard platform or floor mounting.
14. Spark Resistant Construction: AMCA 99-0401 Type [A] [B] [C] [as scheduled].
15. Corrosion Protection Coating:
    a. Provide factory-applied corrosion protection coating on these fan components:
       1) Wheel (or propeller).
       2) Housing.
       3) Accessories.
       4) Interior surfaces in contact with airstream.
    b. [Coating system shall be [baked enamel] [baked polyester] [air-dry epoxy] [baked epoxy] [air-dry phenolic] [baked phenolic] [baked epoxy phenolic] [as scheduled in fan Equipment Schedule], and shall be in accordance with Article Corrosion Protection Coating.]
    c. [Coating system shall be in accordance with Section 09 90 00, Painting and Coating.]

G. Manufacturers and Products:

1. Aerovent; Model TA (Direct); TABD (Belt).
2. Cook; Model EDD (Direct); EDB (Belt).

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3. Greenheck; Model TDI (Direct); TBI (Belt).

2.09 INLINE FAN, VANE AXIAL

A. General:

1. Factory-assembled vane-axial fan; including housing with integral vanes, adjustable pitch fan wheel, drive assembly, motor and accessories.
2. Bearing AMCA Certified Ratings Seal for sound and air performance.

B. Housings:

1. Material: [Steel.] [Aluminum.] [Type 304 stainless steel.] [Type 316 stainless steel.]
2. Construction:
   a. Heavy gauge rolled metal casing, with continuous seam welding.
   b. Air straightening vanes at propeller discharge, integral with housing, fully welded.
   c. Bearing and drive components isolated from air stream within continuously welded tunnel.
   d. Lifting lugs welded to housing.
   e. Mounting brackets, welded to housing, as required for indicated fan arrangement.
3. Bearing Lubrication Lines:
   a. Extended to outside of fan housing.
   b. Type 316 stainless steel construction.
   c. Terminate with zerk fittings.
   d. Motor Base Plate: Minimum of 3/16-inch metal plate, welded to fan housing, to provide belt tensioning and adjustment.
4. Duct Flanges: Angle ring flanges, same diameter as housing, at fan inlet and outlet, heavy construction, factory drilled.

C. Wheel:

1. Hub:
   a. Cast aluminum.
   b. Streamlined hub cover.
2. Blades:
   a. Cast aluminum
   b. Adjustable pitch.
   c. Factory set to required pitch.
   d. Blade angle field adjustable.

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e. Wheel assembly attached to fan shaft with split taper lock bushing.

D. Shaft, Bearings, Drive:

1. Shafts:
   a. Turned, ground, and polished hot-rolled carbon steel.
   b. Keyed for sheave installation.
   c. Corrosion protection coating.
2. Bearings:
   a. Grease lubricated, precision antifriction ball, self-aligning type.
   b. Mounted in cast iron pillow block housing.
   c. Selected for average life (ABMA 9 L_{50}) of not less than 200,000 hours operation at maximum cataloged operating speed.
   d. Suitable for fan operation in vertical configuration.
3. Drives:
   a. In accordance with Paragraph Fan Drives.
   b. Factory set to specified fan revolutions per minute.
   c. Type: [Belt or direct, as indicated in Equipment Schedule.] [Belt.] [Direct.]
   d. Arrangement: [As scheduled in Equipment Schedule.] [Arrangement 1.] [Arrangement 4.] [Arrangement 9.] [Vertical.]

E. Roof Mount Accessories:

1. Motor and Drive Cover:
   a. Factory fabricated; OSHA type.
   b. Sheet metal construction, same material as fan housing.
   c. Vented, openings sufficient size for proper motor cooling.
2. Stack Cap:
   a. Factory fabricated.
   b. Same material as fan housing.
   c. Integral backdraft dampers.
3. Curb Base:
   a. Factory fabricated.
   b. Sized to adapt fan inlet to roof curb.
   c. Same material as fan housing.
4. Accessories: Provide [as scheduled in Equipment Schedule.] [as follows:]
   a. Roof Curb:
      1) Factory fabricated.
      2) [With] [Without] damper tray.
      3) Sloped to match roof pitch and to provide level top.
      4) Height Above Finished Roof: [12 inches.] [As scheduled.]

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5) [Galvanized steel] [Aluminum] construction.
6) Mitered continuous welded corner seams.
7) Pressure-treated wood nailer.
8) Insulation: Minimum 1-1/2 inches thick, 3 pounds per cubic foot density, rigid mineral fiberboard insulation with metal liner.
9) Housing Access Doors: Bolted and gasketed.
10) Disconnect: Factory-installed, nonfused, NEMA Type [3R] [4X].
11) Motor and Drive Cover:
12) Factory fabricated; OSHA type.
13) Sheet metal construction, same material as fan housing.

b. Vented, openings sufficient size for proper motor cooling.

5. Belt Guard: Sheet metal construction; OSHA type.
6. Inlet Vanes: Variable position, for manual or automatic operation.
7. Shaft Seal: Elastomeric.
8. Inlet Screen: Metal, spiral wire type, OSHA approved, removable.
9. Outlet Screen: Metal, spiral wire type, OSHA approved, removable.
10. Inlet Bell: Factory fabricated aerodynamic bell, bolted to fan inlet, same material as fan housing.
11. Inlet Cone: Factory fabricated, conical fan to duct transition, bolted to housing flange, same material as fan housing.
12. Outlet Cone: Factory fabricated, conical fan to duct transition, bolted to housing flange, same material as fan housing.
13. Support Base: Welded metal, for standard platform or floor mounting.
14. Spark Resistant Construction: AMCA 99-0401 Type [A] [B] [C] [as scheduled].
15. Corrosion Protection Coating:
    a. Provide factory-applied corrosion protection coating on these fan components:
        1) Wheel (or propeller).
        2) Housing.
        3) Accessories.
        4) Interior surfaces in contact with airstream.
    b. [Coating system shall be [baked enamel] [baked polyester] [air-dry epoxy] [baked epoxy] [air-dry phenolic] [baked phenolic] [baked epoxy phenolic] [as scheduled in fan Equipment Schedule], and shall be in accordance with Article Corrosion Protection Coating.]
    c. [Coating system shall be in accordance with Section 09 90 00, Painting and Coating.]

F. Manufacturers and Products:

1. Aerovent; Model VWBD (Belt); VW (Direct).

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2. Cook; Model AVAB (Belt); AVAD (Direct).
3. Greenheck; Model VAB (Belt); VAD (Direct).

2.10 ROOF FAN, CENTRIFUGAL UPBLAST

A. General:

1. Factory-assembled centrifugal upblast roof fan; including housing, fan wheel, drive assembly, motor and accessories.
2. Bearing AMCA Certified Ratings Seal for sound and air performance.

B. Housing:

1. Construction: Spun-formed aluminum, minimum 16-gauge marine alloy.
2. Windband: Finish with rolled bead.
3. Top Cap: Motor access via quick release latches.
4. Motor completely sealed from exhaust air stream.
5. Motor cooling via air breather tubes.
6. Integral conduit chase for wiring.
7. Drain trough at lowest point of housing.
8. Fan Inlet:
   a. Full inlet cone of aluminum construction.
   b. Match inlet shroud.

C. Wheel:

1. Aluminum construction, backward inclined centrifugal, nonoverloading type.
2. Machined, cast aluminum hub.
3. Matched to deep spun inlet venturi.

D. Shaft, Bearings, Drive:

1. Shaft:
   a. Turned, ground, and polished carbon steel.
   b. Keyed for sheave installation.
   c. Zinc-phosphate coated and oil emulsion-dipped.
2. Bearings:
   a. Grease lubricated, precision antifriction ball, self-aligning, pillow block style.
   b. Selected for average life (ABMA 9 L_{50}) of not less than 200,000 hours operation at maximum cataloged operating speed.
   c. Terminate with zerk fittings.
3. Drives:

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a. In accordance with Paragraph Fan Drives.
b. Factory set to specified fan revolutions per minute.
c. Type: [Belt or direct, as indicated in Equipment Schedule.] [Belt.] [Direct.]

E. Accessories: Provide [as scheduled on Equipment Schedule.] [as follows:]

1. Gravity Backdraft Damper: Gravity operation, adjustable counterweight, and aluminum construction.
2. Motorized Damper: Aluminum frame, aluminum blades, aluminum hinge pins with nylon bushings, [120V] [24V] operator.
3. Bird Screens: Aluminum construction.
4. Roof Curb:
   a. Factory fabricated, [galvanized steel] [aluminum] construction.
   b. [With] [Without] damper tray.
   c. Sloped to match roof pitch, and to provide level top.
   d. Height Above Finished Roof: [12 inches.] [As scheduled.]
   e. Mitered continuous welded corner seams.
   f. Pressure-treated wood nailer.
   g. Insulation: Minimum 1-1/2 inches thick, 3 pounds per cubic foot density, rigid mineral fiberboard insulation with metal liner.
5. Disconnect: Factory installed, nonfused, NEMA Type [3R] [4X] [as scheduled].
6. Bearing Lubrication Lines:
   a. Extended to outside of fan housing.
   b. Type 316 stainless steel construction.
   c. Terminate with zerk fittings.
7. Spark Resistant Construction Classification: AMCA 99-0401 Type [A] [B] [C] [as scheduled].
8. Corrosion Protection Coating:
   a. Provide factory-applied corrosion protection coating on these fan components:
      1) Wheel.
      2) Housing.
      3) Accessories.
      4) Interior surfaces in contact with airstream.
   b. [Coating system shall be [baked enamel] [baked polyester] [air-dry epoxy] [baked epoxy] [air-dry phenolic] [baked phenolic] [baked epoxy phenolic] [as scheduled in fan Equipment Schedule], and shall be in accordance with Article Corrosion Protection Coating.]
   c. [Coating system shall be in accordance with Section 09 90 00, Painting and Coating.]

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F. Manufacturers and Products:

1. Aerovent: Model ATB.
2. Cook; Model ACRUD (Direct Drive); ACRUB (Belt Drive).
3. Greenheck; Model CUE (Direct Drive); CUBE (Belt Drive).
4. ACME, Model PDU (Direct Drive); PNU (Belt Drive).
5. Twin City Fan; BCRU.

2.11 ROOF FAN, FIBERGLASS CENTRIFUGAL UPBLAST

A. General:

1. Factory-assembled centrifugal upblast fiberglass roof fan; including housing, fan wheel, drive assembly, motor, and accessories.
2. Fiberglass Construction: In accordance ASTM D4167.
3. Suitable to convey air at temperatures up to 150 degrees F.
4. Bearing AMCA Certified Ratings Seal for sound and air performance.

B. Fiberglass Material:

1. Construction: Resin reinforced fiber cloth and mat.
2. Resin:
   a. [Polyester] [Vinyl ester] thermosetting resin.
   b. No fillers or thixotropic agents.
   c. Premium grade and corrosion resistant.
   d. Structural wall resin may be of different chemical resistance, subject to conditions of service and approval by Engineer.
   e. [Flame Spread Index:
      1) ASTM E84, less than 25; fire retardant additives used only in structural layer.
      2) Structural wall resin shall contain a minimum of 3 percent antimony trioxide to achieve required flame spread index.]
   f. Add ultraviolet absorbers to surfacing resin to improve weather resistance.
   g. Color:
      1) Use no dyes, pigments, or colorants [, except in exterior gel coat].
      2) Exterior gel coat shall be [white] [manufacturer’s standard] [_____].
3. Reinforcement:
   a. Veil: Chemical surfacing mat, [Type C (chemical) glass veil] [Nexus surface veil] [carbon veil].

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b. Chopped Strand Mat: Type E glass, minimum 1-1/2 ounces per square foot, with silane finish and styrene soluble binder.
c. Continuous Roving for Chopper Gun Spray-Up: Type E glass.
d. Woven Roving: Type E glass, nominal 24 ounces per square yard, 4 by 5 weave, with silane type finish.

4. Laminate:
   a. Inner Surface (Veil):
      1) Resin rich, veil reinforced, 10 mils to 20 mils thick.
      2) Use no additives.
      3) Finish and binder compatible with lay-up resin.
      4) Reinforcement Content: Not more than 20 percent.
   b. Interior (Corrosion) Layer:
      1) Resin rich, at least two plies of chopped strand mat, nominal 100 mils to 120 mils thick.
      2) Use no additives.
      3) Construct interior layer of resin reinforced with at least two plies of chopped strand mat backing the veil.
      4) Reinforcement Content: 25 plus or minus 5 percent.
   c. Exterior (Structural) Layer:
      1) Resin with mat, cloth, woven roving or chopped strand glass reinforcement.
      2) Enough resin present to prevent surface fiber show.
      3) Exterior surface relatively smooth, with no exposed fibers or sharp projections.
   d. Outer Surface (Gel Coat):
      1) Resin rich.
      2) 10 mils to 20 mils thick.
   e. Wall Thickness: As required for equipment structural integrity, but no less than 3/16 inch.

C. Housing:

1. Windband: FRP construction, finished with smooth edge.
2. Top Cap: FRP construction, with motor access via quick release latches.
3. Motor completely sealed from exhaust air stream.
4. Motor cooling via air breather tubes.
5. Integral conduit chase for wiring, vinyl coated flexible metal.
6. Drain trough at lowest point of housing.
7. Fan Inlet:
   a. Aerodynamic inlet venturi, FRP construction.
   b. Match wheel inlet shroud.
8. Hardware: [Steel, epoxy coated.] [Type 316 stainless steel.]

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D. Wheel:

1. [Aluminum construction, fully welded, epoxy coated.] [Polypropylene.]
2. Backward inclined centrifugal, nonoverloading type.
3. Machined, cast aluminum hub.
4. Matched to housing inlet venturi.

E. Shaft, Bearings, Drive:

1. Shaft:
   a. Turned, ground, and polished Type 316 stainless steel.
   b. Keyed for sheave installation.
2. Bearings:
   a. Grease lubricated, precision antifriction ball, self-aligning, pillow block style.
   b. Selected for average life (ABMA 9 L_{50}) of not less than 200,000 hours' operation at maximum cataloged operating speed.
   c. Terminate with zerk fittings.
3. Drives:
   a. In accordance with Paragraph Fan Drives.
   b. Factory set to specified fan revolutions per minute.
   c. Type: [Belt or direct, as indicated in Equipment Schedule.] [Belt.] [Direct.]

F. Accessories: Provide [as scheduled on Equipment Schedule.] [as follows:]

1. Gravity Backdraft Damper: Gravity operation, adjustable counterweight, and aluminum construction.
2. Motorized Damper: Aluminum frame, aluminum blades, aluminum hinge pins with nylon bushings, [120V] [24V] operator.
3. Bird Screen: Aluminum construction, PVC encapsulated.
4. Roof Curb:
   a. Factory fabricated, [galvanized steel] [aluminum] [FRP] construction.
   b. [With] [Without] damper tray.
   c. Sloped to match roof pitch, and to provide level top.
   d. Height Above Finished Roof: [12 inches.] [As scheduled.]
   e. Mitered continuous welded corner seams.
   f. Pressure-treated wood nailer.
   g. Insulation: Minimum 1-1/2 inches thick, 3 pounds per cubic foot density, rigid mineral fiberboard insulation with metal liner.
5. Disconnect: Factory installed, nonfused, NEMA Type [3R] [4X] [as scheduled].

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6. Bearing Lubrication Lines:
   a. Extended to outside of fan housing.
   b. Type 316 stainless steel construction.
   c. Terminate with zerk fittings.
7. Spark Resistant Construction:
   a. AMCA 99-0401 Type [A] [B] [C] [as scheduled].
   b. Graphite impregnated in housing.
   c. Static grounding.

G. Manufacturers and Products:

1. Twin City; Whirlout Model WA/WAB.
2. Composite Fan Technology; Corro-Vent Model CVC.

2.12 ROOF FAN, HOODED PROPELLER, FILTERED SUPPLY

A. General:

1. Factory-assembled roof mounted supply air fan; including housing, hood, filters, propeller fan wheel, drive assembly, motor and accessories.
2. Bearing AMCA Certified Ratings Seal for sound and air performance.

B. Housing:

1. Minimum 16-gauge [painted steel] [galvanized steel] [aluminum] construction.
2. Integral formed venturi orifice.
3. Continuously welded corners.
4. Bolted to frame.
5. Frame:
   a. Minimum 14-gauge steel construction.
   b. Continuously welded joints.
   c. Reinforced motor base plate.

C. Hood:

1. Arched panel type with interlocking ribs.
2. Same material as housing.
3. Supported by heavy gauge galvanized steel frame.
4. Removable for fan access, bolted to top of fan housing.
5. Sized to allow no more than 500 fpm air intake face velocity.
6. Insulation: Fiberglass, [1/2] [1]-inch thickness, attached to underside of hood.

D. Filters and Frames:

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1. Metal Mesh Type:
   a. Washable, 4-mesh [zinc electroplated steel] [aluminum] screen media.
   b. Thickness: 2 inches.
   c. Minimum [25] [_____] percent dust spot efficiency in accordance with ASHRAE 52.2.
2. Frames:
   a. Located on underside of hood perimeter, permanent reusable.
   b. [16-gauge steel] [Aluminum] holding frame, retainer, and sealer frame.
   c. To allow removal of filters without removal of hood.
3. Manufacturers:
   a. Camfil Farr.
   b. American Air Filter.
   c. Viledon.

E. Curb Base:

1. Same material as housing.
2. Minimum 18 inches tall.
3. [Access door, for service of backdraft damper, motorized damper, insect screen.]
4. Rubber stripping attached to underside of fan curb cap.
5. Lifting lugs, welded to each corner.

F. Wheel:

1. Hub: Cast aluminum.
2. Propeller: Cast aluminum airfoil blade design.
3. Wheel assembly attached to fan shaft with split taper lock bushing.

G. Shaft, Bearings, Drive:

1. Shaft:
   a. Turned, ground, and polished carbon steel.
   b. Keyed for sheave installation.
   c. Zinc-phosphate coated and oil emulsion-dipped.
2. Bearings:
   a. Grease lubricated, precision antifriction ball, self-aligning, pillow block style.
   b. Selected for average life (ABMA 9 L_{50}) of not less than 200,000 hours operation at maximum cataloged operating speed.
   c. Terminate with zerk fittings.
3. Drives:

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a. In accordance with Paragraph Fan Drives.
b. Factory set to specified fan revolutions per minute.
c. Type: [As scheduled in Equipment Schedule.] [Belt.] [Direct.]

H. Accessories: Provide [as scheduled in Equipment Schedule.] [as follows:]

1. Gravity Backdraft Damper: Gravity operation, adjustable counterweight, and aluminum construction.
2. Motorized Damper: Aluminum frame, aluminum blades, aluminum hinge pins with nylon bushings, [120V] [24V] operator.
3. Insect Screen:
   a. [Galvanized steel] [Aluminum] frame.
   b. Aluminum mine mesh screen.
4. Bird Screens: Aluminum construction.
5. Roof Curb:
   a. Factory fabricated, [galvanized steel] [aluminum] construction.
   b. [With] [Without] damper tray.
   c. Sloped to match roof pitch, and to provide level top.
   d. Height Above Finished Roof: [12 inches.] [As scheduled.]
   e. Mitered continuous welded corner seams.
   f. Pressure-treated wood nailer.
   g. Insulation: Minimum 1-1/2 inches thick, 3 pounds per cubic foot density, rigid mineral fiberboard insulation with metal liner.
6. Disconnect: Factory installed, nonfused, NEMA [3R] [4] [as scheduled].
7. Bearing Lubrication Lines:
   a. Extended to outside of fan housing.
   b. Type 316 stainless steel construction.
   c. Terminate with zerk fittings.
8. Filter Pressure Gauge:
   a. Each filter bank shall be furnished with [magnehelic filter gauge (Dwyer Series 2000)] [air filter gauge (Dwyer Mark 25)] [inclined manometer (DWYER 250 AF)].
   b. With adjustable signal flag.
9. Inlet Screen: Removable 1-inch mesh screen of coated steel construction over exposed inlets.
10. Corrosion Protection Coating:
    a. Provide factory-applied corrosion protection coating on these fan components:
       1) Wheel.
       2) Housing.
       3) Accessories.
       4) Interior surfaces in contact with airstream.

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b. [Coating system shall be [baked enamel] [baked polyester] [air-dry epoxy] [baked epoxy] [air dry phenolic] [baked phenolic] [baked epoxy phenolic] [as scheduled in fan Equipment Schedule], and shall be in accordance with Article Corrosion Protection Coating.]
c. [Coating system shall be in accordance with Section 09 90 00, Painting and Coating.]

I. Manufacturers and Products:

1. Aerovent: Model FSR.
2. Greenheck; Model R (Direct Drive); RB (Belt Drive).
3. Cook; Model HEF-D.

2.13 ROOF GRAVITY VENTILATOR, LOUVERED

A. General: Factory-assembled louvered exhaust or gravity relief vent; including housing and accessories, suitable for roof mounting.

B. Housing:

1. Construction:
   a. Rectangular, tiered extruded aluminum construction, with welded miter cut joints, 12-gauge minimum thickness.
   b. Louvered on all four sides.
   c. Aluminum support structure, 8-gauge minimum thickness.
2. Base:
   a. Reinforced and braced.
   b. Integral snow and storm baffle.
   c. Minimum panel thickness, 12 gauge.
   d. Miter cut continuously welded curb cap corners.
3. Hood:
   a. Overhang sufficient to provide weatherproof inlet.
   b. Minimum panel thickness, 14 gauge.
   c. Anticondensate insulation coating inside hood.

C. Accessories: Provide [as scheduled in Equipment Schedule.] [as follows:]

1. Gravity Backdraft Damper: Gravity operation, adjustable counterweight, aluminum construction.
2. Motorized Damper: Aluminum frame, aluminum blades, aluminum hinge pins with nylon bushings, [120] [12]–volt operator.
3. Bird Screen: Aluminum construction.
4. Roof Curb:

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a. Factory fabricated.
b. [With] [Without] damper tray.
c. Sloped to match roof pitch, and to provide level top.
d. Height Above Finished Roof: [12 inches.] [As scheduled.]
e. [Galvanized steel] [Aluminum] construction.
f. Mitered, continuous welded corner seams.
g. Pressure-treated wood nailer.
h. Insulation: Minimum 1-1/2 inches thick, 3 pounds per cubic foot density, rigid mineral fiberboard insulation with metal liner.

5. Inlet Screen: Removable 1-inch mesh screen of coated steel construction over exposed inlets.
6. Corrosion Protection Coating:
   a. Provide factory-applied corrosion protection coating on these fan components:
   b. Housing.
   c. Accessories.
      1) Interior surfaces in contact with airstream.
      2) [Coating system shall be [baked enamel] [baked polyester] [air-dry epoxy] [baked epoxy] [air-dry phenolic] [baked phenolic] [baked epoxy phenolic] [as scheduled in fan Equipment Schedule], and shall be in accordance with Article Corrosion Protection Coating.]
   d. [Coating system shall be in accordance with Section 09 90 00, Painting and Coating.]

D. Manufacturers and Products:

1. Cook; Model TRE.
2. ACME; Model LEV (exhaust); Model LIV (intake).
3. Greenheck; Model WRH (relief); Model WIH (intake)

2.14 UTILITY BLOWER, CENTRIFUGAL SWSI, FIBERGLASS

A. General:

1. Factory-assembled utility blower; including housing, fan wheel, drive assembly, motor and accessories.
2. Fiberglass Construction: In accordance ASTM D4167.
3. Suitable to convey air at temperatures up to 250 degrees F.
4. Fan Performance: AMCA 99-2408 Class [I] [II] [III] [as scheduled].
5. Airstream Hardware: Type 316 stainless steel.

B. Fiberglass Material:

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1. Construction: Resin reinforced fiber cloth and mat.
2. Resin:
3. Vinyl ester or other qualified thermosetting resin.
    a. Selected by fabricator, subject to approval by Engineer and suitable for intended service with no fillers or thixotropic agents.
    b. Premium grade and corrosion resistant.
    c. Structural wall resin may be of different chemical resistance, subject to conditions of service and approval by Engineer.
    d. [Flame Spread Index:
    e. ASTM E84, less than 25; fire retardant additives used only in structural layer.
        1) Structural wall resin shall contain a minimum of 3 percent antimony trioxide to achieve required flame spread index.]
    f. For outdoor locations, add ultraviolet absorbers to surfacing resin to improve weather resistance.
    g. Color:
        1) Use no dyes, pigments, or colorants [, except in exterior gel coat].
        2) Exterior gel coat shall be [white] [_____].
    h. For interior locations, final coat shall be factory-applied intumescent coating to achieve designated results for low smoke development.
4. Reinforcement:
    a. Veil: Chemical surfacing mat, [Type C (chemical) glass veil] [Nexus Surface Veil] [carbon veil].
    b. Chopped Strand Mat: Type E glass, minimum 1-1/2 ounces per square foot, with silane finish and styrene soluble binder.
    c. Continuous Roving for Chopper Gun Spray-Up: Type E glass.
    d. Woven Roving: Type E glass, nominal 24 ounces per square yard, 4 by 5 weave, with silane type finish.
5. Laminate:
    a. Inner Surface (Veil):
        1) Resin rich, veil reinforced, 10 mils to 20 mils thick.
        2) Use no additives.
        3) Finish and binder compatible with lay-up resin.
        4) Reinforcement Content: Not more than 20 percent.
    b. Interior (Corrosion) Layer:
        1) Resin rich, at least two plies of chopped strand mat, nominal 100 mils to 120 mils thick.
        2) Use no additives.
        3) Construct interior layer of resin reinforced with at least two plies of chopped strand mat backing the veil.
        4) Reinforcement Content: 25 plus or minus 5 percent.

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c. Exterior (Structural) Layer:
   1) Resin with mat, cloth, woven roving or chopped strand glass reinforcement.
   2) Enough resin present to prevent surface fiber show.
   3) Exterior surface relatively smooth, with no exposed fibers or sharp projections.
d. Wall Thickness: As required for equipment structural integrity, but no less than 3/16 inch.

C. Housing:

1. Material: Fiberglass.
2. Construction:
   a. Curved scroll configuration.
   b. Integral flanges to ensure housing concentricity and housing strength.
   c. Flanged outlet to permit duct connection.
   d. Drain connection located at lowest point of fan housing.
   e. Inlet:
      1) Die-formed bell mouth of fiberglass construction.
      2) Fiberglass supports.
      3) Bolted to housing to permit wheel removal.
   f. Shaft Seal: Viton construction, located at shaft penetration of housing.
3. Base/Pedestal: All-welded heavy gauge [steel] [Type 316 stainless steel].

D. Wheel:

1. Material: Fiberglass.
2. Fan wheel speed not to exceed 90 percent of manufacturer's listed safe fan speed.
3. Centrifugal, one-piece, nonoverloading, [radial blade type] [backward inclined airfoil blade type] [blade type as scheduled].
4. Wheel hub permanently bonded to shaft and completely encapsulated in fiberglass.

E. Shaft, Bearings, Drive:

1. Shafts:
   a. Turned, ground, and polished Type 304 stainless steel.
   b. Ends drilled and tapped for wheel installation.
   c. Keyed for sheave installation.
2. Bearings:
   a. Grease lubricated, precision antifriction ball, self-aligning type.

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b. Mounted in cast iron pillow block housing.
c. Selected for average life (ABMA 9 L_{50}) of not less than 200,000 hours operation at maximum cataloged operating speed.

3. Drives:
   a. In accordance with Paragraph Fan Drives.
   b. Factory set to specified fan revolutions per minute.
   c. Type: [Belt or direct, as indicated in Equipment Schedule.] [Belt.] [Direct.]
   d. Arrangement: [As scheduled in Equipment Schedule.] [Arrangement 10.] [Arrangement 9.] [Arrangement 4.] [Arrangement 1.]

F. Accessories: Provide [as scheduled in Equipment Schedule.] [as follows:]

1. Housing Access Doors: Bolted and gasketed.
2. Curb Base: Molded one-piece fiberglass, seamless construction.
3. Disconnect: Factory installed, nonfused, NEMA Type [3R] [4X] [as scheduled].
4. Flanged Inlet: Heavy fiberglass construction, factory drilled and flanged.
5. Shaft Seal: Fiberglass and neoprene construction, located at shaft penetration of housing.
6. Belt Guard: OSHA type, carbon steel sheet metal, for complete coverage of belts and sheaves.
7. Shaft and Bearing Guard: Carbon steel sheet metal for complete coverage of shaft and bearings.
8. Motor and Drive Cover:
   a. Factory fabricated; OSHA type.
   b. Carbon steel sheet metal construction.
   c. Vented, openings sufficient size for proper motor cooling.
9. Inlet Screen: Removable 1-inch mesh screen of coated steel construction over exposed inlets.
10. Unitary Subbase:
    a. Structural metal subbase, same material as fan housing.
    b. Bolted to bottom of fan base/pedestal.
    c. Drilled for field installation of vibration isolators.
11. Spark Resistant Construction:
    a. Carbon fiber veil impregnated in housing and wheel fiberglass resin corrosion barrier.
    b. Static grounding.
    c. Classification: AMCA 99-0401 Type [A] [B] [C] [as scheduled].
12. Corrosion Protection Coating:
    a. Provide factory-applied corrosion protection coating on fan steel components.

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b. [Coating system shall be [baked enamel] [baked polyester] [air-dry epoxy] [baked epoxy] [air dry phenolic] [baked phenolic] [baked epoxy phenolic] [as scheduled in fan Equipment Schedule], and shall be in accordance with Article Corrosion Protection Coating.]
c. [Coating system shall be in accordance with Section 09 90 00, Painting and Coating.]

G. Manufacturers and Products:

1. Aerovent; Model RBF.
2. New York Blower; Model FE.
3. Hartzell; Series 41.

2.15 UTILITY BLOWER, CENTRIFUGAL SWSI, HEAVY DUTY

A. General:

1. Factory-assembled utility blower; including housing, fan wheel, drive assembly, motor, and accessories.
2. Suitable to convey air at temperatures up to 250 degrees F.
3. Fan Performance: AMCA 99-2408 Class [I] [II] [III] [as scheduled].
4. Bearing AMCA Certified Ratings Seal for sound and air performance.

B. Housing:

1. Material: [Steel.] [Aluminum.] [Type 304 stainless steel.] [Type 316 stainless steel.]
2. Construction:
   a. Curved scroll configuration, with continuous seam welding and side angle reinforcement.
   b. Lifting lugs welded to housing.
   c. Flanged and drilled outlet to permit duct connection.
   d. Drain connection located at lowest point of fan housing.
   e. Inlet: Spun-formed aerodynamic bell mouth.
3. Base/Pedestal: All-welded heavy gauge [steel] [Type 316 stainless steel].

C. Wheel:

1. Centrifugal, one-piece, nonoverloading, [radial blade type] [backward inclined flat blade type] [backward inclined airfoil blade type] [blade type as scheduled].
2. Fan wheel speed not to exceed 90 percent of manufacturer’s listed safe fan speed.

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3. Material: [Steel.] [Aluminum.] [Type 304 stainless steel.] [Type 316 stainless steel.]
4. Attached to fan shaft with split taper lock bushing.

D. Shaft, Bearings, Drive:

1. Shafts:
   a. Turned, ground, and polished steel.
   b. Ends drilled and countersunk for tachometer readings.
   c. Keyed for sheave installation.
2. Bearings:
   a. Grease lubricated, precision antifriction ball, self-aligning type.
   b. Mounted in cast iron pillow block housing.
   c. Selected for average life (ABMA 9 L_{50}) of not less than 200,000 hours operation at maximum cataloged operating speed.
3. Drives:
   a. In accordance with Paragraph Fan Drives.
   b. Factory set to specified fan revolutions per minute.
   c. Type: [Belt or direct, as indicated in Equipment Schedule.] [Belt.] [Direct.]
   d. Arrangement: [As scheduled in Equipment Schedule.] [Arrangement 9.] [Arrangement 10.] [Arrangement 4.] [Arrangement 1.]

E. Accessories: Provide [as scheduled in Equipment Schedule.] [as follows:]

1. Housing Access Doors: Bolted and gasketed.
2. Disconnect: Factory installed, nonfused, NEMA Type [3R] [4X] [as scheduled].
3. Flanged Inlet: Heavy gauge construction, factory drilled and flanged.
4. Shaft Seal: Viton construction, located at shaft penetration of housing.
5. Belt Guard: OSHA type, sheet metal construction same material as fan housing, for complete coverage of belts and sheaves.
6. Shaft and Bearing Guard: Sheet metal construction same material as fan housing, for complete coverage of shaft and bearings.
7. Motor and Drive Cover:
   a. Factory fabricated; OSHA type.
   b. Sheet metal construction, same material as fan housing.
   c. Vented, openings sufficient size for proper motor cooling.
8. Inlet Guard: Spiral wire type, OSHA approved, removable, same material as fan housing.
9. Unitary Subbase:
   a. Structural metal subbase, same material as fan housing.

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b. Bolted to bottom of fan base/pedestal.
c. Drilled for field installation of vibration isolators.

10. Spark Resistant Construction Classification: AMCA 99-0401 Type [A] [B] [C] [as scheduled].
11. Corrosion Protection Coating:
    a. Provide factory-applied corrosion protection coating on these fan components:
        1) Wheel (or propeller).
        2) Housing.
        3) Accessories.
        4) Interior surfaces in contact with airstream.
    b. [Coating system shall be [baked enamel] [baked polyester] [air-dry epoxy] [baked epoxy] [air dry phenolic] [baked phenolic] [baked epoxy phenolic] [as scheduled in fan Equipment Schedule], and shall be in accordance with Article Corrosion Protection Coating.]
    c. [Coating system shall be in accordance with Section 09 90 00, Painting and Coating.]

F. Manufacturers and Products:

1. Aerovent; Model BI.
2. New York Blower; Acoustafoil/PLR.
3. Cook; CP Series.

2.16 WALL FAN, CENTRIFUGAL

A. General:

1. Factory-assembled centrifugal wall fan; including housing, fan wheel, drive assembly, motor and accessories.
2. Bearing AMCA Certified Ratings Seal for sound and air performance.

B. Housing:

1. Construction: Spun-formed aluminum, minimum 16-gauge marine alloy.
2. Windband: Finish with rolled bead.
3. Cap: Motor access via quick release latches.
4. Motor completely sealed from exhaust air stream.
5. Motor cooling via air breather tubes.
6. Integral conduit chase for wiring.
7. Fan Inlet:
    a. Full inlet cone of aluminum construction.

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b. Match inlet shroud.

8. Wall Flange: Aluminum construction, with prepunched key slot holes.

C. Fan Wheels:

1. Aluminum construction, backward inclined centrifugal, nonoverloading type.
2. Machined, cast aluminum hub.
3. Matched to deep spun inlet venturi.

D. Shaft, Bearings, Drive:

1. Shaft:
   a. Turned, ground, and polished carbon steel.
   b. Keyed for sheave installation.
   c. Zinc-phosphate coated and oil emulsion-dipped.
2. Bearings:
   a. Grease lubricated, precision antifriction ball, self-aligning, pillow block style.
   b. Selected for average life (ABMA 9 L_{50}) of not less than 200,000 hours operation at maximum cataloged operating speed.
   c. Terminate with zerk fittings.
3. Drives:
   a. In accordance with Paragraph Fan Drives.
   b. Factory set to specified fan revolutions per minute.
   c. Type: [Belt or direct, as indicated in Equipment Schedule.] [Belt.] [Direct.]

E. Accessories: Provide [as scheduled in Equipment Schedule.] [as follows:]

1. Gravity Backdraft Damper: Gravity operation, adjustable counterweight, aluminum construction.
2. Motorized Damper: Aluminum frame, aluminum blades, aluminum hinge pins with nylon bushings, [120V] [24V] operator.
3. Bird Screen: Aluminum construction.
4. Disconnect: Factory installed, nonfused, NEMA Type [3R] [4X] [as scheduled].
5. Bearing Lubrication Lines:
   a. Extended to outside of fan housing.
   b. Type 316 stainless steel construction.
   c. Terminate with zerk fittings.
6. Spark Resistant Construction: Classification: AMCA 99-0401 Type [A] [B] [C] [as scheduled].

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7. Corrosion Protection Coating:
    a. Provide factory-applied corrosion protection coating on these fan components:
        1) Wheel.
        2) Housing.
        3) Accessories.
        4) Interior surfaces in contact with airstream.
    b. [Coating system shall be [baked enamel] [baked polyester] [air-dry epoxy] [baked epoxy] [air dry phenolic] [baked phenolic] [baked epoxy phenolic] [as scheduled in fan Equipment Schedule], and shall be in accordance with Article Corrosion Protection Coating.]
    c. [Coating system shall be in accordance with Section 09 90 00, Painting and Coating.]

F. Manufacturers and Products:

1. Cook; Model ACWD (Direct Drive); ACWB (Belt Drive).
2. Greenheck; Model CW (Direct Drive); CWB (Belt Drive).
3. ACME; Model PDU (Direct Drive); PNU (Belt Drive).
4. Aerovent; Model AWX.
5. Twin City; Model TCWX.

2.17 WALL FAN, PROPELLER, HEAVY DUTY

A. General: Factory-assembled wall propeller fan; including housing, propeller, drive assembly, motor and accessories.

B. Housing:

1. Material: Metal components constructed from [steel] [aluminum] [materials as indicated in Equipment Schedule].
2. Panel:
    a. Minimum 14-gauge sheet metal construction.
    b. Integral formed venturi orifice.
    c. Continuously welded corners.
    d. Bolted to frame.
3. Frame:
    a. Minimum 14-gauge metal construction.
    b. Continuously welded joints.
    c. Reinforced motor baseplate.

C. Propeller:

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1. Cast aluminum construction.
2. Hub keyed and mechanically locked to shaft.

D. Shaft, Bearings, Drive:

1. Shaft:
   a. Turned, ground, and polished carbon steel.
   b. Keyed for sheave installation.
2. Bearings:
   a. Grease lubricated, precision antifriction ball, self-aligning, sealed pillow block style.
   b. Mounted in cast iron pillow block housing.
   c. Selected for average life (ABMA 9 L_{50}) of not less than 200,000 hours operation at maximum cataloged operating speed.
3. Drives:
   a. In accordance with Paragraph Fan Drives.
   b. Factory set to specified fan revolutions per minute.
   c. Type: [Belt or direct, as indicated in Equipment Schedule.] [Belt.] [Direct.]

E. Accessories: Provide [as scheduled in Equipment Schedule.] [as follows:]

1. Disconnect: Factory-installed, nonfused, NEMA Type [12] [4X] [as scheduled].
2. Propeller-Side Guard: Galvanized steel construction.
3. Motor-Side Guard: Galvanized steel construction.
4. Weather Hood:
   a. Heavy-gauge galvanized steel construction, to match fan and accessory size.
   b. Galvanized steel expanded metal bird screen.
5. Wall Housing:
   a. Allows fan mounting on interior or exterior wall.
   b. Heavy-gauge galvanized steel construction.
6. Shutters, Gravity Operated:
   a. Welded [steel] [aluminum] frame.
   b. Extruded aluminum blades.
   c. Felt edge seals.
   d. Oil impregnated bronze bushings.
   e. Reverse flange for building exterior mounting. Standard flange for indoor mounting.
7. Shutters, Motor Operated:
   a. Welded [steel] [aluminum] frame.

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b. Extruded aluminum blades.
c. Stainless steel edge seals.
d. Oil impregnated bronze bushings.
e. 120-volt spring return damper actuator with end switch.
f. Reverse flange for building exterior mounting. Standard flange for indoor mounting.

8. Spark Resistant Construction:
   a. Nonferrous blade assembly.
   b. Classification: AMCA 99-0401 Type [A] [B] [C] [as scheduled].
9. Panel Fan Boot:
   a. To adapt fan panel to wall louver.
   b. Size to suit louver dimension as shown on Drawings or indicated in Specifications.
   c. Sheet metal construction, same material as fan housing.
10. Corrosion Protection Coating:
   a. Provide factory-applied corrosion protection coating on these fan components:
      1) Housing.
      2) Accessories.
      3) Interior surfaces in contact with airstream.
   b. [Coating system shall be [baked enamel] [baked polyester] [air-dry epoxy] [baked epoxy] [air dry phenolic] [baked phenolic] [baked epoxy phenolic] [as scheduled in fan Equipment Schedule], and shall be in accordance with Article Corrosion Protection Coating.]
   c. [Coating system shall be in accordance with Section 09 90 00, Painting and Coating.]

F. Manufacturers and Products:

1. Aerovent; Model DDP (Direct); Model BP (Belt).
2. New York Blower; Model NYC.
3. Hartzell; Model Series 02.

2.18 FILTER HOUSING

A. General:

1. Air filtration section, complete with filter media and filter racks.
2. Designed for static pressure ranges of [minus 3] [_____] inches WC to [plus 3] [_____] inches WC.
3. Design temperature not to exceed 200 degrees F.

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4. Leakage at rated airflow upstream to downstream of filter frame shall be less than1 percent at 3 inches WC. Leakage in to or out of housing shall be less than 0.5 percent at 3 inches WC.
5. [V-Bank housings to be used for airflow rates 1,000 acfm or greater.]
6. [Flat panel housings to be used for airflow rates less than 1,000 acfm.]
7. Flanged units suitable for installation in a duct and for space indicated.
8. Housing to fit standard nominal filter sizes, either 24 inches by 24 inches or 24 inches by 12 inches.
9. Maximum 500 fpm face velocity across filters.
10. Filters arranged in a suitable leak-tight frame and enclosure.

B. Housing:

1. Permanent reusable, side-loading [16-gauge galvanized or aluminized steel] [aluminum] [Type 304 stainless steel] frame and retainer.
2. Housing to be supported on a structural steel frame.
3. Doors:
   a. Provide hinged, quick-opening doors for access, service and removal of filters.
   b. Side access doors to be locked closed and opened without use of tools.
   c. Plastic door hardware to be made of UV-resistant materials.
   d. Provide doors on [one] [both] sides of unit. [See Drawings for access door location.]
4. Provide upstream and downstream outwardly turned flanges of same material as housing.
5. Provide gaskets for filter tracks and doors for positive sealing. Filter track gaskets to be replaceable.
6. Treat cabinet and accessory surfaces inside and out with rust-inhibitive surface coating and painted with prime and finish coat of machinery enamel.
7. [Provide weatherproof housing suitable for outdoor/rooftop installation. Silicone seal metal-to-metal joints for watertight seams.]
8. [Inside surfaces of housing insulated with 1-inch thick, 1-1/2-pound density insulation on outdoor units.]
9. Provide upstream and downstream static pressure taps, with 1/4-inch diameter tube connections for measuring pressure drop across filters.
10. Provide lifting lugs suitable for lifting and assembled housing and filters.
11. Provide housing hanging brackets of same material as housing suitable to supporting complete filter housing assembly.

C. Filters:

1. Filter Media Thickness: [2] [4] [6 (flat bank only)] inches.

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2. Arrangement: [Angled V-bank.] [Vertical flat bank.]
3. Pleated panel disposable filters. Nonwoven reinforced [cotton/poly (for MERV 7)] [100 percent synthetic (for MERV 8)] fabric media with a metal support grid and heavy duty beverage board enclosing frame. Minimum MERV [7] [8] [_____] efficiency per ASHRAE 52.2. Minimum [30] [_____] percent dust spot efficiency.
4. Initial clean filter resistance of 0.28-inch WC. Maximum filter resistance of 1-inch WC.
5. [UL Class 2 filter.]

D. Accessories:

1. Filter Pressure Gauge: Furnish each filter bank with [magnehelic gauge (Dwyer Series 2000)] [air filter gauge (Dwyer Mark 25)] [inclined manometer (Dwyer 250 AF)] with connecting polypropylene tubing and adjustable signal flag.

E. Manufacturers and Products:

1. [V-Bank Filter Housings:
   a. Flanders Precisionaire; Sureflo.
   b. Tri-Dim Filter Corp.; Tri-Met VB.
   c. Airguard; Model VB.]
2. [Flat Panel Filter Housings:
   a. Camfil Farr; 4P Glid Pack.
   b. Flanders Precisionair; Superpleat.
   c. Tri-Dim Filter Corp.; Tri-Met FB.
   d. Airguard; Model FB.]

2.19 CORROSION PROTECTION COATING

A. General:

1. Factory-applied corrosion protection coating for application to fan components and accessories, where required by this section.
2. Quality Control:
   a. Verify dry film thickness before final baking.
   b. Finished coating system shall be free from voids, checks, cracks, and blisters.
3. Surface Cleaning: Clean parts to be coated as follows:
   a. Immerse parts in heated cleaning solution to remove lubricants, machining oils, and residual factory contamination.

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b. Follow with immersion in potable water bath to neutralize and remove cleaning solution.
c. Chemical Pretreatment: Immerse parts in heated chemical solution, iron phosphate for steel, clear/yellow chromate for aluminum.

B. Baked Enamel:

1. Material: Alkyd modified urea-melamine single component baking enamel.
2. Surface Preparation: Clean surface to SSPC SP 3.
3. Application: Standard air-pressurized spray equipment.
4. Curing: Oven baked at a metal temperature not to exceed 300 degrees F.
5. Finished Thickness: 1-mil to 2-mil dry film thickness.
6. Performance: Coating shall meet or exceed following criteria:
   a. Impact Resistance: 10-inch pounds, ASTM D2794 test method.
   b. Pencil Hardness: 2H, ASTM D3363 test method.
   c. Service Temperature: Maximum 230 degrees F, continuous.

C. Baked Polyester:

1. Material: Polyester.
2. Surface Preparation: Sandblast surface to SSPC SP 5.
3. Application: Electrostatic spray.
4. Curing: Oven baked at a metal temperature not to exceed 400 degrees F.
5. Finished Thickness: 1.5-mil to 2.5-mil dry film thickness.
6. Performance: Coating shall meet or exceed following criteria:
   a. Salt Spray Test: Minimum 1,000-hour duration, ASTM B117 test method.
   b. Humidity Resistance: Minimum 1,000-hour duration, ASTM D2247 test method.
   c. Impact Resistance: 100-inch pounds, ASTM D2794 test method.
   d. Pencil Hardness: 2H, ASTM D3363 test method.
   e. Service Temperature: Maximum 230 degrees F, continuous.

D. Air-Dry Epoxy:

1. Material: Two-part catalyzed epoxy.
2. Surface Preparation: Clean surface to SSPC SP 3.
3. Application: Standard air-pressurized spray equipment.
4. Curing: Air dry.
5. Finished Thickness: 4-mil to 6-mil dry film thickness.
6. Performance: Coating shall meet or exceed following criteria:

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a. Salt Spray Test: Minimum 1,500-hour duration, ASTM B117 test method.
b. Pencil Hardness: H-2H, ASTM D3363 test method.
c. Service Temperature: Maximum 150 degrees F, continuous.

E. Baked Epoxy:

1. Material: Epoxy.
2. Surface Preparation: Sandblast surface to SSPC SP 10.
3. Application: Electrostatic spray.
4. Curing: Oven baked at a metal temperature not to exceed 400 degrees F.
5. Finished Thickness: 2.5-mil to 3.5-mil dry film thickness.
6. Performance: Coating shall meet or exceed following criteria:
   a. Salt Spray Test: Minimum 1,000-hour duration, ASTM B117 test method.
   b. Humidity Resistance: Minimum 1,000-hour duration, ASTM D2247 test method.
   c. Impact Resistance: 100 inch pounds, ASTM D2794 test method.
   d. Pencil Hardness: 2H, ASTM D3363 test method.
   e. Service Temperature: Maximum 230 degrees F, continuous.

F. Air Dry Phenolic:

1. Material:
   a. Phenolic resin, Heresite VR-500 Series or equal.
   b. For outdoor applications, apply an UV resistant topcoat, Heresite UC-5500 or equal.
2. Surface Preparation: Sandblast surface to SSPC SP 6.
3. Application: Standard air-pressurized spray equipment.
4. Curing: Air dry.
5. Finished Thickness: 4-mil to 6-mil dry film thickness.
6. Performance: Coating shall meet or exceed following criteria:
   a. Salt Spray Test: Minimum 500-hour duration, ASTM B117 test method.
   b. Humidity Resistance: Minimum 500-hour duration, ASTM D2247 test method.
   c. Service Temperature: Maximum 180 degrees F, continuous.

G. Baked Phenolic:

3. Material: Phenolic resin, Heresite P-403 or equal.
4. Surface Preparation: Sandblast surface to SSPC SP 5.
5. Application: Standard air-pressurized spray equipment.

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6. Curing: Oven baked at a metal temperature not to exceed 400 degrees F.
7. Finished Thickness: 5-mil to 7-mil dry film thickness.
8. Performance: Coating shall meet or exceed following criteria:
   a. Salt Spray Test: Minimum 1,000-hour duration, ASTM B117 test method.
   b. Humidity Resistance: Minimum 1,000-hour duration, ASTM D2247 test method.
   c. Impact Resistance: 100-inch pounds, ASTM D2794 test method.
   d. Pencil Hardness: 2H, ASTM D3363 test method.
   e. Service Temperature: Maximum 250 degrees F, continuous.

C. Baked Epoxy Phenolic:
   1. Material:
      a. Baking cross-linked epoxy-phenolic.
      b. For outdoor applications, apply an UV-resistant topcoat.
   2. Surface Preparation: Sandblast surface to SSPC SP 5.
   3. Application: Electrostatic or conventional compressed air spray equipment.
   4. Curing: Oven baked at a metal temperature not to exceed 400 degrees F.
   5. Finished Thickness: 6-mil to 8-mil dry film thickness.
   6. Performance: Coating shall meet or exceed following criteria:
      a. Salt Spray Test: Minimum 1,000-hour duration, ASTM B117 test method.
      b. Humidity Resistance: Minimum 1,000-hour duration, ASTM D2247 test method.
      c. Impact Resistance: 160-inch pounds, ASTM D2794 test method.
      d. Pencil Hardness: 3H, ASTM D3363 test method.
   7. Service Temperature: Maximum 350 degrees F, continuous.

2.20 MOTORS

A. General:

1. Fan motors shall comply with provisions of Section 26 20 00, Low-Voltage AC Induction Motors.
2. Provide integral self-resetting overload protection on single-phase motors.
3. Motors for fans specified for use with variable frequency drives shall be inverter duty type.
4. Motors shall not operate into service factor in any case.

B. Motor requirements shall be as follows, unless designated otherwise on Equipment Schedule:

1. Torque Characteristics: Sufficient to accelerate driven loads satisfactorily.
2. Winding Thermal Protection: None.

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3. Space Heater: No.
4. Number of Speeds: Single.
5. Number of Windings: One.
6. Motor Efficiency: [Energy efficient.] [Premium efficient.]
7. Shaft Type: Solid, carbon steel.
8. Mounting: As required for fan arrangement.
9. Service Factor: 1.15.

2.21 ACCESSORIES

A. Equipment Identification Plates: Furnish 16-gauge [Type _____] stainless steel identification plate securely mounted on each separate equipment component [and control panel] in a readily visible location. Plate shall bear [3/8] [1/4]-inch high [engraved] [die-stamped] block type [black enamel filled] equipment [identification number] [and letters] indicated in this Specification [and as shown on Drawings].

B. Lifting Lugs: Furnish suitably attached for equipment assemblies and components weighing over 100 pounds.

2.22 SOURCE QUALITY CONTROL

A. General:

1. Fan shall operate at single stable point as indicated by fan curve. Fans having two potential operating points are not acceptable.
2. Fan and motor combination shall be capable of delivering 110 percent of scheduled air quantity and static pressure. Motor shall not operate into motor service factor in any listed case.
3. Consider drive efficiency in motor selection according to manufacturer's published recommendation or according to AMCA 203, Appendix L.

B. Testing Provisions:

1. Provide tachometer access holes large enough to accept standard tachometer drive shaft.
2. Center punch fan shaft to accommodate tachometer readings.

C. Acoustical Levels:

1. Perform noise tests in accordance with AMCA 300 and AMCA 301.
2. Fan sound power levels (dB, Reference 10^{-12} Watts) shall be no greater than scheduled values.

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D. Balancing:

1. Unless noted otherwise, each fan wheel shall be statically and dynamically balanced to ASA S2.19 Grade G6.3.
2. Fans controlled by variable frequency drives shall be dynamically balanced at speeds 25 percent, 50 percent, 75 percent, and 100 percent of design revolutions per minute.

E. Vibration Test:

1. Each fan furnished with 5-horsepower or larger motor shall have factory run vibration test, including vibration signatures taken on each bearing in horizontal, vertical, and axial direction.
2. Vibration reading as measured at scheduled rotational speed shall not exceed the following values when fan is rigidly mounted:
   a. Belt Drive (except Vane Axial): 0.15 inch per second peak velocity.
   b. Belt Drive Vane Axial: 0.08 inch per second peak velocity.
   c. Direct Drive: 0.08 inch per second peak velocity.
3. Written records of run test and vibration test shall be made available upon request.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install fans level and plumb.

B. Secure roof-mounted fans to roof curbs with [cadmium-plated steel] [Type 316 stainless steel] hardware.

C. Ceiling Units: Suspend units from structure; use steel wire or metal straps.

D. Scroll Drains: Pipe drain connection through running trap to floor drain.

E. Labeling:

1. Label fans in accordance with Article Accessories.
2. Mark exhaust fans serving fume hoods with arrows to indicate proper direction of rotation, in accordance with NFPA 45.

F. Service Access: Locate units to provide access spaces required for motor, drive, bearing servicing, and fan shaft removal.

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G. Equipment Support and Restraints:

H. Refer to Section 23 05 48, Vibration Isolation [and Seismic Control].

I. Install floor-mounted units on concrete bases [designed to withstand, without damage to equipment, the seismic force required by code].

1. Secure vibration [and seismic] controls to concrete bases using anchor bolts cast in concrete base.
2. Seismic Restraint Snubbers: Install with sufficient clearance so unit isolators are not restricted for proper free isolation, but do limit movement in all directions.

J. Connections:

1. Refer to Section [23 31 13, Metal Ducts and Accessories] [and] [23 31 16.16, Thermoset Fiberglass-Reinforced Plastic Ducts and Accessories].
2. Isolate duct connections to fans.
3. Install ductwork adjacent to fans to allow proper service and maintenance.

3.02 FIELD QUALITY CONTROL

A. Functional Tests:

1. Verify blocking and bracing used during shipping are removed.
2. Verify fan is secure on mountings and supporting devices, and connections to ducts and electrical components are complete.
3. Verify proper thermal-overload protection is installed in motors, starters, and disconnect switches.
4. Verify cleaning and adjusting are complete.
5. Disconnect fan drive from motor; verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation.
6. Reconnect fan drive system; align and adjust belts and install belt guards.
7. Verify lubrication for bearings and other moving parts.
8. Verify manual and automatic volume control and fire and smoke dampers in connected ductwork are in fully open position.

B. Performance Tests:

1. Starting Procedures:
   a. Energize motor and adjust fan to indicated revolutions per minute.
   b. Measure and record motor voltage and amperage.
2. Operational Test:

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3. After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
    a. Repair or replace malfunctioning units; retest as specified after repairs or replacement is made.
    b. Test and adjust control safeties.
    c. Replace damaged and malfunctioning controls and equipment.

3.03 MANUFACTURER'S SERVICES

A. Manufacturer's Representative: Present at site or classroom designated by [Owner,] [_____,] for minimum person-days listed below, travel time excluded:

1. [_____] person-days for [installation assistance] [and] [inspection.]
2. [_____] person-days for [functional] [and] [performance] testing and completion of Manufacturer's Certificate of Proper Installation.
3. [_____] person-days for prestartup classroom or site training.
4. [_____] person-days for facility startup.
5. [_____] person-days for post-startup training [of Owner's personnel.]
6. [Training shall not commence until an accepted detailed lesson plan for each training activity has been reviewed by [Owner] [Engineer] [_____].]

B. Refer [Section 01 43 33, Manufacturers' Field Services] [and] [Section 01 91 14, Equipment Testing and Facility Startup.]

3.04 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Adjust belt tension.

C. Lubricate bearings.

D. Balancing:

1. Perform air system balancing as specified in Section 23 05 93, Testing, Adjusting, and Balancing for HVAC.
2. Replace fan and motor sheaves as required to achieve design airflow.

E. Vibration Testing:

1. Perform field testing on rotating equipment, where specified in Section 23 05 93, Testing, Adjusting, and Balancing for HVAC, to determine actual operating vibration.

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2. If vibration limits described therein are exceeded, rebalance equipment in-place until design tolerances are met.
    a. Vibration readings as measured at actual rotational speed shall not exceed the following values:
        1) Belt Drive, Flexibility Mounted: 0.25 inch per second peak velocity.
        2) Belt Drive, Rigidly Mounted: 0.16 inch per second peak velocity.

3.05 CLEANING

A. After completing system installation, including outlet fitting and devices, inspect exposed finish. Remove burrs, dirt, and construction debris, and repair damaged finishes.

B. On completion of installation, internally clean fans according to manufacturers' written instructions. Remove foreign material and construction debris. Vacuum fan wheel and cabinet.

3.06 SUPPLEMENTS

A. The supplements listed below, following "End of Section," are a part of this Specification.

1. 23 34 00.01, Fan Schedule.
2. 23 34 00.02, Ceiling Fan Schedule.

END OF SECTION

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SECTION 23 81 00.01
SPLIT SYSTEM DX INDOOR UNITS

SYMBOL						
SERVING						
FAN DATA	SUPPLY AIR	CFM				
	OUTSIDE AIR	CFM				
	EXTERNAL STATIC PRESS.	IN W.G.				
DX COOLING DATA	NET CAPACITY	BTU/HR				
	NET SENS.	BTU/HR				
	ENTERING AIR DEG. F	DB				
	TEMP.DEG. F	WB				
	AMBIENT TEMP.	DEG. F				
DX HEATING DATA	NET TOTAL	BTU/HR				
	ENTERING AIR TEMP.	DEG. F				
	AMBIENT TEMP.	DEG. F				
ELECTRIC HEATING DATA	NET CAPACITY	kW				
	ENTERING AIR TEMP.	DEG. F				
	STEPS					
	VOLT					
	PH					
FAN MOTOR DATA	HP					
	VOLT					
	PH					
ELECTRICAL DATA	# CONN.					
	MCA					
	FUSE					
	VOLT					
	PH					
DIMENSIONS	LENGTH	INCHES				
	WIDTH	INCHES				
	HEIGHT	INCHES				
	MAXIMUM WEIGHT	LBS				

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MANUFACTURER				
MODEL NO. APPLICABLE REMARKS:				
REMARKS: A. HARD SHUTOFF TXV B. DUAL REFRIGERATION CIRCUITS C. HOT GAS REHEAT COIL D. AIR DISCHARGE PLENUM E. RETURN-AIR GRILLE F. UNIT SUBBASE G. ECONOMIZER H. OVERHEAD SUSPENSION PACKAGE I. PREMIUM ELECTRONIC THERMOSTAT J. ELECTRO-MECHANICAL THERMOSTAT				

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SECTION 26 05 02
BASIC ELECTRICAL REQUIREMENTS

PART 1 - GENERAL

1.01 RELATED SECTIONS

A. Requirements specified within this section apply to Division 26, Electrical. Work specified herein shall be performed as if specified in the individual sections.

1.02 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. National Electrical Contractors Association (NECA): National Electrical Installation Standards.
2. National Electrical Manufacturers Association (NEMA):
3. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
4. Z535.4, Product Safety Signs and Labels.
5. National Fire Protection Association (NFPA): 70, National Electrical Code (NEC).
6. Underwriters Laboratories, Inc. (UL).

1.03 ELECTRIC SERVICE DIVISION OF RESPONSIBILITY

A. Incoming aerial electrical service facilities provided by the serving utility as part of its normal obligation to customers is work provided outside this Contract. Under this Contract provide customer required service provisions and electrical work including, but not limited to, primary duct system, metering components and associated conduit,. Schedule and coordinate work of serving utility as required to provide electric service to the Work.

B. [Incoming telephone [and cable television] service facilities provided by the serving utilities as part of their normal obligation to customers is work provided outside this Contract. Under this Contract provide customer required service provisions and electrical work.]

C. [Interior telecommunications central and station equipment (telephone instruments, telephone switches, data switches, and hubs, servers, software, etc.) is work provided outside this Contract. Under this Contract provide [raceways,] [outlet and junction boxes,] [cover plates,] [pull wires,] [as indicated].]

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1.04 SUBMITTALS

A. Provide manufacturers' data for the following:

1. Electrical service components.
2. Telephone service components.
3. Nameplates, signs, and labels.

1.05 QUALITY ASSURANCE

A. Provide the Work in accordance with NFPA 70. Where required by Authority Having Jurisdiction (AHJ), material and equipment shall be labeled or listed by a nationally recognized testing laboratory or other organization acceptable to the AHJ, in order to provide a basis for approval under the NEC.

B. Materials and equipment manufactured within the scope of standards published by Underwriters Laboratories Inc. shall conform to those standards and shall have an applied UL listing mark or label.

C. Provide materials and equipment acceptable to AHJ for Class, Division, and Group of hazardous area indicated.

1.06 ENVIRONMENTAL CONDITIONS

A. The following areas are classified hazardous, Class I, Division 2, Group D, due to the potential for accumulation of hazardous concentrations of combustible gases, and for exposure to corrosive environment. Use materials and methods required for such areas.

1. MW Bench and TW Bench Equipment Buildings, as shown on the Drawings.

B. The following areas are classified nonhazardous, wet, and corrosive. Use materials and methods required for such areas.

1. Inside of wet wells.

C. The following areas are classified nonhazardous and wet. Use materials and methods required for such areas.

1. Outdoor abovegrade areas not covered above.
2. Belowgrade vaults.

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D. The following areas are classified as indoor and dry:

1. All other Building interior spaces not covered above.
2. Electrical Room.

E. The following areas are not classified. Use dust-tight and oil-tight NEMA 12 materials and methods.

1. Areas not covered above.

PART 2 - PRODUCTS

2.01 GENERAL

A. Where two or more units of the same class of material or equipment are required, provide products of a single manufacturer. Component parts of materials or equipment need not be products of the same manufacturer.

B. Material and equipment installed in heated and ventilated areas shall be capable of continuous operation at their specified ratings within an ambient temperature range of 40 degrees F to 122 degrees F.

C. Materials and equipment installed outdoors shall be capable of continuous operation at their specified rating within the ambient temperature range stated in Section 01 61 00, Common Product Requirements.

D. Equip panels installed outdoors in direct sun with sun shields.

E. Electrical ratings of materials and equipment that are reduced by increased elevation shall be derated as required for Site elevation specified in Section 01 61 00, Common Product Requirements.

2.02 EQUIPMENT FINISH

A. Manufacturer’s standard finish color, except where specific color is indicated. If manufacturer has no standard color, finish equipment in accordance with Section 09 90 00, Painting and Coating.

2.03 NAMEPLATES

A. Material: Laminated plastic.

B. Attachment Screws: Stainless steel.

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C. Color: Black, engraved to a white core.

D. Letter Height:

1. Pushbuttons/Selector Switches: 1/8 inch.
2. Other electrical equipment: 1/4 inch.

2.04 SIGNS AND LABELS

A. Sign size, lettering, and color shall be in accordance with NEMA Z535.4.

PART 3 - EXECUTION

3.01 GENERAL

A. Electrical Drawings show general locations of equipment, devices, and raceway, unless specifically dimensioned. Contractor shall be responsible for actual location of equipment and devices and for proper routing and support of raceways, subject to approval of ENGINEER.

B. Check approximate locations of light fixtures, switches, electrical outlets, equipment, and other electrical system components shown on Drawings for conflicts with openings, structural members, and components of other systems and equipment having fixed locations. In the event of conflicts, notify ENGINEER in writing.

C. Install work in accordance with NECA Standard of Installation, unless otherwise specified.

D. Keep openings in boxes and equipment closed during construction.

E. Lay out work carefully in advance. Do not cut or notch any structural member or building surface without specific approval of ENGINEER. Carefully perform cutting, channeling, chasing, or drilling of floors, walls, partitions, ceilings, paving, or other surfaces required for the installation, support, or anchorage of conduit, raceways, or other electrical materials and equipment. Following such work, restore surfaces to original condition.

3.02 ANCHORING AND MOUNTING

A. Equipment anchoring and mounting shall be in accordance with manufacturer’s requirements for seismic criteria given in Section 01 61 00, Common Product Requirements.

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3.03 COMBINING CIRCUITS INTO COMMON RACEWAY

A. Homerun circuits shown on Drawings indicate functional wiring requirements for power and control circuits. Circuits may be combined into common raceways in accordance with the following requirements:

1. Analog control circuits from devices in same general area to same destination.
    a. No power or AC discrete control circuits shall be combined in same conduit with analog circuits.
    b. No Class 2 or Class 3 circuits including, but not limited to, HVAC control circuits, fire alarm circuits, paging system circuits shall be combined with power or Class 1 circuits.
    c. Analog circuits shall be continuous from source to destination. Do not add TJB, splice, or combine into a multi-pair cable without authorization of ENGINEER. Raceways shall be sized per Conduit and Cable Schedule on Drawings and shall not exceed 40 percent fill. Conduit and Cable on Drawings shall Changes shall be documented on record drawings.
2. Discrete control circuits from devices in the same general area to the same destination.
    a. No power or analog control circuits shall be combined in same conduit with discrete circuits.
    b. No Class 2 or Class 3 circuits including, but not limited to, HVAC control circuits, fire alarm circuits, and paging system circuits shall be combined with power or Class 1 circuits.
    c. Raceways shall be sized per the Conduit and Cable Schedule on Drawings and shall not exceed 40 percent fill.
    d. Changes shall be documented on record drawings.
3. Power circuits from loads in same general area to same source location (such as: panelboard, switchboard, low voltage motor control center).
    a. Lighting Circuits: Combine no more than three circuits to a single raceway. Contractor shall be responsible for increasing conduit and conductor size if derating is required by NEC.
    b. Receptacle Circuits, 120-Volt Only: Combine no more than three circuits to a single raceway. Provide a separate neutral conductor for each circuit. Contractor shall be responsible for increasing conduit and conductor size if derating is required by NEC.
    c. All Other Power Circuits: May be combined as covered in part b above.

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3.04 NAMEPLATES, SIGNS, AND LABELS

A. Arc Flash Protection Warning Signs:

1. Field mark switchboards, motor control centers, panelboardsdisconnect switches, and combination motor starters to warn qualified persons of potential arc-flash hazards. Locate marking so to be clearly visible to persons before working on energized equipment.
2. Use arc flash hazard boundary, energy level, PPE level and description, shock hazard, bolted fault current, and equipment name [from study required in Section 26 05 70, Electrical Systems Analysis] [from ENGINEER] as basis for warning signs.

B. Multiple Power Supply Sign: Install permanent plaque or directory at each service disconnect location denoting other services, feeders, and branch circuits supplying the building, and the area served by each.

C. Equipment Nameplates:

1. Provide a nameplate to label electrical equipment including switchgear, switchboards, motor control centers, panelboards, motor starters, transformers, terminal junction boxes, disconnect switches, switches and control stations.
2. Switchgear, motor control center, transformer, and terminal junction box nameplates shall include equipment designation.
3. Disconnect switch, starter, and control station nameplates shall include name and number of equipment powered or controlled by that device.
4. Switchboard and panelboard nameplates shall include equipment designation, service voltage, and phases.

3.05 LOAD BALANCE

A. Drawings and Specifications indicate circuiting to electrical loads and distribution equipment.

B. Balance electrical load between phases as nearly as possible on switchboards, panelboards, motor control centers, and other equipment where balancing is required.

C. When loads must be reconnected to different circuits to balance phase loads, maintain accurate record of changes made, and provide circuit directory that lists final circuit arrangement.

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3.06 CLEANING AND TOUCHUP PAINTING

A. Cleaning: Throughout the Work, clean interior and exterior of devices and equipment by removing debris and vacuuming.

B. Touchup Paint:

1. Touchup scratches, scrapes and chips on exterior and interior surfaces of devices and equipment with finish matching type, color, and consistency and type of surface of original finish.
2. If extensive damage is done to equipment paint surfaces, refinish entire equipment in a manner that provides a finish equal to or better than factory finish, that meets requirements of Specification, and is acceptable to ENGINEER

3.07 PROTECTION FOLLOWING INSTALLATION

A. Protect materials and equipment from corrosion, physical damage, and effects of moisture on insulation and contact surfaces.

B. When equipment intended for indoor installation is installed at Contractor’s convenience in areas where subject to dampness, moisture, dirt or other adverse atmosphere until completion of construction, ensure adequate protection from these atmospheres is provided and acceptable to ENGINEER.

END OF SECTION

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SECTION 26 05 04
BASIC ELECTRICAL MATERIALS AND METHODS

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM):
   a. A167, Standard Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip.
   b. A1011/A1011M, Standard Specification for Steel, Sheet, and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low Alloy and High-Strength Low Alloy Formability.
   c. E814, Method of Fire Tests of Through-Penetration Fire Stops.
2. Canadian Standards Association (CSA).
3. International Society of Automation (ISA): RP12.06.01, Wiring Practices for Hazardous (Classified) Locations Instrumentation–Part 1: Intrinsic Safety.
4. National Electrical Manufacturers Association (NEMA):
   a. 250, Enclosures for Electrical Equipment (1,000 Volts Maximum).
   b. AB 1, Molded Case Circuit Breakers, Molded Case Switches, and Circuit-Breaker Enclosures.
   c. C12.1 Code for Electricity Metering.
   d. C12.6 Phase-Shifting Devices Used in Metering, Marking and Arrangement of, Terminals for.
   e. CP 1, Shunt Capacitors.
   f. ICS 2, Industrial Control and Systems: Controllers, Contactors, and Overload Relays Rated 600 Volts.
   g. ICS 5, Industrial Control and Systems: Control Circuit and Pilot Devices.
   h. KS 1, Enclosed and Miscellaneous Distribution Switches (600 Volts Maximum).
5. National Fire Protection Association (NFPA): 70, National Electrical Code (NEC).
6. Underwriters Laboratories Inc. (UL):
   a. 98, Standard for Enclosed and Dead-Front Switches.
   b. 248, Standard for Low Voltage Fuses.
   c. 486E, Standard for Equipment Wiring Terminals for use with Aluminum and/or Copper Conductors.

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d. 489, Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit Breaker Enclosures.
e. 508, Standard for Industrial Control Equipment.
f. 810, Standard for Capacitors.
g. 943, Standard for Ground-Fault Circuit-Interrupters.
h. 1059, Standard for Terminal Blocks.
i. 1479, Fire Tests of Through-Penetration Fire Stops.

1.02 SUBMITTALS

A. Action Submittals:

1. Provide manufacturers' data for the following:
   a. Control devices.
   b. Control relays.
   c. Circuit breakers.
   d. Fused switches.
   e. Nonfused switches.
   f. Timers.
   g. Fuses.
   h. Magnetic contactors.
   i. Intrinsic safety barriers.
   j. Firestopping.
   k. Enclosures: Include enclosure data for products having enclosures.
2. Seismic anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Seismic Anchorage and Bracing.

B. Informational Submittals: Seismic anchorage and bracing calculations as required by Section 01 88 15, Seismic Anchorage and Bracing.

1.03 EXTRA MATERIALS

A. Furnish, tag, and box for shipment and storage the following spare parts and special tools:

1. Fuses, 0 to 600 Volts: Six of each type and each current rating installed.

PART 2 - PRODUCTS

2.01 MOLDED CASE CIRCUIT BREAKER THERMAL MAGNETIC, LOW VOLTAGE

A. General:

1. Type: Molded case.

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2. Trip Ratings: 15-800 amps.
3. Voltage Ratings: 120, 240, 277, 480, and 600V ac.
4. Suitable for mounting and operating in any position.
5. NEMA AB 1 and UL 489.

B. Operating Mechanism:

1. Overcenter, trip-free, toggle type handle.
2. Quick-make, quick-break action.
3. Locking provisions for padlocking breaker in open position.
4. ON/OFF and TRIPPED indicating positions of operating handle.
5. Operating handle to assume a center position when tripped.

C. Trip Mechanism:

1. Individual permanent thermal and magnetic trip elements in each pole.
2. Variable magnetic trip elements with a single continuous adjustment 3X to 10X for frames greater than 100 amps.
3. Two and three pole, common trip.
4. Automatically opens all poles when overcurrent occurs on one pole.
5. Test button on cover.
6. Calibrated for 50 degrees C ambient, unless shown otherwise.
7. Do not provide single-pole circuit breakers with handle ties where multi-pole circuit breakers are shown.

D. Short Circuit Interrupting Ratings:

1. [Not less than the following RMS symmetrical currents for the indicated trip ratings:
   a. Up to 100A, less than 250V ac: As shown.
   b. Up to 100A, 250-600V ac: As shown.
   c. Over 100A: As shown.
2. Series Connected Ratings: Do not apply series connected short circuit ratings.

E. Ground Fault Circuit Interrupter (GFCI): Where indicated, equip breaker as specified above with ground fault sensor and rated to trip on 5-mA ground fault within 0.025 second (UL 943, Class A sensitivity, for protection of personnel).

1. Ground fault sensor shall be rated same as circuit breaker.
2. Push-to-test button.

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F. Equipment Ground Fault Interrupter (EGFI): Where indicated, equip breaker specified above with ground fault sensor and rated to trip on 30-mA ground fault (UL-listed for equipment ground fault protection).

G. Magnetic Only Type Breakers: Where shown; instantaneous trip adjustment which simultaneously sets magnetic trip level of each individual pole continuously through a 3X to 10X trip range.

H. Accessories: Shunt trip, auxiliary switches, handle lock ON devices, mechanical interlocks, key interlocks, unit mounting bases, double lugs as shown or otherwise required. Shunt trip operators shall be continuous duty rated or have coil-clearing contacts.

I. Connections:

1. Supply (line side) at either end.
2. Mechanical wire lugs, except crimp compression lugs where shown.
3. Lugs removable/replaceable for breaker frames greater than 100 amperes.
4. Suitable for 75 degrees C rated conductors without derating breaker or conductor ampacity.
5. Use bolted bus connections, except where bolt-on is not compatible with existing breaker provisions.

J. Enclosures for Independent Mounting:

1. See Article Enclosures.
2. Service Entrance Use: Breakers in required enclosure and required accessories shall be UL 489 listed.
3. Interlock: Enclosure and switch shall interlock to prevent opening cover with switch in the ON position. Provide bypass feature for use by qualified personnel.

2.02 FUSED SWITCH, INDIVIDUAL, LOW VOLTAGE

A. UL 98 listed for use and location of installation.

B. NEMA KS 1.

C. Short Circuit Rating: 200,000 amps RMS symmetrical with Class R, Class J, or Class L fuses installed.

D. Quick-make, quick-break, motor rated, load-break, heavy-duty (HD) type with external markings clearly indicating ON/OFF positions.

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E. Connections:

1. Mechanical lugs, except crimp compression lugs where shown.
2. Lugs removable/replaceable.
3. Suitable for 75 degrees C rated conductors at NEC 75 degrees C ampacity.

F. Fuse Provisions:

1. 30-amp to 600-amp rated shall incorporate rejection feature to reject all fuses except Class R.
2. 601-amp rated and greater shall accept Class L fuses, unless otherwise shown.

B. Enclosures: See Article Enclosures.

C. Interlock: Enclosure and switch to prevent opening cover with switch in ON position. Provide bypass feature for use by qualified personnel.

2.03 NONFUSED SWITCH, INDIVIDUAL, LOW VOLTAGE

A. NEMA KS 1.

B. Quick-make, quick-break, motor rated, load-break, heavy-duty (HD) type with external markings clearly indicating ON/OFF positions.

C. Lugs: Suitable for use with 75 degrees C wire at NEC 75 degrees C ampacity.

D. Enclosures: See Article Enclosures.

E. Interlock: Enclosure and switch to prevent opening cover with switch in ON position. Provide bypass feature for use by qualified personnel.

2.04 FUSE, 250-VOLT AND 600-VOLT

A. Power Distribution, General:

1. Current-limiting, with 200,000 ampere rms interrupting rating.
2. Provide to fit mountings specified with switches.
3. UL 248.

B. Power Distribution, Ampere Ratings 1 Amp to 600 Amps:

1. Class: RK-1.
2. Type: Dual element, with time delay.

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3. Manufacturers and Products:
   a. Bussmann; Types LPS-RK (600 volts) and LPN-RK (250 volts).
   b. Littelfuse; Types LLS-RK (600 volts) and LLN-RK (250 volts).

C. Power Distribution, Ampere Ratings 601 Amps to 6,000 Amps:

1. Class: L.
2. Double O-rings and silver links.
3. Manufacturers and Products:
   a. Bussmann; Type KRP-C.
   b. Littelfuse, Inc.; Type KLPC.

D. Cable Limiters:

1. 600V or less; crimp to copper cable, bolt to bus or terminal pad.
2. Manufacturer and Product: Bussmann; K Series.

E. Ferrule:

1. 600V or less, rated for applied voltage, small dimension.
2. Ampere Ratings: 1/10 amp to 30 amps.
3. Dual-element time-delay, time-delay, or nontime-delay as required.
4. Provide with blocks or holders as indicated and suitable for location and use.
5. Manufacturers:
   a. Bussmann.
   b. Littlefuse, Inc.

2.05 PUSHBUTTON, INDICATING LIGHT, AND SELECTOR SWITCH

A. Contact Rating: 7,200VA make, 720VA break, at 600V, NEMA ICS 5 Designation A600.

B. Selector Switch Operating Lever: Standard.

C. Indicating Light: Push-to-test. LED, full voltage.

D. Pushbutton Color:

1. ON or START: Black.
2. OFF or STOP: Red.

E. Pushbutton and selector switch lockable in OFF position where indicated.

F. Legend Plate:

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1. Material: Aluminum.
2. Engraving: Enamel filled in high contrasting color.
3. Text Arrangement: 11-character/spaces on one line, 14-character/spaces on each of two lines, as required, indicating specific function.
4. Letter Height: 7/64-inch.

G. Manufacturers and Products:

1. Heavy-Duty, Oil-Tight Type:
   a. General Electric Co.; Type CR 104P.
   b. Square D Co.; Type T.
   c. Eaton/Cutler-Hammer; Type 10250T.
2. Heavy-Duty, Watertight, and Corrosion-Resistant Type:
   a. Square D Co.; Type SK.
   b. General Electric Co.; Type CR 104P.
   c. Eaton/Cutler-Hammer; Type E34.
   d. Crouse-Hinds; Type NCS.

2.06 TERMINAL BLOCK, 600 VOLTS

A. UL 486E and UL 1059.

B. Size components to allow insertion of necessary wire sizes.

C. Capable of termination of control circuits entering or leaving equipment, panels, or boxes.

D. Screw clamp compression, dead front barrier type, with current bar providing direct contact with wire between compression screw and yoke.

E. Yoke, current bar, and clamping screw of high strength and high conductivity metal.

F. Yoke shall guide all strands of wire into terminal.

G. Current bar shall ensure vibration-proof connection.

H. Terminals:

1. Capable of wire connections without special preparation other than stripping.
2. Capable of jumper installation with no loss of terminal or rail space.
3. Individual, rail mounted.

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I. Marking system, allowing use of preprinted or field-marked tags.

J. Manufacturers:

1. Weidmuller, Inc.
2. Ideal.
3. Electrovert USA Corp.

2.07 MAGNETIC CONTROL RELAY

A. Industrial control with field convertible contacts rated 10 amps continuous, 7,200VA make, 720VA break.

B. NEMA ICS 2, Designation: A300 (300 volts).

C. Time Delay Relay Attachment:

1. Pneumatic type, timer adjustable from 0.2 second to 60 seconds (minimum).
2. Field convertible from ON delay to OFF delay and vice versa.

D. Latching Attachment: Mechanical latch, having unlatching coil and coil clearing contacts.

E. Manufacturers and Products:

1. Eaton/Cutler-Hammer; Type M-300.
2. General Electric Co.; Type CR120A.

2.08 TIME DELAY RELAY

A. Industrial relay with contacts rated 5 amps continuous, 3,600VA make, 360VA break.

B. NEMA ICS 2 Designation: B150 (150 volts).

C. Solid-state electronic, field convertible ON/OFF delay.

D. One normally open and one normally closed contact (minimum).

E. Repeat accuracy plus or minus 2 percent.

F. Timer adjustment from 1 second to 60 seconds, unless otherwise indicated on Drawings.

G. Manufacturers and Products:

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1. Square D Co.; Type F.
2. Eaton/Cutler-Hammer.
3. General Electric Co.

2.09 RESET TIMER

A. Drive: Synchronous motor, solenoid-operated clutch.

B. Mounting: Semiflush panel.

C. Contacts: 10 amps, 120 volts.

D. Manufacturers and Products:

1. Eagle Signal Controls; Bulletin 125.
2. Automatic Timing and Controls; Bulletin 305.

2.10 ELAPSED TIME METER

A. Drive: Synchronous motor.

B. Range: 0 hour to 99,999.9 hours, nonreset type.

C. Mounting: Semiflush panel.

D. Manufacturers and Products:

1. General Electric Co.; Type 240, 2-1/2-inch Big Look.
2. Eagle Signal Controls; Bulletin 705.

2.11 MAGNETIC CONTACTOR

A. UL listed.

B. Electrically operated, electrically held.

C. Main Contacts:

1. Power driven in one direction with mechanical spring dropout.
2. Silver alloy with wiping action and arc quenchers.
3. Continuous-duty, rated As shown.
4. Poles: As shown.

D. Control: As shown.

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E. Auxiliary Contacts: One normally open and one normally closed, rated 7200VA make, 720VA break, at 600V, A600 per NEMA ICS 5.

F. Enclosures: See Article Enclosures.

G. Manufacturers and Products:

1. Eaton/Cutler-Hammer; Class A201.
2. General Electric Co.; CR 353.
3. Square D Co.; Class 8910.

2.12 PHASE MONITOR RELAY

A. Features:

1. Voltage and phase monitor relay shall drop out on low voltage, voltage unbalance, loss of phase, or phase reversal.
2. Contacts: Single-pole, double-throw, 10 amperes, 120/240V ac. Where additional contacts are shown or required, provide magnetic control relays.
3. Adjustable trip and time delay settings.
4. Transient Protection: 1,000V ac.
5. Mounting: Multipin plug-in socket base.

B. Manufacturer and Product: Automatic Timing and Controls; SLD Series.

2.13 SUPPORT AND FRAMING CHANNELS

A. Carbon Steel Framing Channel:

1. Material: Rolled, mild strip steel, 12-gauge minimum, ASTM A1011/A1011M, Grade 33.
2. Finish: Hot-dip galvanized after fabrication.

B. Paint Coated Framing Channel: Carbon steel framing channel with electro-deposited rust inhibiting acrylic or epoxy paint.

C. PVC Coated Framing Channel: Carbon steel framing channel with 40-mil polyvinyl chloride coating.

D. Stainless Steel Framing Channel: Rolled, ASTM A167, Type 316 stainless steel, 12-gauge minimum.

E. Extruded Aluminum Framing Channel:

1. Material: Extruded from Type 6063-T6 aluminum alloy.

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2. Fittings fabricated from Alloy 5052-H32.

F. Nonmetallic Framing Channel:

1. Material: Fire retardant, fiber reinforced vinyl ester resin.
2. Channel fitting of same material as channel.
3. Nuts and bolts of long glass fiber reinforced polyurethane.

G. Manufacturers:

1. B-Line Systems, Inc.
2. Unistrut Corp.
3. Aickinstrut.

2.14 INTRINSIC SAFETY BARRIER

A. Provides a safe energy level for exposed wiring in a Class I, Division 1 or Division 2 hazardous area when circuit is connected to power source in nonhazardous area.

B. Rating: Power source shall be rated 24 volts dc, nominal, with not more than 250 volts available under fault conditions.

C. Contact Rating: 5 amps, 250 volts ac.

D. Mounting: Rail or surface.

E. Manufacturers and Products:

1. MTL, Inc.; Series 2000 or Series 3000.
2. R. Stahl, Inc.

2.15 SWITCHBOARD MATTING

A. Provide matting having a breakdown of 20 kV minimum.

B. Manufacturer: U.S. Mat and Rubber Company.

2.16 FIRESTOPS

A. General:

1. Provide UL 1479 classified hourly fire-rating equal to, or greater than, the assembly penetrated.

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2. Prevent the passage of cold smoke, toxic fumes, and water before and after exposure to flame.
3. Sealants and accessories shall have fire-resistance ratings as established by testing identical assemblies in accordance with ASTM E814, by Underwriters Laboratories Inc., or other testing and inspection agency acceptable to authorities having jurisdiction.

B. Comply with Section 07 84 00, Firestopping.

C. Firestop System:

1. Formulated for use in through-penetration firestopping around cables, conduit, pipes, and duct penetrations through fire-rated walls and floors.
2. Fill, Void, or Cavity Material: 3M Brand Fire Barrier Caulk CP25, Putty 303, Wrap/Strip FS195, Composite Sheet CS195 and Penetration Sealing Systems 7902 and 7904 Series.
3. Two-Part, Foamed-In-Place, Silicone Sealant: Dow Corning Corp. Fire Stop Foam, General Electric Co. Pensil 851.
4. Fire Stop Devices: See Section 26 05 33, Raceway and Boxes, for raceway and cable fittings.

2.17 ENCLOSURES

A. Finish: Sheet metal structural and enclosure parts shall be completely painted using an electrodeposition process so interior and exterior surfaces as well as bolted structural joints have a complete finish coat on and between them.

B. Color: Manufacturer’s standard color (gray) baked-on enamel, unless otherwise shown.

C. Barriers: Provide metal barriers within enclosures to separate wiring of different systems and voltage.

D. Enclosure Selections: Except as shown otherwise, provide electrical enclosures according to the following table:

Enclosures			
Location	**Finish**	**Environment**	**NEMA 250 Type**
Indoor	Finished	Dry	1
Indoor	Unfinished	Dry	1
Indoor	Unfinished	Industrial Use	12

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Enclosures			
Location	**Finish**	**Environment**	**NEMA 250 Type**
Indoor and Outdoor	Any	Wet	4
Indoor and Outdoor	Any	Denoted "WP"	3R
Indoor and Outdoor	Any	Wet and Corrosive	4X 316 Stainless Steel
Indoor and Outdoor	Any	Wet, Dust or Oil	13
Indoor and Outdoor	Any	Hazardous Gas	7
Indoor and Outdoor	Any	Hazardous Dust	9

PART 3 - EXECUTION

3.01 GENERAL

A. Install equipment in accordance with manufacturer's recommendations.

3.02 PUSHBUTTON, INDICATING LIGHT, AND SELECTOR SWITCH

A. Unless otherwise shown, install heavy-duty, oil-tight type in nonhazardous, indoor, dry locations, including motor control centers, control panels, and individual stations.

B. Unless otherwise shown, install heavy-duty, watertight and corrosion-resistant type in nonhazardous, outdoor, or normally wet areas.

3.03 SUPPORT AND FRAMING CHANNEL

A. Install where required for mounting and supporting electrical equipment, raceway, and cable tray systems.

B. Channel Type:

1. Interior, Wet or Dry (Noncorrosive) Locations:
   a. Aluminum Raceway: Extruded aluminum.
   b. PVC-Coated Conduit: PVC coated.

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c. Steel Raceway and Other Systems Not Covered: Carbon steel or paint coated.

2. Interior, Corrosive (Wet or Dry) Locations:
   a. Aluminum Raceway: Extruded aluminum.
   b. PVC Conduit: Type 316 stainless steel or nonmetallic.
   c. PVC-Coated Steel Conduit and Other Systems Not Covered: Type 316 stainless steel, nonmetallic, or PVC-coated steel.
3. Outdoor, Noncorrosive Locations:
   a. Steel Raceway: Carbon steel or paint coated framing channel, except where mounted on aluminum handrail, then use aluminum framing channel.
   b. Aluminum Raceway and Other Systems Not Covered: Aluminum framing channel.
4. Outdoor Corrosive Locations:
   a. PVC Conduit: Type 316 stainless steel or nonmetallic.
   b. Aluminum Raceway: Aluminum.
   c. PVC-Coated Steel Conduit and Other Systems Not Covered: Type 316 stainless steel, nonmetallic, or PVC coated steel.

C. Paint cut ends prior to installation with the following:

1. Carbon Steel Channel: Zinc-rich primer.
2. Painted Channel: Rust-inhibiting epoxy or acrylic paint.
3. Nonmetallic Channel: Epoxy resin sealer.
4. PVC-Coated Channel: PVC patch.

3.04 INTRINSIC SAFETY BARRIERS

A. Install in compliance with ISA RP12.06.01.

B. Arrange conductors such that wiring from hazardous areas cannot short to wiring from nonhazardous area.

C. Stencil “INTRINSICALLY SAFE CIRCUIT” on all boxes enclosing barriers.

3.05 SWITCHBOARD MATTING

A. Install 36-inch width at switchgear, switchboard, motor control centers, and panelboards.

B. Matting shall run full length of all sides of equipment that have operator controls or afford access to devices.

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3.06 FIRESTOPS

A. Install in strict conformance with manufacturer's instructions. Comply with installation requirements established by testing and inspecting agency.

B. Sealant: Install sealant, including forming, packing, and other accessory materials, to fill openings around electrical services penetrating floors and walls, to provide firestops with fire-resistance ratings indicated for floor or wall assembly in which penetration occurs.

END OF SECTION

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SECTION 26 05 05
CONDUCTORS

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. Association of Edison Illuminating Companies (AEIC): CS 8, Specification for Extruded Dielectric Shielded Power Cables Rated 5 kV through 46 kV.
2. ASTM International (ASTM):
   a. A167, Standard Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip.
   b. B3, Standard Specification for Soft or Annealed Copper Wire.
   c. B8, Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft.
   d. B496, Standard Specification for Compact Round Concentric-Lay-Stranded Copper Conductors.
3. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
   a. 48, Standard Test Procedures and Requirements for Alternating-Current Cable Terminations Used on Shielded Cables Having Laminated Insulation Rated 2.5 kV through 765 kV or Extruded Insulation Rated 2.5 kV Through 500 kV.
   b. 386, Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600V.
   c. 404, Standard for Extruded and Laminated Dielectric Shielded Cable Joints Rated 2500 V to 500000 V.
4. Insulated Cable Engineer's Association, Inc. (ICEA):
   a. S-58-679, Standard for Control Cable Conductor Identification.
   b. S-73-532, Standard for Control Thermocouple Extensions and Instrumentation Cables.
   c. T-29-520, Conducting Vertical Cable Tray Flame Tests with Theoretical Heat Input of 210,000 Btu/hour.
5. National Electrical Manufacturers' Association (NEMA):
   a. CC 1, Electric Power Connectors for Substations.
   b. WC 57, Standard for Control, Thermocouple Extension, and Instrumentation Cables.
   c. WC 70, Standard for Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy.

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d. WC 71, Standard for Nonshielded Cables Rated 2001-5000 Volts for Use in the Distribution of Electric Energy.
e. WC 74, 5-46 kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy.

6. National Fire Protection Association (NFPA):
   a. 70, National Electrical Code (NEC).
   b. 262, Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces.
7. Telecommunications Industry Association (TIA): TIA-568-C, Commercial Building Telecommunications Cabling Standard.
8. Underwriters Laboratories Inc. (UL):
   a. 13, Standard for Safety for Power-Limited Circuit Cables.
   b. 44, Standard for Safety for Thermoset-Insulated Wires and Cables.
   c. 62, Standard for Safety for Flexible Cord and Cables.
   d. 486A-486B, Standard for Safety for Wire Connectors.
   e. 486C, Standard for Safety for Splicing Wire Connectors.
   f. 510, Standard for Safety for Polyvinyl Chloride, Polyethylene, and Rubber Insulating Tape.
   g. 854, Standard for Safety for Service-Entrance Cables.
   h. 1072, Standard for Safety for Medium-Voltage Power Cables.
   i. 1277, Standard for Safety for Electrical Power and Control Tray Cables with Optional Optical-Fiber Members.
   j. 1569, Standard for Safety for Metal-Clad Cables.
   k. 1581, Standard for Safety for Reference Standard for Electrical Wires, Cables, and Flexible Cords.

1.02 SUBMITTALS

A. Action Submittals:

1. Product Data:
   a. Wire and cable.
   b. Wire and cable accessories.
   c. Cable fault detection system.
2. Manufactured Wire Systems:
   a. Product data.
   b. Rating information.
   c. Dimensional drawings.
   d. Special fittings.
3. Busway:
   a. Product data.
   b. Rating information.

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c. Dimensional drawings.
d. Special fitting.
e. Equipment interface information for equipment to be connected to busways.

4. Cable Pulling Calculations:
   a. Ensure submitted and reviewed before cable installation.
   b. Provide for the following cable installations:
      1) Medium voltage cable runs that cannot be hand pulled.
      2) Multiconductor 600-volt cable sizes larger than 2 AWG that cannot be hand pulled.
      3) Power and control conductor, and control and instrumentation cable installations in ductbanks.
      4) Feeder circuits; single conductors #4/0 and larger.

B. Informational Submittals:

1. Certified Factory Test Report for conductors 600 volts and below.
2. Certified Factory Test Report per AEIC CS 8, including AEIC qualification report for conductors above 600 volts.

1.03 QUALITY ASSURANCE

A. Authority Having Jurisdiction (AHJ):

1. Provide the Work in accordance with NFPA 70. Where required by the AHJ, material and equipment shall be labeled or listed by a nationally recognized testing laboratory or other organization acceptable to the AHJ in order to provide a basis for approval under NEC.
2. Materials and equipment manufactured within the scope of standards published by Underwriters Laboratories Inc. shall conform to those standards and shall have an applied UL listing mark.

B. Terminations and Splices for Conductors above 600 Volts: Work shall be done by journeyman lineman with splicing credentials or electrician certified to use materials approved for cable splices and terminations.

PART 2 - PRODUCTS

2.01 CONDUCTORS 600 VOLTS AND BELOW

A. Conform to applicable requirements of NEMA WC 70.

B. Conductor Type:

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1. 120-Volt and 277-Volt Lighting, 10 AWG and Smaller: Solid copper.
2. 120-Volt Receptacle Circuits, 10 AWG and Smaller: Solid copper.
3. All Other Circuits: Stranded copper.

C. Insulation: Type THHN/THWN-2, except for sizes No. 6 and larger, with XHHW-2 insulation.

D. Direct Burial and Aerial Conductors and Cables:

1. Type USE/RHH/RHW insulation, UL 854 listed, or Type RHW-2/USE-2.
2. Conform to physical and minimum thickness requirements of NEMA WC 70.

E. Flexible Cords and Cables:

1. Type SOW-A/50 with ethylene propylene rubber insulation in accordance with UL 62.
2. Conform to physical and minimum thickness requirements of NEMA WC 70.

2.02 CONDUCTORS ABOVE 600 VOLTS

A. EPR Insulated Cable:

1. Extrusion: Single-pass, triple-tandem, of conductor screen, insulation, and insulation screen.
2. Type: [5] [8] [15] kV, [shielded,] [nonshielded,] UL 1072, Type MV-105.
3. Conductors: [Copper,] [Aluminum,] concentric lay Class B round stranded in accordance with ASTM B3, ASTM B8, and ASTM B496.
4. [Strand Fill: Waterproof strand compound enclosing conductors.]
5. Conductor Screen: Extruded, semiconducting ethylene-propylene rubber in accordance with NEMA WC 71 and AEIC CS 8.
6. Insulation: 133 percent insulation level, ethylene-propylene rubber (EPR) containing no polyethylene, in accordance with NEMA WC 71, and AEIC CS 8.
7. Insulation Thickness: [115-mil, 5 kV,] [140-mil, 8 kV,] [220-mil, 15 kV,] nominal.
8. Insulation Screen: Thermosetting, semiconducting ethylene-propylene rubber (EPR), extruded directly over insulation in accordance with NEMA WC 74 and AEIC CS 8.
9. Metallic Shield: Uncoated, 5-mil, copper shielding tape, helically applied with [12-1/2] [17-1/2] percent minimum overlap.

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10. Jacket: Extruded [polyvinyl chloride (PVC)] [neoprene (polychloroprene)] [hypalon (chlorosulfonated polyethylene)] [chlorinated polyethylene (CPE)] compound applied in accordance with NEMA WC 71 or NEMA WC 74.
11. Operating Temperature: 105 degrees C continuous normal operations, 130 degrees C emergency operating conditions, and 250 degrees C short-circuit conditions.
12. Manufacturers:
    a. Okonite Co.
    b. Pirelli Wire and Cable.
    c. General Cable.
    d. Southwire Co.

B. TR-XLP Insulated Cable:

1. Extrusion: Single-pass, triple-tandem, of conductor screen, insulation, and insulation screen.
2. Type: [5] [8] [15] kV, [shielded,] [nonshielded,] UL 1072, Type MV 105.
3. Conductors: [Copper,] [Aluminum,] concentric lay Class B round stranded in accordance with ASTM B3, ASTM B8, and ASTM B496.
4. Strand Fill: Waterproof strand compound enclosing conductors.
5. Conductor Screen: Extruded, semiconducting thermosetting compound in accordance with NEMA WC 71 and AEIC CS 8.
6. Insulation: 133 percent insulation level, thermosetting, tree-resistant, cross-link polyethylene (TR-XLP), in accordance with NEMA WC 71 and AEIC CS 8.
7. Insulation Thickness: [115-mil, 5 kV,] [140-mil, 8 kV,] [220-mil, 15 kV,] nominal.
8. Insulation Screen: Thermosetting, semiconducting cross-link polyethylene, extruded directly over insulation.
9. Metallic Shield: [Coated, 5-mil, copper shielding tape, helically applied with [12-1/2] [17-1/2] percent minimum overlap.] [Concentric serve of 24 AWG solid bare copper wires with overlapping binder tape.]
10. Jacket: Extruded [polyvinyl chloride (PVC)] [neoprene (polychloroprene)] [hypalon (chlorosulfonated polyethylene)] [chlorinated polyethylene (CPE)] compound applied in accordance with NEMA WC 71 or NEMA WC 74 and AEIC CS 8.
11. Operating Temperature: 105 degrees C continuous normal operations, 130 degrees C emergency operating conditions, and 250 degrees C short-circuit conditions.
12. Manufacturers:
    a. Okonite Co.
    b. Pirelli Wire and Cable.

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c. General Cable.
d. Southwire Co.

2.03 600-VOLT RATED CABLE

A. General:

1. Type TC, meeting requirements of UL 1277, including Vertical Tray Flame Test at 70,000 Btu per hour, and NFPA 70, Article 340, or UL 13 meeting requirements of NFPA 70, Article 725.
2. Permanently and legibly marked with manufacturer's name, maximum working voltage for which cable was tested, type of cable, and UL listing mark.
3. Suitable for installation in open air, in cable trays, or conduit.
4. Minimum Temperature Rating: 90 degrees C dry locations, 75 degrees C wet locations.
5. Overall Outer Jacket: PVC, flame-retardant, sunlight- and oil-resistant.

B. Type 1, Multiconductor Control Cable:

1. Conductors:
   a. 14 AWG, seven-strand copper.
   b. Insulation: 15-mil PVC with 4-mil nylon.
   c. UL 1581 listed as Type THHN/THWN rated VW-1.
   d. Conductor group bound with spiral wrap of barrier tape.
   e. Color Code: In accordance with ICEA S-58-679, Method 1, Table 2.
2. Cable: Passes the ICEA T-29-520, 210,000 Btu per hour Vertical Tray Flame Test.
3. Cable Sizes:

No. of Conductors	Max. Outside Diameter (Inches)	Jacket Thickness (Mils)
3	0.41	45
5	0.48	45
7	0.52	45
12	0.72	60
19	0.83	60
25	1.00	60
37	1.15	80

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4. Manufacturers:
   a. Okonite Co.
   b. Southwire.

C. Type 2, Multiconductor Power Cable:

1. General:
   a. Meet or exceed UL 1581 for cable tray use.
   b. Meet or exceed UL 1277 for direct burial and sunlight-resistance.
   c. Overall Jacket: PVC.
2. Conductors:
   a. Class B stranded, coated copper.
   b. Insulation: Chemically cross-linked ethylene-propylene or cross-linked polyethylene.
   c. UL rated VW-1 or listed Type XHHW-2.
   d. Color Code:
      1) Conductors, size 8 AWG and smaller, colored conductors, ICEA S-58-679, Method 1, Table 1.
      2) Conductors, size 6 AWG and larger, ICEA S-73-532, Method 4.
3. Cable shall pass ICEA T-29-520, 210,000 Btu per hour Vertical Tray Flame Test.
4. Cable Sizes:

Conductor Size	Minimum Ground Wire Size	No. of Current Carrying Conductors	Max. Outside Diameter (Inches)	Nominal Jacket Thickness (Mils)
12	12	2 3 4	0.42 0.45 0.49	45
10	10	2 3 4	0.54 0.58 0.63	60
8	10	3 4	0.66 0.75	60
6	8	3 4	0.74 0.88	60
4	6	3 4	0.88 1.04	60 80

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Conductor Size	Minimum Ground Wire Size	No. of Current Carrying Conductors	Max. Outside Diameter (Inches)	Nominal Jacket Thickness (Mils)
2	6	3 4	1.01 1.16	80
1	6	3 4	1.10 1.25	80
1/0	6	3 4	1.22 1.35	80
2/0	4	3 4	1.32 1.53	80
3/0	4	3 4	1.40 1.60	80
4/0	4	3 4	1.56 1.78	80 110

5. Manufacturers:
   a. Okonite Co.
   b. Southwire.

D. Type 3, 16 AWG, Twisted, Shielded Pair, Instrumentation Cable: Single pair, designed for noise rejection for process control, computer, or data log applications meeting NEMA WC 57 requirements.

1. Outer Jacket: 45-mil nominal thickness.
2. Individual Pair Shield: 1.35-mil, double-faced aluminum/synthetic polymer overlapped to provide 100 percent coverage.
3. Dimension: 0.31-inch nominal OD.
4. Conductors:
   a. Bare soft annealed copper, Class B, seven-strand concentric, meeting requirements of ASTM B8.
   b. 20 AWG, seven-strand tinned copper drain wire.
   c. Insulation: 15-mil nominal PVC.
   d. Jacket: 4-mil nominal nylon.
   e. Color Code: Pair conductors, black and red.
5. Manufacturers:
   a. Okonite Co.

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b. Alpha Wire Corp.
c. Belden.

E. Type 4, 16 AWG, Twisted, Shielded Triad Instrumentation Cable: Single triad, designed for noise rejection for process control, computer, or data log applications meeting NEMA WC 57 requirements.

1. Outer Jacket: 45-mil nominal.
2. Individual Pair Shield: 1.35-mil, double-faced aluminum/synthetic polymer, overlapped to provide 100 percent coverage.
3. Dimension: 0.32-inch nominal OD.
4. Conductors:
   a. Bare soft annealed copper, Class B, seven-strand concentric, meeting requirements of ASTM B8.
   b. 20 AWG, seven-strand, tinned copper drain wire.
   c. Insulation: 15-mil nominal PVC.
   d. Jacket: 4-mil nylon.
   e. Color Code: Triad conductors black, red, and blue.
5. Manufacturers:
   a. Okonite Co.
   b. Alpha Wire Corp.
   c. Belden.

F. Type 5, 18 AWG, Multitwisted Shielded Pairs, with a Common Overall Shield, Instrumentation Cable: Designed for use as instrumentation, process control, and computer cable, meeting NEMA WC 57 requirements.

1. Conductors:
   a. Bare soft annealed copper, Class B, seven-strand concentric, in accordance with ASTM B8.
   b. Tinned copper drain wires.
   c. Pair drain wire size AWG 20, group drain wire size AWG 18.
   d. Insulation: 15-mil PVC.
   e. Jacket: 4-mil nylon.
   f. Color Code: Pair conductors, black and red with red conductor numerically printed for group identification.
   g. Individual Pair Shield: 1.35-mil, double-faced aluminum/synthetic polymer.
2. Cable Shield: 2.35-mil, double-faced aluminum/synthetic polymer, overlapped for 100 percent coverage.
3. Cable Sizes:

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Number of Pairs	Maximum Outside Diameter (Inches)	Nominal Jacket Thickness (Mils)
4	0.50	45
8	0.68	60
12	0.82	60
16	0.95	80
24	1.16	80
36	1.33	80
50	1.56	80

4. Manufacturers:
   a. Okonite Co.
   b. Alpha Wire Corp.
   c. Belden.

G. Type 6, 18 AWG, Multitwisted Pairs with Common Overall Shield Instrumentation Cable: Designed for use as instrumentation, process control, and computer cable meeting NEMA WC 57.

1. Conductors:
   a. Bare soft annealed copper, Class B, seven-strand concentric, in accordance with ASTM B8.
   b. Tinned copper drain wire size AWG 18.
   c. Insulation: 15-mil nominal PVC.
   d. Jacket: 4-mil nylon.
   e. Color Code: Pair conductors, black and red with red conductor numerically printed for group identification.
2. Cable Shield: 2.35-mil, double-faced aluminum/synthetic polymer, overlapped for 100 percent coverage.

Cable Sizes: Number of Pairs	Maximum Outside Diameter (Inches)	Nominal Jacket Thickness (Mils)
4	0.48	45
8	0.63	60
12	0.75	60

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Cable Sizes: Number of Pairs	Maximum Outside Diameter (Inches)	Nominal Jacket Thickness (Mils)
16	0.83	60
24	1.10	80
36	1.21	80
50	1.50	80

1. Manufacturers:
   a. Okonite Co.
   b. Alpha Wire Corp.
   c. Belden.

2.04 300-VOLT RATED CABLE

A. General:

1. Type PLTC, meeting requirements of UL 13 and NFPA 70, Article 725.
2. Permanently and legibly marked with manufacturer's name, maximum working voltage for which cable was tested, type of cable, and UL listing mark.
3. Suitable for installation in open air, in cable trays, or conduit.
4. Minimum Temperature Rating: 105 degrees C.
5. Passes Vertical Tray Flame Test.
6. Outer Jacket: PVC, flame-retardant, sunlight- and oil-resistant.

B. Type 20, 16 AWG, Twisted, Shielded Pair Instrumentation Cable: Single pair, designed for noise rejection for process control, computer, or data log applications meeting NEMA WC 57.

1. Outer Jacket: 35-mil nominal.
2. Individual Pair Shield: 1.35-mil, double-faced aluminum/synthetic polymer, overlapped to provide 100 percent coverage.
3. Dimension: 0.26-inch nominal OD.
4. Conductors:
   a. Bare soft annealed copper, Class B, seven-strand concentric, ASTM B8.
   b. 20 AWG, seven-strand tinned copper drain wire.
   c. Insulation: 15-mil PVC.
   d. Color Code: Pair conductors black and white.

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5. Manufacturers:
    a. Okonite Co.
    b. Alpha Wire Corp.

C. Type 21, 16 AWG, Twisted, Shielded Triad Instrumentation Cable: Single triad, designed for noise rejection for process control, computer, or data log applications meeting requirements of NEMA WC 57.

1. Outer Jacket: 35-mil nominal thickness.
2. Individual Pair Shield: 1.35-mil, double-faced aluminum/synthetic polymer, overlapped to provide 100 percent coverage.
3. Dimension: 0.28-inch nominal OD.
4. Conductors:
    a. Bare soft annealed copper, Class B, seven-strand concentric, ASTM B8.
    b. 20 AWG, seven-strand tinned copper drain wire.
    c. Insulation: 15-mil PVC.
    d. Color Code: Triad conductors; black, red, and white.
5. Manufacturers:
    a. Okonite Co.
    b. Alpha Wire Corp.

D. Type 22, 18 AWG, Multitwisted, Shielded Pairs with a Common Overall Shield Instrumentation Cable: Designed for use as instrumentation, process control, and computer cable meeting NEMA WC 57.

1. Conductors:
    a. Bare soft annealed copper, Class B, seven-strand concentric, ASTM B8.
    b. Tinned copper drain wires.
    c. Pair drain wire size AWG 20, group drain wire size AWG 18.
    d. Insulation: 15-mil PVC.
    e. Color Code: Pair conductors black and white; white conductor numerically printed for group identification.
    f. Individual Pair Shield: 1.35-mil aluminum/mylar.
    g. Cable Shield: 2.35-mil, double-faced aluminum/synthetic polymer, overlapped for 100 percent coverage.

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2. Cable Sizes:

Number of Pairs	Maximum Outside Diameter (Inches)	Nominal Jacket Thickness (Mils)
4	0.50	50
8	0.66	60
12	0.79	60
16	0.91	60
24	1.13	70
36	1.31	70
50	1.55	80

3. Manufacturers:
   a. Okonite Co.
   b. Alpha Wire Corp.
   c. Belden.

E. Type 23, 18 AWG, Multitwisted Pairs with Common Overall Shield Instrumentation Cable: Designed for use as instrumentation, process control, and computer cable meeting NEMA WC 57.

1. Conductors:
   a. Bare soft annealed copper, Class B, seven-strand concentric, ASTM B8.
   b. Tinned copper.
   c. Group drain wire size AWG 20, minimum.
   d. Insulation: 15-mil PVC.
   e. Color Code: Pair conductors black and white; white conductor numerically printed for group identification.
   f. Cable Shield: 2.35-mil, double-faced aluminum/synthetic polymer, overlapped for 100 percent coverage.
2. Cable Sizes:

Number of Pairs	Maximum Outside Diameter (Inches)	Nominal Jacket Thickness (Mils)
4	0.48	50
8	0.63	60

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Number of Pairs	Maximum Outside Diameter (Inches)	Nominal Jacket Thickness (Mils)
12	0.73	60
16	0.77	60
24	0.96	70
36	1.09	70
50	1.45	50

3. Manufacturers:
   a. Okonite Co.
   b. Alpha Wire Corp.
   c. Belden.

F. Type 24, Twisted Pair Fire Alarm Cable [, Shielded] [, Nonshielded]: Power limited fire protective signaling circuit cable meeting requirements of NFPA 70, Article 760.

1. Cable: Pass NFPA 262, 70,000 Btu flame test and listed by [California] [_____] State Fire Marshall.
2. Outer Jacket: Red in color, identified along its entire length as fire protective signaling circuit cable.
3. Conductors:
   a. Solid, tinned, or bare copper [, shielded, with stranded tinned copper drain wire].
   b. Insulation: 15-mil PVC.
   c. [Shield: Aluminum/mylar spiral wound along entire length.]
4. Cable Sizes:

Wire Size	Maximum Outside Diameter (Inches)	Nominal Jacket Thickness (Inches)
12	0.36	0.042
14	0.32	0.042
16	0.26	0.037
18	0.23	0.037

5. Manufacturers:

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a. West Penn Wire.
b. Coleman Cable, Inc.

2.05 SPECIAL CABLES

A. Type 30, Unshielded Twisted Pair (UTP) Telephone and Data Cable, 300V:

1. Category 6 UTP, UL listed, and third party verified to comply with TIA/EIA 568-C Category 6 requirements.
2. Suitable for high speed network applications including gigabit ethernet and video. Cable shall be interoperable with other standards compliant products and shall be backward compatible with Category 5 and Category 5e.
3. Provide four each individually twisted pair, 23 AWG conductors, with FEP insulation and blue PVC jacket.
4. NFPA 70 Plenum (CMP) rated; comply with flammability plenum requirements of NFPA 70 and NFPA 262.
5. Cable shall withstand a bend radius of 1-inch minimum at a temperature of minus 20 degrees C maximum without jacket or insulation cracking.
6. Manufacturer and Product: Belden; 7852A.

2.06 GROUNDING CONDUCTORS

A. Equipment: Stranded copper with green, Type USE/RHH/RHW-XLPE or THHN/THWN, insulation.

B. Direct Buried: Bare stranded copper.

2.07 ACCESSORIES FOR CONDUCTORS 600 VOLTS AND BELOW

A. Tape:

1. General Purpose, Flame Retardant: 7-mil, vinyl plastic, Scotch Brand 33+, rated for 90 degrees C minimum, meeting requirements of UL 510.
2. Flame Retardant, Cold and Weather Resistant: 8.5-mil, vinyl plastic, Scotch Brand 88.
3. Arc and Fireproofing:
   a. 30-mil, elastomer.
   b. Manufacturers and Products:
      1) 3M; Scotch Brand 77, with Scotch Brand 69 glass cloth tapebinder.
      2) Plymouth; 53 Plyarc, with 77 Plyglas glass cloth tapebinder.

B. Identification Devices:

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1. Sleeve:
   a. Permanent, PVC, yellow or white, with legible machine-printed black markings.
   b. Manufacturers and Products:
      1) Raychem; Type D-SCE or ZH-SCE.
      2) Brady, Type 3PS.
2. Heat Bond Marker:
   a. Transparent thermoplastic heat bonding film with acrylic pressure sensitive adhesive.
   b. Self-laminating protective shield over text.
   c. Machine printed black text.
   d. Manufacturer and Product: 3M Co.; Type SCS-HB.
3. Marker Plate: Nylon, with legible designations permanently hot stamped on plate.
4. Tie-On Cable Marker Tags:
   a. Chemical-resistant white tag.
   b. Size: 1/2 inch by 2 inches.
   c. Manufacturer and Product: Raychem; Type CM-SCE.
5. Grounding Conductor: Permanent green heat-shrink sleeve, 2-inch minimum.

C. Connectors and Terminations:

1. Nylon, Self-Insulated Crimp Connectors:
   a. Manufacturers and Products:
      1) Thomas & Betts; Sta-Kon.
      2) Burndy; Insulug.
      3) ILSCO.
2. Nylon, Self-Insulated, Crimp Locking-Fork, Torque-Type Terminator:
   a. Suitable for use with 75 degrees C wire at full NFPA 70, 75 degrees C ampacity.
   b. Seamless.
   c. Manufacturers and Products:
      1) Thomas & Betts; Sta-Kon.
      2) Burndy; Insulink.
      3) ILSCO; ILSCONS.
3. Self-Insulated, Freespring Wire Connector (Wire Nuts):
   a. UL 486C.
   b. Plated steel, square wire springs.
   c. Manufacturers and Products:
      1) Thomas & Betts.
      2) Ideal; Twister.

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2. Self-Insulated, Set Screw Wire Connector:
   a. Two piece compression type with set screw in brass barrel.
   b. Insulated by insulator cap screwed over brass barrel.
   c. Manufacturers:
      1) 3M Co.
      2) Thomas & Betts.
      3) Marrette.

D. Cable Lugs:

1. In accordance with NEMA CC 1.
2. Rated 600 volts of same material as conductor metal.
3. Uninsulated Crimp Connectors and Terminators:
   a. Suitable for use with 75 degrees C wire at full NFPA 70, 75 degrees C ampacity.
   b. Manufacturers and Products:
      1) Thomas & Betts; Color-Keyed.
      2) Burndy; Hydent.
      3) ILSCO.
4. Uninsulated, Bolted, Two-Way Connectors and Terminators:
   a. Manufacturers and Products:
      1) Thomas & Betts; Locktite.
      2) Burndy; Quiklug.
      3) ILSCO.

E. Cable Ties:

1. Nylon, adjustable, self-locking, and reusable.
2. Manufacturer and Product: Thomas & Betts; TY-RAP.

F. Heat Shrinkable Insulation:

1. Thermally stabilized cross-linked polyolefin.
2. Single wall for insulation and strain relief.
3. Dual Wall, adhesive sealant lined, for sealing and corrosion resistance.
4. Manufacturers and Products:
   a. Thomas & Betts; SHRINK-KON.
   b. Raychem; RNF-100 and ES-2000.

2.08 ACCESSORIES FOR CONDUCTORS ABOVE 600 VOLTS

A. Molded Splice Kits:

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1. Components necessary to provide insulation, metallic shielding and grounding systems, and overall jacket.
2. Capable of making splices with a current rating equal to, or greater than cable ampacity, conforming to IEEE 404.
3. Class [5] [and] [15] kV, with compression connector, EPDM molded semiconductive insert, peroxide-cured EPDM insulation, and EPDM molded semiconductive outer shield.
4. Premolded splice shall be rejacketed with a heat shrinkable adhesive-lined sleeve to provide a waterproof seal.
5. Manufacturers:
   a. Elastimold.

d. Cooper Industries.

B. Heat Shrinkable Splice Kits:

1. Components necessary to provide insulation, metallic shielding and grounding systems, and overall jacket.
2. Capable of making splices with a current rating equal to, or greater than, cable ampacity, conforming to IEEE 404.
3. Class [5] [and] [15] kV, with compression connector, splice insulating and conducting sleeves, stress-relief materials, shielding braid and mesh, and abrasion-resistant heat shrinkable adhesive-lined rejacketing sleeve to provide a waterproof seal.
4. Manufacturers:
   a. Raychem.
   b. 3M Co.

C. Termination Kits:

1. Capable of terminating [5] [8] [and] [15] kV, single-conductor, polymeric-insulated [shielded] cables [plus a shield ground clamp].
2. Capable of producing a termination with a current rating equal to, or greater than, cable ampacity meeting Class 1 requirements of IEEE 48.
3. Capable of accommodating cable shielding or construction without need for special adapters or accessories.
4. Manufacturers:
   a. Raychem.
   b. 3M Co.

D. Bus Connection Insulation:

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1. Heat shrinkable tubing, tape, and sheets of flexible cross-linked polymeric material formulated for high dielectric strength.
2. Tape and sheet products to have coating to prevent adhesion to metal surfaces.
3. [Insulating materials to be removable and reusable.]
4. Manufacturer: Raychem.

E. Elbow Connector Systems:

1. Molded, peroxide-cured, EPDM-insulated, Class [15] [25] kV, [95] [125] kV BIL, [200A, 10,000A rms load-break] [200A, 15,000A rms nonload-break] [and] [600A, 40,000 rms nonload-break] elbows [as shown,] having copper current-carrying parts in accordance with IEEE 386.
2. Protective Caps: Class [15] [25] kV, [95] [125] kV BIL, [200] [and] [600] amperes, with molded EPDM insulated body.
3. Insulated Standoff Bushings: Class [15] [25] kV, [95] [125] kV BIL, [200] [and] [600] amperes, complete with EPDM rubber body, stainless steel eyebolt with brass pressure foot, and stainless steel base bracket.
4. Bushing Inserts: Class [15] [25] kV, [95] [125] kV BIL, [200A, load-break] [200A, nonload-break] [600A, nonload-break] with EPDM rubber body and all-copper, current-carrying parts.
5. Junctions: Class [15] [25] kV, [95] [125] kV [two-way,] [three-way,] [four-way,] [200A, load-break,] [and] [600A, nonload-break,] having EPDM rubber body mounted on adjustable bracket.
6. Mounting Plates: [Two] [Three] [Four]-way, ASTM A167 stainless steel, complete with universal mounting brackets, grounding lugs and two parking stands.
7. Manufacturers:
   a. Cooper Industries.
   b. Elastimold.

F. Cable Lugs:

1. In accordance with NEMA CC1.
2. Rated [5] [and] [15] kV of same material as conductor metal.
3. Manufacturers and Products, Uninsulated Compression Connectors and Terminators:
   a. Burndy; Hydent.
   b. Thomas & Betts; Color-Keyed.
   c. ILSCO.
4. Manufacturers and Products, Uninsulated, Bolted, Two-Way Connectors and Terminators:

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a. Thomas & Betts; Locktite.
b. ILSCO.

2.09 PULLING COMPOUND

A. Nontoxic, noncorrosive, noncombustible, nonflammable, water-based lubricant; UL listed.

B. Suitable for rubber, neoprene, PVC, polyethylene, hypalon, CPE, and lead-covered wire and cable.

C. Approved for intended use by cable manufacturer.

D. Suitable for zinc-coated steel, aluminum, PVC, bituminized fiber, and fiberglass raceways.

E. Manufacturers:

1. Ideal Co.
2. Polywater, Inc.
3. Cable Grip Co.

2.10 MANUFACTURED WIRING SYSTEMS

A. System Rating:

1. 20 amperes load-carrying capacity each phase with final assemblies consisting of maximum of three-phase conductors.
2. Composition: Type MC cable with 90 degrees C insulation and stranded copper conductors.

B. Cable Configuration: Three, single-phase, five-wire circuit with standard color wire coding:

1. 208/120 Volt: Black, red, blue, white, green.
2. 480/277 Volt: Brown, orange, yellow, white, green.

C. Locking Mechanism: Latch/strike with voltage clearly marked on latch.

D. NFPA 262 listed for use in air handling plenums, listed to connect or disconnect under load, and manufactured in accordance with NFPA 70, Article No. 604.

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2.11 WARNING TAPE

A. As specified in Section 26 05 33, Raceway and Boxes.

2.12 SOURCE QUALITY CONTROL

A. Conductors 600 Volts and Below: Test in accordance with UL 44 and UL 854.

B. Conductors Above 600 Volts: Test in accordance with [NEMA WC 71 and AEIC CS 8 partial discharge level test for EPR] [NEMA WC 71 and AEIC CS 8 corona level test for TR-XLP] insulated cable.

PART 3 - EXECUTION

3.01 GENERAL

A. Conductor installation shall be in accordance with manufacturer's recommendations.

B. Conductor and cable sizing shown is based on copper conductors, unless noted otherwise.

C. Do not exceed cable manufacturer's recommendations for maximum pulling tensions and minimum bending radii.

D. Terminate conductors and cables, unless otherwise indicated.

E. Tighten screws and terminal bolts in accordance with UL 486A-486B for copper conductors.

F. Cable Lugs: Provide with correct number of holes, bolt size, and center-to-center spacing as required by equipment terminals.

G. Bundling: Where single conductors and cables in manholes, handholes, vaults, cable trays, and other indicated locations are not wrapped together by some other means, bundle conductors from each conduit throughout their exposed length with cable ties placed at intervals not exceeding 18inches on center.

H. Ream, remove burrs, and clear interior of installed conduit before pulling wires or cables.

I. Concrete-Encased Raceway Installation: Prior to installation of conductors, pull through each raceway a mandrel approximately 1/4 inch smaller than raceway inside diameter.

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3.02 POWER CONDUCTOR COLOR CODING

A. Conductors 600 Volts and Below:

1. 6 AWG and Larger: Apply general purpose, flame retardant tape at each end, and at accessible locations wrapped at least six full overlapping turns, covering area 1-1/2 inches to 2 inches wide.
2. 8 AWG and Smaller: Provide colored conductors.
3. Colors:

System	Conductor	Color
All Systems	Equipment Grounding	Green
240/120 Volts, Single-Phase, Three-Wire	Grounded Neutral One Hot Leg Other Hot Leg	White Black Red
208Y/120 Volts, Three-Phase, Four-Wire	Grounded Neutral Phase A Phase B Phase C	White Black Red Blue
240/120 Volts, Three-Phase, Four-Wire, Delta, Center Tap, Ground on Single-Phase	Grounded Neutral Phase A High (wild) Leg Phase C	White Black Orange Blue
480Y/277 Volts, Three-Phase, Four-Wire	Grounded Neutral Phase A Phase B Phase C	White Brown Orange Yellow
NOTE: Phase A, B, C implies direction of positive phase rotation.		

4. Tracer: Outer covering of white with identifiable colored strip, other than green, in accordance with NFPA 70.

B. Conductors Above 600 Volts:

1. Apply general purpose, flame retardant tape at each end, and at accessible locations wrapped at least six full overlapping turns, covering area 1-1/2 inches to 2 inches wide.
2. Colors:

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a. Grounded Neutral: White.
b. Phase A: Brown.
c. Phase B: Orange.
d. Phase C: Yellow.

3.03 CIRCUIT IDENTIFICATION

A. Identify power, instrumentation, and control conductor circuits at each termination, and in accessible locations such as manholes, handholes, panels, switchboards, motor control centers, pull boxes, and terminal boxes.

B. All wires that are electrically the same (connected to common termination points) and do not pass through a contact or other switching device shall have the same wire identification. The wire labeling code for each end of the same wire shall be identical.

1. The wire identification code for internal panel wiring shall be the number/letter as designated on the Contract elementary and/or approved shop drawings.
2. Wire labeling for field wiring shall contain the panel/equipment name as a prefix and the termination point name. (I.E. PLC50-A103 or P10-124). The hierarchy of label names is 1) PLC panel name, 2) MCC equipment name, and 3) Equipment name. Therefore, wires from PLC50 to the MCC50 P10 cubicle will be labeled PLC50-XXX. Wires from MCC50 P10 to field pressure switch PSH10 will be labeled P10-XXX.
3. Wire labels shall be exactly per interconnection submittal -- abbreviations determined in the field are not allowed. Abbreviations may be used in the wire label as submitted and approved in the interconnection drawings submittal.
4. Wire labels for lighting and receptacle circuits shall consist of the panel board and circuit number and a unique node number. (I.E. LP#3-A, LP#3-B, LP#3-N)
5. Wire labels may be omitted on “neutral jumpers” less than 8” in length.

C. Method:

1. Conductors 3 AWG and Smaller: Identify with sleeves or heat bond markers.
2. Cables and Conductors 2 AWG and Larger:
   a. Identify with marker plates or tie-on cable marker tags.
   b. Attach with nylon tie cord.
3. Taped-on markers or tags relying on adhesives not permitted.

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3.04 CONDUCTORS 600 VOLTS AND BELOW

A. Install 10 AWG or 12 AWG conductors for branch circuit power wiring in lighting and receptacle circuits.

B. Do not splice incoming service conductors and branch power distribution conductors 6 AWG and larger, unless specifically indicated or approved by Engineer.

C. Connections and Terminations:

1. Install wire nuts only on solid conductors. Wire nuts are not allowed on stranded conductors.
2. Install nylon self-insulated crimp connectors and terminators for instrumentation and control, circuit conductors.
3. Install self-insulated, set screw wire connectors for two-way connection of power circuit conductors 12 AWG and smaller.
4. Install uninsulated crimp connectors and terminators for instrumentation, control, and power circuit conductors 4 AWG through 2/0 AWG.
5. Install uninsulated, bolted, two-way connectors and terminators for power circuit conductors 3/0 AWG and larger.
6. Install uninsulated terminators bolted together on motor circuit conductors 10 AWG and larger.
7. Place no more than one conductor in any single-barrel pressure connection.
8. Install crimp connectors with tools approved by connector manufacturer.
9. Install terminals and connectors acceptable for type of material used.
10. Compression Lugs:
    a. Attach with a tool specifically designed for purpose. Tool shall provide complete, controlled crimp and shall not release until crimp is complete.
    b. Do not use plier type crimpers.

D. Do not use soldered mechanical joints.

E. Splices and Terminations:

1. Insulate uninsulated connections.
2. Indoors: Use general purpose, flame retardant tape or single wall heat shrink.
3. Outdoors, Dry Locations: Use flame retardant, cold- and weather-resistant tape or single wall heat shrink.
4. Below Grade and Wet or Damp Locations: Use dual wall heat shrink.

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F. Cap spare conductors with UL listed end caps.

G. Cabinets, Panels, and Motor Control Centers:

1. Remove surplus wire, bridle and secure.
2. Where conductors pass through openings or over edges in sheet metal, remove burrs, chamfer edges, and install bushings and protective strips of insulating material to protect the conductors.

H. Control and Instrumentation Wiring:

1. Where terminals provided will accept such lugs, terminate control and instrumentation wiring, except solid thermocouple leads, with insulated, locking-fork compression lugs.
2. Terminate with methods consistent with terminals provided, and in accordance with terminal manufacturer's instructions.
3. Locate splices in readily accessible cabinets or junction boxes using terminal strips.
4. Where connections of cables installed under this section are to be made under Section 40 90 00, Instrumentation and Control for Process Systems, leave pigtails of adequate length for bundled connections.]
5. Cable Protection:
   a. Under Infinite Access Floors: May install without bundling.
   b. All Other Areas: Install individual wires, pairs, or triads in flex conduit under floor or grouped into bundles at least 1/2 inch in diameter.
   c. Maintain integrity of shielding of instrumentation cables.
   d. Ensure grounds do not occur because of damage to jacket over shield.

I. Extra Conductor Length: For conductors to be connected by others, install minimum 6 feet of extra conductor in freestanding panels and minimum 2 feet in other assemblies.

3.05 CONDUCTORS ABOVE 600 VOLTS

A. Do not splice unless specifically indicated or approved by Engineer.

B. Make joints and terminations with splice and termination kits, in accordance with kit manufacturer's instructions.

C. Install splices or terminations as continuous operation in accessible locations under clean, dry conditions.

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D. Single Conductor Cable Terminations: Provide heat shrinkable stress control and outer nontracking insulation tubings, high relative permittivity stress relief mastic for insulation shield cutback treatment, and a heat-activated sealant for environmental sealing, plus a ground braid and clamp.

E. Install terminals or connectors acceptable for type of conductor material used.

F. Provide outdoor rain skirts for riser pole and outdoor switchgear terminations.

G. Provide shield termination and grounding for terminations.

H. Provide necessary mounting hardware, covers, and connectors.

I. Where elbow connectors are specified, install in accordance with manufacturer's instructions.

J. Connections and Terminations:

1. Install uninsulated crimp connectors and terminators for power circuit conductors 4 AWG and larger.
2. Install uninsulated, bolted, two-way connectors for motor circuit conductors No. 12 and larger.
3. Insulate bus connections with heat shrinking tubing, tape, and sheets.
4. Make bus connections removable and reusable in accordance with manufacturer's instructions.

K. Give 2 working days notice to Engineer prior to making splices or terminations.

3.06 CONDUCTOR ARC AND FIREPROOFING

A. Install arc and fireproofing tape on 600-volt single conductors and cables, except those rated Type TC at splices in manholes, handholes, vaults, cable trays, and other indicated locations.

B. [Install arc and fireproofing tape on [5 kV] [and] [15 kV] cables [throughout entire exposed length] [at splices] in manholes, handholes, vaults, cable trays, and other indicated locations].

C. Wrap conductors of same circuit entering from separate conduit together as single cable.

D. Follow tape manufacturer's installation instructions.

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E. Secure tape at intervals of [5] [10] [_____] feet with bands of tapebinder. Each band to consist of a minimum of two wraps directly over each other.

END OF SECTION

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SECTION 26 05 26
GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes:

1. Rod electrodes.
2. Active electrodes.
3. Wire.
4. Grounding well components.
5. Mechanical connectors.
6. Exothermic connections.

B. Related Sections:

1. Section 03 20 00, Concrete Reinforcing: Bonding or welding bars when reinforcing steel is used for electrodes.
2. Section 09 69 00, Access Flooring: Grounding systems for access flooring.
3. Section 26 41 00, Facility Lightning Protection: Grounding of lightning protection system.
4. Section 33 79 00, Site Grounding: Site related grounding components for buildings and facilities.

1.02 REFERENCES

A. Institute of Electrical and Electronics Engineers:

1. IEEE 142, Recommended Practice for Grounding of Industrial and Commercial Power Systems.
2. IEEE 1100, Recommended Practice for Powering and Grounding Electronic Equipment.

B. International Electrical Testing Association: NETA ATS, Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems.

C. National Fire Protection Association:

1. NFPA 70, National Electrical Code.
2. NFPA 99, Standard for Health Care Facilities.

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1.03 SYSTEM DESCRIPTION

A. Grounding systems use the following elements as grounding electrodes:

1. Metal underground water pipe.
2. Metal building frame.
3. Concrete-encased electrode.
4. Ground ring specified in Section 33 79 00 <<Not in this package>>.
5. Rod electrode.
6. Plate electrode.

1.04 DESIGN REQUIREMENTS

A. Construct and test grounding systems for access flooring systems on conductive floors accordance with IEEE 1100. Refer to Section 09 69 00 <<Not in this package>>.

1.05 PERFORMANCE REQUIREMENTS

A. Grounding System Resistance: 5ohms maximum.

1.06 SUBMITTALS

A. Section 01 33 00, Submittal Procedures: Requirements for submittals.

B. Product Data: Submit data on grounding electrodes and connections.

C. Test Reports: Indicate overall resistance to ground [and resistance of each electrode].

D. Manufacturer's Installation Instructions: Submit for active electrodes.

E. Manufacturer's Certificate: Certify Products meet or exceed specified requirements.

1.07 CLOSEOUT SUBMITTALS

A. Section 01 70 00, Execution and Closeout Requirements: Requirements for submittals.

B. Project Record Documents: Record actual locations of components and grounding electrodes.

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1.08 QUALITY ASSURANCE

A. Provide grounding materials conforming to requirements of NEC, IEEE 142, and UL labeled.

B. Perform Work in accordance with State of California Public Work's standard.

C. Maintain one copy of each document on site.

1.09 QUALIFICATIONS

A. Manufacturer: Company specializing in manufacturing Products specified in this section with minimum three years experience.

B. Installer: Company specializing in performing work of this section with minimum three years documented experience.

1.10 , DELIVERY, STORAGE, AND HANDLING

A. Section 01 60 00, Product Requirements: Requirements for transporting, handling, storing, and protecting products.

B. Accept materials on site in original factory packaging, labeled with manufacturer's identification.

C. Protect from weather and construction traffic, dirt, water, chemical, and mechanical damage, by storing in original packaging.

D. Do not deliver items to project before time of installation. Limit shipment of bulk and multiple-use materials to quantities needed for immediate installation.

1.11 COORDINATION

A. Section 01 30 00, Administrative Requirements: Requirements for coordination.
A. Complete grounding and bonding of building reinforcing steel prior concrete placement.

PART 2 - PRODUCTS

2.01 ROD ELECTRODES

A. Manufacturers:

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1. Erico, Inc..
2. O-Z Gedney Co..
3. Thomas & Betts, Electrical l.
4.
5. Substitutions: [Section 01 60 00, Product Requirements] [Not Permitted].

B. Product Description:

1. Material: Copper-clad steel.
2. Diameter: 3/4 inch .
3. Length: 10 feet.

C. Connector: Connector for exothermic welded connection.

2.02 WIRE

A. Material: Stranded copper.

B. Foundation Electrodes: 4AWG.

C. Grounding Electrode Conductor: Copper conductor bare.

D. Bonding Conductor: Copper conductor bare.

2.03 EXOTHERMIC CONNECTIONS

A. Manufacturers:

1. Copperweld, Inc. .
2. ILSCO Corporation .
3. O-Z Gedney Co. .
4. Thomas & Betts, Electrical.
4.

B. Product Description: Exothermic materials, accessories, and tools for preparing and making permanent field connections between grounding system components.

PART 3 -EXECUTION

3.01 EXAMINATION

A. Section 01 30 00, Administrative Requirements: Verification of existing conditions before starting work.

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B. Verify final backfill and compaction has been completed before driving rod electrodes.

3.02 PREPARATION

A. Remove paint, rust, surface contaminants at connection points.

3.03 EXISTING WORK

A. Modify existing grounding system to maintain continuity to accommodate renovations.

B. Extend existing grounding system using materials and methods [compatible with existing electrical installations, or] as specified.

3.04 INSTALLATION

A. Install in accordance with IEEE [142] [1100].

B. Install rod electrodes at locations as indicated on Drawings . Install additional rod electrodes to achieve specified resistance to ground.

C. Install grounding and bonding conductors concealed from view.

D. Install grounding well pipe with cover at [each rod location] [rod locations as indicated on Drawings]. Install well pipe top flush with finished grade.

E. Install bare copper wire in foundation footing as indicated on Drawings.

3.05 FIELD QUALITY CONTROL

A. Section 01 40 00, Quality Requirements, 01 70 00, Execution and Closeout Requirements: Field inspecting, testing, adjusting, and balancing.

B. Inspect and test in accordance with NETA ATS, except Section 4.

C. Grounding and Bonding: Perform inspections and tests listed in NETA ATS, Section 7.13.

D. Perform ground resistance testing in accordance with IEEE 142.

E. Perform leakage current tests in accordance with NFPA 99.

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F. Perform continuity testing in accordance with IEEE 142.

G. When improper grounding is found on receptacles, check receptacles in entire project and correct. Perform retest.

END OF SECTION

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SECTION 26 05 33
RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.01 SUMMARY

A. Section includes conduit and tubing, surface raceways, wireways, outlet boxes, pull and junction boxes, and handholes.

B. Related Sections:

1. Section 26 05 03, Equipment Wiring Connections.
2. Section 26 05 26, Grounding and Bonding for Electrical Systems.
3. Section 26 05 53, Identification for Electrical Systems.
4. Section 26 27 16, Electrical Cabinets and Enclosures.
5. Section 26 27 26, Wiring Devices.
6. Section 27 05 33, Conduits and Backboxes for Communications Systems.
7. Section 33 71 19, Electrical Underground Ducts and Manholes.

1.02 UNIT PRICE - MEASUREMENT AND PAYMENT

A. Raceway:

1. Basis of Measurement: By linear foot.
2. Basis of Payment: Includes materials, delivery, handling, and installing.

B. Boxes:

1. Basis of Measurement: By cubic foot.
2. Basis of Payment: Includes materials, delivery, handling, and installing.

1.03 REFERENCES

A. American National Standards Institute:

1. ANSI C80.1, Rigid Steel Conduit, Zinc Coated.
2. ANSI C80.3, Specification for Electrical Metallic Tubing, Zinc Coated.
3. ANSI C80.5, Aluminum Rigid Conduit - (ARC).

B. National Electrical Manufacturers Association:

1. NEMA 250, Enclosures for Electrical Equipment (1000 Volts Maximum).

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2. NEMA FB 1, Fittings, Cast Metal Boxes, and Conduit Bodies for Conduit and Cable Assemblies.
3. NEMA OS 1, Sheet Steel Outlet Boxes, Device Boxes, Covers, and Box Supports.
4. NEMA OS 2, Nonmetallic Outlet Boxes, Device Boxes, Covers, and Box Supports.
5. NEMA RN 1, Polyvinyl Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit.
6. NEMA TC 2, Electrical Polyvinyl Chloride (PVC) Tubing and Conduit.
7. NEMA TC 3, PVC Fittings for Use with Rigid PVC Conduit and Tubing.

1.04 SYSTEM DESCRIPTION

A. Raceway and boxes located as indicated on Drawings, and at other locations required for splices, taps, wire pulling, equipment connections, and compliance with regulatory requirements. Raceway and boxes are shown in approximate locations unless dimensioned. Provide raceway to complete wiring system.

B. Underground Provide conduit per schedule.

C. Outdoor Locations, Above Grade: Provide rigid steel conduit unless otherswise noted on the drawings. Provide cast metal or nonmetallic outlet, pull, and junction boxes.

D. In Slab Above Grade: Provide conduit per schedule.

1.05 DESIGN REQUIREMENTS

A. Minimum Raceway Size: 3/4 inch unless otherwise specified.

1.06 SUBMITTALS

A. Section 01 33 00, Submittal Procedures: Submittal procedures.

B. Product Data: Submit for the following:

1. Flexible metal conduit.
2. Liquidtight flexible metal conduit.
3. Nonmetallic conduit.
4. Flexible nonmetallic conduit.
5. Nonmetallic tubing.
6. Raceway fittings.
7. Conduit bodies.
8. Surface raceway.

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9. Wireway.
10. Pull and junction boxes.
11. Handholes.

C. Manufacturer's Installation Instructions: Submit application conditions and limitations of use stipulated by Product testing agency specified under Regulatory Requirements. Include instructions for storage, handling, protection, examination, preparation, and installation of Product.

1.07 CLOSEOUT SUBMITTALS

A. Section 01 70 00, Execution and Closeout Requirements: Closeout procedures.

B. Project Record Documents:

1. Record actual routing of conduits larger than 3/4 inch.
2. Record actual locations and mounting heights of outlet, pull, and junction boxes.

1.08 DELIVERY, STORAGE, AND HANDLING

A. Section 01 60 00, Product Requirements: Product storage and handling requirements.

B. Protect conduit from corrosion and entrance of debris by storing above grade. Provide appropriate covering.

C. Protect PVC conduit from sunlight.

1.09 COORDINATION

A. Section 01 30 00, Administrative Requirements: Coordination and project conditions.

B. Coordinate installation of outlet boxes for equipment connected under Section 26 05 03.

C. Coordinate mounting heights, orientation and locations of outlets mounted above counters, benches, and backsplashes.

PART 2 - PRODUCTS

2.01 METAL CONDUIT

A. Manufacturers:

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1. Carlon Electrical Products.
2. Hubbell Wiring Devices.
3. Thomas & Betts Corp.
4. Walker Systems Inc.
5. The Wiremold Co.] Model [_____].
6. Substitutions: Section 01 60 00, Product Requirements.

B. Rigid Steel Conduit: ANSI C80.1.

C. Rigid Aluminum Conduit: ANSI C80.5.

D. Fittings and Conduit Bodies: NEMA FB 1; material to match conduit

2.02 PVC COATED METAL CONDUIT

A. Manufacturers:

1. Carlon Electrical Products.
2. Hubbell Wiring Devices.
3. Thomas & Betts Corp.
4. Walker Systems Inc..
5. The Wiremold Co..
6. Substitutions: Section 01 60 00, Product Requirements.

B. Product Description: NEMA RN 1; rigid steel conduit with external PVC coating, 40 mil thick.

C. Fittings and Conduit Bodies: NEMA FB 1; steel fittings with external PVC coating to match conduit.

2.03 FLEXIBLE METAL CONDUIT

A. Manufacturers:

1. Carlon Electrical Products.
2. Hubbell Wiring Devices.
3. Thomas & Betts Corp..
4. Walker Systems Inc..
5. The Wiremold Co..
6. Substitutions: Section 01 60 00, Product Requirements.

B. Product Description: Interlocked steel construction.

C. Fittings: NEMA FB 1.

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2.04 LIQUID-TIGHT FLEXIBLE METAL CONDUIT

A. Manufacturers:

1. Carlon Electrical Products.
2. Hubbell Wiring Devices.
3. Thomas & Betts Corp..
4. Walker Systems Inc..
5. The Wiremold Co..
6. Substitutions: Section 01 60 00, Product Requirements.

B. Product Description: Interlocked steelconstruction with PVC jacket.

C. Fittings: NEMA FB 1.

2.05 ELECTRICAL METALLIC TUBING (EMT)

A. Manufacturers:

1. Carlon Electrical Products.
2. Hubbell Wiring Devices.
3. Thomas & Betts Corp..
4. Walker Systems Inc..
5. The Wiremold Co..
6. Substitutions: Section 01 60 00, Product Requirements.

B. Product Description: ANSI C80.3; galvanized tubing.

C. Fittings and Conduit Bodies: NEMA FB 1; steel or malleable iron set screw type.

2.06 NONMETALLIC CONDUIT

A. Manufacturers:

1. Carlon Electrical Products.
2. Hubbell Wiring Devices.
3. Thomas & Betts Corp..
4. Walker Systems Inc..
5. The Wiremold Co..
6. Substitutions: Section 01 60 00, Product Requirements.

B. Product Description: NEMA TC 2; Schedule 40or 80 PVC.

C. Fittings and Conduit Bodies: NEMA TC 3.

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2.07 WIREWAY

A. Manufacturers:

1. Carlon Electrical Products.
2. Hubbell Wiring Devices.
3. Thomas & Betts Corp..
4. Walker Systems Inc..
5. The Wiremold Co..
6. Substitutions: Section 01 60 00, Product Requirements.

B. Product Description: General purpose type wireway.

C. Knockouts: None.

D. Size: length as indicated on Drawings.

E. Cover: Hinged cover with full gaskets.

F. Connector: Slip-in or Flanged.

G. Fittings: Lay-in type with removable side.

H. Finish: Rust inhibiting primer coating with gray enamel finish.

2.08 OUTLET BOXES

A. Manufacturers:

1. Carlon Electrical Products.
2. Hubbell Wiring Devices.
3. Thomas & Betts Corp..
4. Walker Systems Inc..
5. The Wiremold Co..
6. Substitutions: Section 01 60 00, Product Requirements.

B. Sheet Metal Outlet Boxes: NEMA OS 1, galvanized steel.

1. Luminaire and Equipment Supporting Boxes: Rated for weight of equipment supported; furnish 1/2 inch male fixture studs where required.
2. Concrete Ceiling Boxes: Concrete type.

C. Nonmetallic Outlet Boxes: NEMA OS 2.

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D. Cast Boxes: NEMA FB 1, Type FD, cast feralloy. Furnish gasketed cover by box manufacturer.

E. Wall Plates for Finished Areas: As specified in Section 26 27 26.

F. Wall Plates for Unfinished Areas: Furnish gasketed cover.

2.09 PULL AND JUNCTION BOXES

A. Manufacturers:

1. Carlon Electrical Products.
2. Hubbell Wiring Devices.
3. Thomas & Betts Corp..
4. Walker Systems Inc..
5. The Wiremold Co..
6. Substitutions: Section 01 60 00, Product Requirements.

B. Sheet Metal Boxes: NEMA OS 1, galvanized steel.

C. Hinged Enclosures: As specified in Section 26 27 16.

D. Surface Mounted Cast Metal Box: NEMA 250, Type 4X; flat-flanged, surface mounted junction box:

1. Material: Stainless steel.
2. Cover: Furnish with ground flange, neoprene gasket, and stainless steel cover screws.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Section 01 30 00, Administrative Requirements: Coordination and project conditions.

B. Verify outlet locations and routing and termination locations of raceway prior to rough-in.

3.02 INSTALLATION

A. Ground and bond raceway and boxes in accordance with Section 26 05 26.

B. Fasten raceway and box supports to structure and finishes in accordance with Section 26 05 29.

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C. Identify raceway and boxes in accordance with Section 26 05 53.

D. Arrange raceway and boxes to maintain headroom and present neat appearance.

3.03 INSTALLATION, RACEWAY

A. Raceway routing is shown in approximate locations unless dimensioned. Route to complete wiring system.

B. Arrange raceway supports to prevent misalignment during wiring installation.

C. Support raceway using coated steel or malleable iron straps, lay-in adjustable hangers, clevis hangers, and split hangers.

D. Group related raceway; support using conduit rack. Construct rack using steel channel specified in Section 26 05 29; provide space on each for 25 percent additional raceways.

E. Do not support raceway with wire or perforated pipe straps. Remove wire used for temporary supports

F. Do not attach raceway to ceiling support wires or other piping systems.

G. Construct wireway supports from steel channel specified in Section 26 05 29.

H. Route exposed raceway parallel and perpendicular to walls.

I. Route raceway installed above accessible ceilings parallel and perpendicular to walls.

J. Route conduit in and under slab from point-to-point.

K. Maximum Size Conduit in Slab Above Grade: 3/4 inch. Do not cross conduits in slab.

L. Maintain clearance between raceway and piping for maintenance purposes.

M. Maintain 12 inch clearance between raceway and surfaces with temperatures exceeding 104 degrees F.

N. Cut conduit square using saw or pipe cutter; de-burr cut ends.

O. Bring conduit to shoulder of fittings; fasten securely.

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P. Join nonmetallic conduit using cement as recommended by manufacturer. Wipe nonmetallic conduit dry and clean before joining. Apply full even coat of cement to entire area inserted in fitting. Allow joint to cure for minimum 20 minutes.

Q. Install conduit hubs or sealing locknuts to fasten conduit to sheet metal boxes in damp and wet locations and to cast boxes.

R. Install no more than equivalent of three 90 degree bends between boxes. Install conduit bodies to make sharp changes in direction, as around beams. Use hydraulic one-shot bender to fabricator installed factory elbows for bends in metal conduit larger than 2 inch size.

S. Avoid moisture traps; install junction box with drain fitting at low points in conduit system.

T. Install fittings to accommodate expansion and deflection where raceway crosses seismic, control and expansion joints.

U. Install suitable pull string or cord in each empty raceway except sleeves and nipples.

V. Install suitable caps to protect installed conduit against entrance of dirt and moisture.

W. Surface Raceway: Install flat-head screws, clips, and straps to fasten raceway channel to surfaces; mount plumb and level. Install insulating bushings and inserts at connections to outlets and corner fittings.

X. Close ends and unused openings in wireway.

3.04 INSTALLATION - BOXES

A. Install wall mounted boxes at elevations to accommodate mounting specified in section for outlet device.

B. Adjust box location up to 10 feet prior to rough-in to accommodate intended purpose.

C. Orient boxes to accommodate wiring devices oriented as specified in Section 26 27 26.

D. Install pull boxes and junction boxes above accessible ceilings and in unfinished areas only.

E. In Accessible Ceiling Areas: Install outlet and junction boxes no more than 6 inches from ceiling access panel or from removable recessed luminaire.

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F. Locate flush mounting box in masonry wall to require cutting of masonry unit corner only. Coordinate masonry cutting to achieve neat opening.

G. Do not install flush mounting box back-to-back in walls; install with minimum 6 inches separation. Install with minimum 24 inches separation in acoustic rated walls.

H. Secure flush mounting box to interior wall and partition studs. Accurately position to allow for surface finish thickness.

I. Install stamped steel bridges to fasten flush mounting outlet box between studs.

J. Install flush mounting box without damaging wall insulation or reducing its effectiveness.

K. Install adjustable steel channel fasteners for hung ceiling outlet box.

L. Do not fasten boxes to ceiling support wires or other piping systems.

M. Support boxes independently of conduit.

N. Install gang box where more than one device is mounted together. Do not use sectional box.

O. Install gang box with plaster ring for single device outlets.

3.05 INTERFACE WITH OTHER PRODUCTS

A. Install conduit to preserve fire resistance rating of partitions and other elements, using materials and methods in accordance with Section 07 84 00.

B. Route conduit through roof openings for piping and ductwork or through suitable roof jack with pitch pocket. Coordinate location with roofing installation specified in Section [_____].

C. Locate outlet boxes to allow luminaires positioned as indicated on Drawings.

D. Align adjacent wall mounted outlet boxes for switches, thermostats, and similar devices.

3.06 ADJUSTING

A. Section 01 70 00, Execution and Closeout Requirements: Testing, adjusting, and balancing.

B. Adjust flush-mounting outlets to make front flush with finished wall material.

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A. Install knockout closures in unused openings in boxes.

3.07 CLEANING

A. Section 01 70 00, Execution and Closeout Requirements: Final cleaning.

B. Clean interior of boxes to remove dust, debris, and other material.

C. Clean exposed surfaces and restore finish.

END OF SECTION

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SECTION 26 12 02
OIL-FILLED PAD MOUNTED TRANSFORMERS

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM): D3487, Standard Specification for Mineral Insulating Oil Used in Electrical Apparatus.
2. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
   a. 386, Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600V.
   b. C57.12.00, Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.
   c. C57.12.22, Pad-Mounted, Compartmental-Type, Self-Cooled, Three-Phase Distribution Transformers with High-Voltage Bushings, 2,500 kVA and Smaller.
   d. C57.12.26, Pad-Mounted, Compartmental-Type, Self-Cooled, Three-Phase Distribution Transformers for Use with Separable Insulated High Voltage Connectors.
   e. C57.12.28, Switchgear and Transformers—Pad-Mounted Equipment, Enclosure Integrity.
   f. C57.12.90, Standard Test Code for Liquid Immersed Distribution, Power, and Regulating Transformers.
   g. C57.106, Guide for Acceptance and Maintenance of Insulating Oil in Equipment.
   h. C62.11, Metal-Oxide Surge Arrestors for Alternating-Current Power Circuits (>1 kV).
3. National Electrical Manufacturers Association (NEMA):
   a. TR 1, Transformers, Regulators, Reactors.
   b. TP 1, Guide for Determining Energy Efficiency for Distribution Transformers.
4. National Fire Protection Association (NFPA): 70, National Electrical Code (NEC).
5. Underwriters Laboratories Inc. (UL).

1.02 SUBMITTALS

A. Action Submittals:

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1. [Descriptive information.]
2. [Dimensional drawings.]
3. [Transformer nameplate data.]
4. [Schematic and connection diagrams.]
5. Seismic anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Seismic Anchorage and Bracing.

B. Informational Submittals:

1. Seismic anchorage and bracing calculations as required by Section 01 88 15, Seismic Anchorage and Bracing.
2. Component and attachment testing seismic certificate of compliance as required by Section 01 45 33, Special Inspection [, Observation,] and Testing.
3. [Operation and Maintenance Data: As specified in Section 01 78 23, Operation and Maintenance Data.]
4. [Factory test reports [certified].]

1.03 QUALITY ASSURANCE

A. Design, test, and assemble in accordance with applicable standards of NEMA TR 1, IEEE C57.12.00, IEEE C57.12.22, IEEE C57.12.26, and IEEE C57.12.90.

1.04 EXTRA MATERIALS

A. Furnish, tag, and box for shipment and storage [and deliver prior to [_____] percent Project completion] the following [spare parts,] [special tools,] [and] [materials:]

1. One quart of paint to match color and quality of equipment final shop finish.
2. [One] [Two] spare fuses [links] for each replaceable fuse size.
3. [Pentahead socket for 1/2-inch socket drive.]

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Cutler-Hammer.

B. Square D Co.

C. General Electric.

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D. Cooper Power System.

2.02 GENERAL

A. Integral Unit: Compartmental type unit consisting of transformer, oil-filled tank, and high and low voltage terminating compartments, assembled on a common structural base.

B. Anchor Bolts: [Galvanized,] [Type 316 stainless steel,] [sized by equipment manufacturer,] [1/2-inch minimum diameter,] and as specified in Section 05 50 00, Metal Fabrications.

2.03 TRANSFORMER

A. kVA Rating: [150,] [225,] [300,] [500,] [750,] [and] [_____] [As shown.]

B. Primary Voltage: [4.16] [13.8] [_____] kV line-to-line, [_____] volts, [three-phase,] [as shown,] [four-wire,] 60-Hz.

C. Secondary Voltage: [240/120] [208/120] [480/277] [_____] volts, [three-phase,] [as shown,] [four-wire,] 60 Hz.

D. BIL Rating:

1. [60 BIL for 5] [95 BIL for 15] kV insulation class transformers.
2. 30 BIL for secondary.

E. Temperature Rise: [65] [55/65] degrees C above 30 degrees average ambient with maximum ambient not to exceed 40 degrees C.

F. Impedance:

1. [1.35 percent minimum for transformers rated 150 kVA and less.]
2. [3.0 percent minimum for transformers rated 225, 300, and 500 kVA.]
3. [5.75 percent for transformers rated 750 kVA and above.]

G. Efficiency: Meet or exceed values in Table 4-1 of NEMA TP 1.

H. Dielectric Coolant: [Fully biodegradable, nontoxic, and nonbio-accumulating fluid, qualifying as “less flammable” per NEC 450.23; Factory Mutual Approved or UL Classified.] [Normally formulated, hydro-refined inhibited mineral oil, meeting minimum requirements in Table 1 of ASTM D3487 and IEEE C57.106.]

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[Silicone, qualifying as "less flammable" per NEC 450.23; Factory Mutual Approved or UL Classified.]

I. Primary Taps:

1. Full capacity, two 2-1/2 percent below and two 2-1/2 percent above, rated voltage.
2. Externally operated no-load tap changer.
3. Provisions for locking handle in any position.

J. Coil Conductors: [Copper] [Aluminum] windings.

K. Wye-wye transformers wound on [five-legged] [or] [triplex] cores.

L. Sound Level: In accordance with manufacturer's standards and NEMA..

2.04 ENCLOSURE

A. In accordance with IEEE C57.12.28 requirements.

B. Welded carbon steel transformer tank, with cooling panels when required, and lifting eyes.

C. 12-gauge sheet steel terminal compartment enclosure having no exposed screws, bolts, or other fasteners that are externally removable.

D. Color: Provide [gray] [_____] finish as approved by [Owner] [Engineer].

2.05 TERMINAL COMPARTMENTS

A. General: IEEE C57.12.28, enclosed high and low voltage compartments side by side, separated by steel barrier, bolted to transformer tank.

1. Doors:
   a. Individual, full-height, air-filled.
   b. Low voltage door with three-point latching mechanism, vault type handle, and single padlocking provision.
   c. High voltage door fastenings inaccessible until low voltage door has been opened.
   d. Door Bolts: [Hex] [Penta]-head type.
   e. Lift-off, stainless steel hinges and door stops.
   f. Removable front sill to facilitate rolling or skidding over conduit stubs.

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g. Recessed lock pocket, with steel door release bolt adjacent to secondary compartment door handle.

B. High Voltage Compartment:

1. [Livefront in accordance with IEEE C57.12.22] [Deadfront in accordance with IEEE C57.12.26] type construction.
2. Protective fuses.
3. High voltage bushings.
4. Transformer grounding pad.
5. [Surge arrestors] [with] [without] [barriers].
6. [Radial feed, two] [Loop feed, four] [alternate source/primary selective] [loop/radial] position sectionalizing load-break switch.

C. Low Voltage Compartment:

1. Livefront in accordance with IEEE C57.12.26 type construction.
2. Low voltage bushings [and main circuit breaker].
3. [Main circuit breaker to have interrupting capacity of no less than that for a bolted, three-phase fault at the secondary terminals with a calculated primary source zero-impedance using actual transformer impedance and X/R ratio.]
4. Grounding pad.
5. Stainless steel equipment nameplate.
6. Liquid level gauge.
7. 1-inch upper filter press and filling plug.
8. Drain valve with sampling device.
9. Dial type thermometer.
10. Pressure relief valve.
11. [Pressure relief device, self-resealing with indicator.]
12. [Pressure-vacuum gauge.]
13. [Mounting provision for current and potential transformers.]
14. [Busway opening.]
15. Nameplate.

2.06 BUSHINGS

A. High Voltage:

1. Livefront Termination:
   a. Porcelain bushings with [clamp type connections.] [two-hole blade terminals.]

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b. Bushings externally clamped and front removable.
c. Rated for [200] [600] amperes continuous, 95 kV BIL, [5] [15] kV.

2. Deadfront Termination:
a. [Universal bushing well rated at 15 kV] [Integrated bushing rated at 8.3 kV phase-to-ground/14.4 kV phase-to-phase] in accordance with IEEE 386.
b. Bushings externally clamped and front removable.
c. Rated for [200] [600] amperes continuous, 95 kV BIL.
d. Standoff brackets located adjacent to bushings.

B. Low Voltage:

1. Molded epoxy bushing clamped to tank with [4] [6] [8] [_____] hole spade type terminals.
2. Rated 150 percent of continuous full-load current, 30 BIL, 600 volts.
3. Internally connected neutral extending to neutral bushing.

2.07 HIGH VOLTAGE SWITCHING

A. Internal, oil-immersed, gang-operated load-break, manually operated switches.

B. Hot stick operated handle located in high voltage compartment.

C. Capable of operating at full-load current.

D. Feed Switch: [Two-position, ON/OFF radial.] [Three-position, selector.] [Four-position, indexing plate, loop.] [Four-position, loop/radial.]

2.08 HIGH VOLTAGE PROTECTION

A. [Internally Mounted, Oil-Immersed Cartridge Fuses:

1. Accessible through tank handhole.
2. Sized approximately three times primary current.
3. Interrupting capability of 2,500 amperes rms asymmetrical.]

B. [Bayonet-Type, Oil-Immersed Expulsion Fuses:

1. Accessible through primary compartment.
2. Externally replaceable with hot stick.
3. [Fault] [Overload] sensing with interrupting capacity of 1,800 amperes rms asymmetrical.]

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C. [Current-Limiting, Dry Well, Canister Mounted Fuses:

1. Accessible through primary compartment.
2. [Load-break rated 100 amperes minimum.] [Non-load-break.]
3. Interrupting capacity of 50,000 amperes rms symmetrical.
4. Externally replaceable with hot stick.]

D. [Bayonet Type, Oil-Immersed Current-Limiting Fuses:

1. Accessible through primary compartment.
2. Interrupting capacity of 50,000 amperes rms symmetrical.
3. Externally replaceable with hot stick.]

E. [Combination Oil-Immersed Bayonet Expulsion and Current Limiting Fuses:

1. Accessibility:
   a. Bayonet expulsion fuse accessible through primary compartment.
   b. Current-limiting fuse accessible through tank handhole.
2. Expulsion Fuse for Low Current Faults: Interrupting capacity of 1,800 amperes rms asymmetrical.
3. Current Limiting for High Current Faults: Interrupting capacity of 50,000 amperes rms symmetrical.
4. Bayonet fuse externally replaceable with hot stick.]

2.09 LOW VOLTAGE PROTECTION

A. Molded-case circuit breaker, three-pole, 600 volt, of current rating as shown on Drawings and as specified in Section 26 05 04, Basic Electrical Material and Methods.

B. Interrupting Rating: [As shown.] [[25] [30] [35] [50] [65] [_____] amperes rms symmetrical.]

C. Circuit breaker mounted on exterior surface of transformer tank wall, below low voltage bushings.

2.10 SURGE ARRESTORS

A. [Distribution Class Type: [3] [6] [9] [_____] kV, livefront, with mounting bracket in accordance with IEEE C62.11.]

B. [Elbow Valve Type: Uninsulated body, [3] [6] [9] [_____] kV [with] [without] barriers in accordance with IEEE C62.11.]

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C. [Metal-Oxide, Varistor Type:

1. Insulated body, elbow type, [313.2] [6] [9] [_____] kV in accordance with IEEE C62.11.
2. Installed in high voltage compartment.
3. Connected to transformer high voltage terminals.]

1.1 TANK GROUNDING PADS

A. High and Low Voltage Compartments:
1. Connected together with bare No. 2/0 stranded copper conductors.
4. Wye-wye high and low voltage neutrals internally connected with link and brought out to insulated low voltage bushing externally grounded to tank.
5. Low voltage neutral connected to externally mounted insulating bushing in low voltage compartment and grounded to tank with removable strap.

2.11 TAP CHANGER WARNING SIGN

A. Red laminated plastic, engraved to white core.

B. Engrave to read: DO NOT OPERATE WHEN TRANSFORMER ENERGIZED.

C. Mount above tap changer handle.

2.12 FACTORY TESTS

A. Production tests in accordance with IEEE C57.12.90 and IEEE C57.12.00, Section 8 and Table 16.

B. [Dielectric test in accordance with IEEE C57.12.26.]

PART 3 - EXECUTION

3.01 GENERAL

A. Secure to mounting pads with anchor bolts.

B. Install plumb and longitudinally in alignment with pad or adjacent building wall.

C. Ground neutrals and enclosures in accordance with applicable codes.

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3.02 ADJUSTMENTS

A. Adjust voltage taps to obtain rated output voltage under normal operating load conditions.

END OF SECTION

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SECTION 26 13 16.01
METAL-ENCLOSED SWITCHGEAR

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American National Standards Institute (ANSI): C39.1, Electrical Analog Indicating Instruments, Requirements for.
2. ASTM International (ASTM):
   a. B117, Standard Test Method for Salt Spray (FOG) testing.
   b. B187, Standard Specifications for Copper Bus Bar, Rod, and Shapes.
   c. B236, Standard Specifications for Aluminum Bars for Electrical Purposes.
   d. D523, Standard Test Method for Specular Gloss.
   e. D659, Standard Method of Evaluating Degree of Chalking of Exterior Paints.
   f. D714, Standard Test Method for Evaluating Degree of Blistering of Paint.
   g. D1654, Standard Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments.
   h. D2247, Standard Practice for Testing Water Resistance of Coatings in 100 Percent Relative Humidity.
   i. D2794, Standard Test Method for Resistance of Organic Coating to the Effects of Rapid Deformation.
   j. D3359, Standard Test Methods for Measuring Adhesion by Tape Test.
   k. D4060, Standard Test Method for Abrasion Resistance to Organic Coatings by the Tabor Abraser.
   l. G154, Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials.
3. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
   a. C37.20.3, Metal-Enclosed Interrupter Switchgear.
   b. C37.46, Specifications for Power Fuses and Fused Disconnecting Switches.
   c. C37.57, Metal-Enclosed Interrupter Switchgear Assemblies-Conformance Testing.
   d. C37.58, Indoor AC Medium Voltage Switches for Use in Metal-Enclosed Switchgear.

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e. C37.90, Standard for Relays and Relay Systems Associated with Electric Power Apparatus.
f. C37.90.1, Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus.
g. C37.91, Guide for Protective Relay Applications to Power Transformers.
h. C57.12.28, Switchgear and Transformers-Pad-Mounted Equipment-Enclosure Integrity.
i. C57.13, Standard Requirements for Instrument Transformers.
j. C62.11, Standard for Metal-Oxide Surge Arrestors for AC Power Circuits.

4. National Electrical Manufacturers Association (NEMA):
   a. C29.9, Wet-Process Porcelain Insulators, Apparatus Post Type.
   b. C29.10, Wet-Process Porcelain Insulators, Indoor Apparatus Type.
   c. LA 1, Surge Arrestors.
   d. SG 2, High Voltage Fuses.
5. National Fire Protection Association (NFPA): 70, National Electrical Code. (NEC).
6. [International Building Code: Sections 1613 through 1623, Earthquake Loads.] [Uniform Building Code (UBC): Section 2312, Earthquake Requirements.]

1.02 SUBMITTALS

A. Action Submittals:

1. Descriptive product information.
2. Dimensional drawings.
3. Itemized bill of material.
4. Operational description.
5. Switchgear configuration.
6. Interrupter switch data.
7. Bus data.
8. One-line, three-line, and control schematic drawings.
9. Fuse-data and time-current characteristics on transparencies.
10. [Connection and Interconnection drawings.]
11. [Conduit entrance locations.]
12. [Power operator [and source transfer controller with voltage sensor] data.]
13. [Anchoring instructions and details.]
14. Seismic anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Seismic Anchorage and Bracing.

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B. Informational Submittals:

1. Seismic anchorage and bracing calculations as required by Section 01 88 15, Seismic Anchorage and Bracing.
2. [Certified] Factory Test Reports.
3. Manufacturer's installation instructions.
4. Component and attachment testing seismic certificate of compliance as required by Section 01 45 33, Special Inspection [, Observation,] and Testing.
5. Operation and Maintenance Data: As specified in Section 01 78 23, Operation and Maintenance Data.
6. [Manufacturer's Certificate of Proper Installation in accordance with Section 01 43 33, Manufacturers' Field Services.]

1.03 DELIVERY, STORAGE, AND HANDLING

A. Shipping Splits: [As shown] [Established by Contractor] to facilitate ingress of equipment to final installation location within the building.

1.04 EXTRA MATERIALS

A. Furnish, tag, and box for shipment and storage the following spare parts, special tools, and materials:

1. [Fuse handling tool and universal pole, compatible with installed fuses.]
2. [[One] [Two] [_____] sets of three grounding jumpers, [6] [8] [10] feet in length, complete with canvas storage bag for each set.]
3. [Voltage tester with audio and visual signals, batteries, shotgun clamp-stick adapter, and storage case.]
4. [[6] [8] feet, 5-1/2 inches long shotgun clamp stick with canvas storage bag.]
5. [Portable remote control station with 50-foot cord.]
6. [Solid material fuse [end fittings] [holders] and [fuse] [refill] units for each installed fuse size.]
7. [Electron fuse [interrupting module] [and] [control module] and [fuse] [refill] units for each installed fuse size.]
8. [Voltage transformer fuse unit for each installed fuse size.]
9. [Portable test accessory for preliminary checkout of source transfer system.]

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. S&C Co.

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B. [_____]

C. [No "or-equal" or substitute products will be considered.]

D. Provide metal-enclosed switchgear that is the product of a single manufacturer. Assembled units with component parts of several manufacturers will not be acceptable with the exception that minor items as terminal blacks, test switch, wiring, etc., may be manufactured by others.

2.02 GENERAL

A. Equipment suitable for [4,160] [12,500] [13,200] [13,800] [_____] volts, three-phase [three-wire] [four-wire] [solid] [low resistance] [high resistance] [grounded-wye] [ungrounded] electrical system having an available short-circuit current at line terminals of [_____] amperes rms symmetrical [as shown.]

B. Front accessible, metal-enclosed switchgear complete with one or more [indoor] [outdoor] self-supporting bays having interrupter switches, [solid material] [and] [electronic] power fuses, and necessary accessory components.

C. Designed, tested, and assembled in accordance with IEEE 37.20.3, IEEE C37.57, and IEEE C57.12.28 [, and UL Listed per Certificate of Compliance File No. E138023.]

D. Operating Conditions:

1. Altitude not greater than [3,300] [5,000] [6,000] feet above sea level.
2. Ambient Temperature: Maximum [40] [50] [_____] degrees C.
3. [Seismic Conditions: [IBC, Section 1616 Seismic Design Category [_____]] [UBC, Section 2313, Zone [_____,] importance factor of [_____]
4. Equipment shall be fully rated without derating for these operating conditions.

E. Anchor Bolts: [Galvanized,] [Type 316 stainless steel,] 5/8-inch diameter, length sized by manufacturer, and as specified in Section 05 50 00, Metal Fabrications.

2.03 EQUIPMENT RATINGS

A. Integrated Switchgear Assembly Ratings At 60-Hz:

1. Voltage: [4.16 kV nominal, 4.8 kV maximum.] [13.8 kV nominal, 17 kV maximum.]

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2. Insulation Level: [60] [95] kV BIL.
3. Main Bus Current: [600] [1,200] [and] [2,000] continuous amperes [, as shown on one-line diagram.]
4. Three-Pole Interrupter Switches:
   a. Current: [600] [and] [1,200] amperes continuous and live switching rating [as shown on one-line diagram.]
   b. Two-Time Duty-Cycle Fault Closing: [[125] [180] [270] amperes rms asymmetrical at rated 4.16] [[20,000] [22,400] [40,000] amperes rms asymmetrical rated at 13.8 kV nominal voltage.]
5. Short-Circuit Rating: [[17,200] [25,000] [37,500] amperes rms symmetrical, [125] [180] [270] mVA three-phase symmetrical at rated 4.16] [[12,500] [14,000] [25,000] amperes symmetrical, [300] [335] [AI: 600] mVA three-phase symmetrical at rated 13.8 kV nominal voltage.]

B. Fault-closing ratings to equal, or exceed, the short-circuit ratings of the metal-enclosed switchgear with:

1. Momentary and two-time duty-cycle rating of switches.
2. Momentary rating of bus.
3. Interrupting ratings of fuses.

2.04 ENCLOSURE

A. [Modular] [Custom] unitized monocoque modules constructed of 11-gauge sheet steel.

B. Each module a complete unit in itself with continuous 7-gauge steel base on all four sides of each module.

C. Sides, rear, and roof panels, doors, and future bus extension cover plates bolted together internally with no exposed bolt connections.

D. [IEEE C37.57, Category [A] [B] [UL Listed for enclosure in accordance with IEEE C37.57, Category A, IEEE C57.12.28 and additional padlockable covers for windows, manual operating handles, and accessories.]

E. Access Doors:

1. [Overlapping double-doors] [Bulkhead type] construction with 90-degree flange overlapping door openings.
2. Sheared edges folded back [parallel to the inside of door, except at bottom of door and on the right edge of medium voltage compartment door.] [toward inside of door.]

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3. Concealed galvanized steel hinges with Type 316 stainless steel hinge pins:
   a. Three hinges for doors over 40 inches in height.
   b. Two hinges for doors under 40 inches in height.
4. Padlockable door handles [with cover shields] for each [right-hand low voltage compartment] [bulkhead] access door.
5. [Mechanically] [Key] interlock access doors to fused interrupter switches to prevent:
   a. Opening door if switch is closed.
   b. Opening door if switch is open.
6. Padlockable, flush mounted, key-operated snaplock on access doors to nonfused interrupter switches [, hinged-bolted panels to high voltage compartments, and hinged-bolted covers to low-voltage compartments.]
7. [Mechanical] [Key] interlock access doors to stored energy switch operators to prevent operation while door is opened.
8. Flush mounted, key-operated snaplock on doors to nonfused interrupter switches.
9. Right-hand door for low voltage compartment to control access to medium voltage compartment.

F. Door Latch:

1. Automatic positive action, three-point, spring-loaded latching mechanism for [right-hand, low voltage compartment] [each medium voltage] access door.
2. Pentahead socket wrench to actuate mechanism for unlatching door and recharging spring for next closing operation in same motion.
3. Tamper-proof padlocking shackle coordinated with latches to prevent:
   a. Unlatching mechanism until padlock is removed.
   b. Inserting padlock until mechanism is completely latched closed.

G. Self-latching door holders for medium voltage compartment doors [and manual holders for low voltage compartment doors].

H. Access doors to power fuses [and fused transformers] equipped with storage space for replacement fuse components and operating instructions.

I. Raintight ventilating louvers with baffles and screens in lower and upper portion of each rear panel, lower [and upper] portion of each access door [, and upper portion of each front panel] [, complete with externally accessible glass-fiber filters].

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J. Impact resistance, molded gasketed viewing windows in doors providing access to interrupter switches.

K. 3mpartments:

1. Grounded, isolated metal enclosures for switch operators, [source transfer controls,] [meters,] [instruments,] [relays,] and low voltage components.
2. Low voltage wiring in grounded conduit and/or wireways.

L. Front accessible cable termination space.

M. Removable lifting eyes [with blind-tapped sockets] for each individual module.

N. Weatherproofing:

1. Resilient compression gaskets around all door openings [, hinged-bolted panels] [, hinged-bolted covers] [and] [future bus extension cover plates.]
2. Gasket seals at top and side edges of adjoining bays.
3. [Sides and top channel gaskets at bus openings between bays.] [External labyrinthine metal rainshields over enclosure roof flanges between adjacent bays.]
4. Applied sealant between vertical sides and roofs.
5. Insulation nondrip compound applied to underside of roof.

O. Space Heaters:

1. One strip heater with high temperature chrome steel sheath and thermostat in each high [and low] voltage compartment.
2. Wired to [external 120-volt power supply via enclosed toggle handle switch with thermal overload] [internal power supply from control transformer with secondary [fuse block and fuses] [circuit breaker]] in each cubicle.

P. Finish:

1. Multistage process applied to interior and exterior surfaces, joints, and blind areas prior to enclosure assembly.
   a. Pretreatment protective film.
   b. Baked epoxy finished coating.
   c. [Baked acrylic enamel top coating in accordance with IEEE C57.12.28.]
2. Color: [Gray finish as approved by [Owner.] [Engineer.] [Munsell 7GY3.29/1.5, olive green.] [Manufacturer’s standard.] [_____]
3. Tests:

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a. Salt-spray test in accordance with ASTM B117.
b. Humidity test in accordance with ASTM D2247 and ASTM D714.
c. Accelerated weather tests in accordance with ASTM G154, ASTM D659, and ASTM D523.
d. Adhesion tests in accordance with ASTM D3359, Method B and ASTM D2794.
e. Corrosion tests in accordance with ASTM D1654.
f. Abrasion tests in accordance with ASTM D4060.
g. Oil resistance testing with no shift in color, streaking, blistering, or loss of hardness.

2.05 HIGH VOLTAGE BUS

A. [Copper] [Aluminum] bus bar extending entire length of switchgear, bus supports [, future bus extensions,] and interconnections to have short-circuit rating equal to that of integrated assembly.

B. [Square edged, hard-drawn copper bar in accordance with ASTM B187.] [Aluminum bar with minimum 56 percent conductivity of annealed copper in accordance with ASTM B236.]

C. [Silver-plated copper-to-copper bar connection made with 1/2-inch by 13-inch stainless steel bolts with one flat-brass washer under bolthead and one flat washer and stainless steel split washer between flat washer and nut.] [Aluminum-to-aluminum bar connections made with 1/2-inch by 13-inch galvanized steel bolts with Belleview spring washers under bolthead and nut.]

D. Bus rated [600] [1,200]-ampere with provisions for [one] [two]-cable terminations per phase.

2.06 GROUND BUS

A. [Copper] [Aluminum] bus bar, bolted to nickel-plated steel brackets, extending throughout switchgear and having short-circuit rating equal to that of the integrated assembly.

B. [Square-edged, hard-drawn copper bar in accordance with ASTM B187.] [Aluminum bar with minimum 56 percent conductivity of annealed copper in accordance with ASTM B236.]

C. Minimum one welded in-place nickel-plated steel bracket per module with one Belleville spring washer per bolted bus bar connection.

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D. [Silver-plated copper-to-copper bar connections made with 1/2-inch by 13-inch stainless steel bolts with one flat brass washer under bolthead and one flat washer and stainless steel split washer between flat washer and nut.] [Aluminum-to-aluminum bar connection made with 1/2-inch by 13-inch galvanized steel bolts with Belleview spring washers under bolthead and nut.]

E. Two No. 2 through 500 kc mil [copper] [aluminum] ground cable connectors for connecting ground bus to station ground.

2.07 GROUND CONNECTION

A. [Copper] [Aluminum] ground connected, bolted to nickel-plated bracket having short-circuit rating equal to that of the integrated module.

B. Welded in-place nickel-plated, steel bracket with one Belleville spring washer.

C. Two No. 2 through 500 kc mil [copper] [aluminum] ground cable connections for connecting to station ground.

2.08 INSULATORS

A. Interrupter switch and fuse mounting insulators, insulated operating shafts, and push rods constructed of cycloaliphatic epoxy resin in accordance with NEMA C29.9 and NEMA C29.10.

2.09 ISOLATING THROUGH-BUSHINGS

A. BIL rated, nontracking, self-scouring, nonweathering, cycloaliphatic epoxy resin bushings between [bay No. _____ and bay No. _____] [all bays].

B. Maximum 9-1/2 inches overall length with 12-1/2 inches leakage distance between energized bus conductors and ground plane.

C. Close openings between bushings and bus conductors with semi-conducting grommet.

D. Rigid direct connections between bushing bus conductors and main bus conductors.

E. Formed homogeneous flange at ground plane interface.

F. Bushings secured to ground plane by clamps overlapping bushing flanges.

G. Drain channel installed above isolating through-bushings.

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2.10 INTERRUPTER SWITCHES

A. [External handle] [Power]-operated, nonfused, group-operated with quick-make quick-break mechanism for live, full load, open and close switching in accordance with IEEE C37.58.

B. Quick-make quick-break mechanism independent of switch [handle] [operator] speed.

C. Quick-make quick-break mechanism [integrally mounted to switch frame] [and] [integral part of switch] [as shown].

D. Externally, manually operated, nonremovable handle with provisions for padlocking in open and closed positions.

E. Single insulated shaft with blades and journals permanently molded in place for positive and inherently sequenced blade position.

F. One-piece, formed hard-drawn copper blades with silver-clad contact surfaces per phase for circuit closing, fault closing, continuous current carrying and circuit interruption.

G. Multifinger, convexed, silver-clad copper jaw contacts with stainless steel springs for constant contact pressure.

H. Equip each blade assembly with arc compressor, strain-guard terminals, and support insulators.

I. Circuit interruption with external arc or flame contained within interrupter, complete with vented exhaust through [labyrinthine muffler for 1,200-ampere switches] [and] [deionizing vents for 600-ampere switches].

J. Visible open gap when in open position.

K. Switch assembly and operator mounted on a rigid, welded steel frame.

L. [Switches rated 1,200-ampere] [, 600-ampere switches with 600-ampere fuses,] [and] [interance-bay] terminals to accommodate two cables per phase.

2.11 SWITCH OPERATORS

A. Switch operators installed behind hinged padlockable cover doors equipped with windows and gasketing between cover door and mounting surface.

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B. [Stored energy type with integral quick-make quick-break mechanism for opening and closing associated interrupter switch in response to a control signal and independent of charging motor speed or manual operating handle.]

C. Tripping solenoid opening and closing time not to exceed four cycles.

D. Quick-make quick-break mechanism charged by torque limiter equipped motor within 1-1/2 seconds after switch operation.

E. Local electrical trip-open and trip-closed pushbuttons [interlocked to prevent local control when source transfer is in automatic control].

F. Manual charging access port, interlocked to prevent operation of charging motor when access port is open and removable manual-charging handle.

G. Local mechanical trip-open and trip-close operation upon loss of control power.

H. Mounted on drawout carriage within grounded, metal-enclosed, low voltage compartment in switchgear stile with:

1. Decoupler on drawout carriage for testing and exercising switch operator.
2. Decoupled switch operator to allow for padlocking interrupter switch in open or closed position.
3. Mechanically interlocked to prevent recoupling switch operator unless in same open or closed position as interrupter switch.
4. Operational counter.

I. Visible targets to indicate:

1. Charged or discharged quick-make quick-break mechanism.
2. Operator switch-open or -closed position.
3. Interrupter switch-open or -closed position.
4. Coupled or decoupled operator position.

J. Stored energy type with integral quick-make quick-break mechanism for opening associated interrupter switch in response to a control signal and independent of manual charging handle.

K. Tripping solenoid opening time not to exceed four cycles.

L. Removable manual-operating handle for closing associated interrupter switch to recharge quick-make quick-break mechanism.

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M. Nondrawout operator mounted in switchgear stile.

N. Equipped with manual trip level for mechanical manual trip-open operation.

O. Visible targets to indicate open or closed position of associated interrupter switch.

P. A chain coupled to associated interrupter switch operating shaft for opening and closing interrupter switch by charging quick-make quick-break mechanism integrally mounted on interrupter switch frame.

Q. Motor drive equipped with torque limiter to open and close interrupter switch within 1-1/2 seconds.

R. Local electrical trip-open and trip-close pushbuttons [interlocked to prevent local control when source transfer is in automatic mode].

S. Manual-operating shaft with removable handle for switch operation upon loss of control power.

T. Mounted within grounded, metal-enclosed, low voltage compartment in switchgear stile with:

1. Decoupler for testing and exercising switch operator.
2. Mechanically interlocked to prevent recoupling switch operator unless in same open or closed position as interrupter switch.
3. Operational counter.

U. Visible targets to indicate:

1. Interrupter switch open or closed position.
2. Coupled or decoupled operation position.

V. Equipped with extra four-pole double-throw auxiliary switch coupled to switch operator.

W. Equipped with extra six-pole double-throw auxiliary switch coupled to interrupter switch.

X. Receptacle for attachment of remote control station for electrical trip-open and trip-close operation from adjacent area.

Y. Auxiliary tripping relay for remote supervisory operation.

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2.12 FUSES

A. Solid Material Power Fuse:

1. In accordance with NEMA SG 2.
2. End fitting, upper end pull ring fitting, blown-fuse target, expendable fuse unit, aluminum-bronze lower end fitting, and silencer.
3. Manufacturer and Product: [S&C Co.; Type SM-20.] [_____]

B. Electronic Power Fuse:

1. With fuse holder, expendable interrupting module, reusable control module, and blown-fuse target.
2. Interrupting module with main current section and fault-interrupting section arranged coaxially within single housing.
3. Control module with factory-sealed, cylindrical cast aluminum housing containing self-power electronic components and integrally mounted current transformers with no external control wiring or connections to ground.
4. Manufacturer and Product: [S&C Co.; Fault Filter.] [_____]

2.13 AUTOMATIC SOURCE TRANSFER

A. Source transfer control for [common-bus] [split-bus] primary selective system with transfer on loss and return of source voltage via capacitively coupled voltage sensor or two phases and a voltage transformer for sensing and control power on the third phase.

B. Normal condition with [one interrupter switch normally closed and one interrupter switch normally closed] [two interrupter switches normally closed and bus-tie switch normally open].

C. Control to monitor conditions of both sources and initiate automatic switching upon loss, or reduction of, [preferred] [either] voltage system.

D. Automatic switching to open the [preferred source interrupter switch and close the alternate source] [affected source interrupter switch and close the bus-tie] interrupter switch to restore power to the switchgear bus.

E. Return of normal voltage to affected source shall initiate retransfer to original configuration if in automatic mode, or await manual retransfer if in hold return mode.

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F. Control to automatic initiate retransfer to [preferred] [restored] source if [alternate source] [source in use] fails when in return mode.

G. Control to provide [open] [closed] transition on retransfer, as field programmed, when in automatic mode.

H. Control to continuously monitor negative-sequence voltage and initiate automatic switching when system unbalance exceeds predetermined value.

I. Solid state, microprocessor control modules located in grounded, metal-enclosed low voltage compartment in switchgear stile, behind hinged padlockable cover doors equipped with windows and gasketing between cover door and mounting surface.

J. Control Modules Complete with:

1. Liquid Crystal Display with Backlighting for:
    a. Operating characteristics.
    b. Operating parameters.
    c. Operational information menu.
    d. Selected diode lamp status messages.
    e. System events.
    f. Present status of discrete control input and outputs.
    g. Present voltage and current inputs.
2. Code Accessible Keypad for:
    a. Programming source transfer control operating characteristics and its voltage, current, and time-related operating parameters.
    b. Automatic calibration of known voltage on each source.
    c. Examining, by dedicated examine key, inputs and outputs.
    d. Analyzing, by dedicated event key, system events.
3. Light-Emitting Diode Lamps Indicating:
    a. Presents of acceptable high voltage on each source.
    b. Switch operator coupling and position status.
    c. Control automatic mode status.
    d. Access door closed and latched status.
    e. Control circuitry status.
    f. Built-in diagnostics status.
    g. Lockout condition.
4. Selector Switch for Manual or Automatic Operating Mode:
    a. Pushbuttons for electric trip-open and -closed operations when in manual mode.
    b. Automatic switching inhibited when in manual mode.

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5. Built-In Diagnostics for Analyzing System Events to Record for Each:
   a. System status.
   b. Source transfer control status.
   c. Display by dedicated event key.
6. Test Keys to:
   a. Simulate loss of voltage on each source.
   b. Check functioning of lamps, display, and keypad.
7. Simulate overcurrent condition on each source.
8. Overcurrent lockout to prevent automatic transfer into a fault, complete with reset key [and manual reset from remote location].
9. Remote Indication Provisions for Remote Monitoring:
   a. Presence or absence of preferred and alternate source voltage.
   b. Operating mode of source transfer mode.
   c. Status of selected diode lamps.
   d. Overcurrent lockout.
10. Supervisory control provisions for remote switch operations.
11. Test Panel for Checkout of:
   a. Source transfer scheme.
   b. Overcurrent lockout.
   c. Unbalance detection using external, adjustable, and three-phase source.
12. Gold over nickel-plated interconnecting cable connector pins and receptacle contacts and interconnecting cables.

K. Source transfer control system surge withstand capacity in accordance with IEEE C37.91.

2.14 OPEN-PHASE DETECTORS

A. Solid state device to monitor the phase sum of three-phase feeder's line-to-ground voltages via capacitively coupled voltage sensors on three-phases.

B. Located in grounded, metal-enclosed low voltage compartment in switchgear stile.

C. Field adjustable timer with range of 5 seconds to 30 seconds delay after detection of open-phase condition or voltage unbalance.

D. Equipped with trip indicator and reset pushbutton.

E. Open-phase detector surge withstand capacity in accordance with IEEE C37.90.1.

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2.15 SINGLE-PHASING PROTECTION

A. Solid state device to monitor current in each phase of feeder circuit using closed gap current sensors.

B. Located in grounded, metal-enclosed low voltage compartment in switchgear stile.

C. Field adjustable trip-level detector with range of 400 amperes to 2,400 amperes.

D. Field adjustable delay timer with range of 1 second to 35 seconds between detection of overcurrent and tripping operation.

E. 2-millisecond time delay before initiating field adjustable timer.

F. Field selective inrush restraint to inhibit 2-millisecond time delay relay for 1 second.

G. Reset if normal load current of 3.5-ampere or greater returns on all three phases before delay timer times out.

H. Blocking circuit to prevent tripping while overcurrent exceeds 600 amperes.

I. Red trip indicator target for operation of relay.

J. Indicating Lights with Push-To-Test Feature:

1. Elapsed time indicator for delay timer.
2. Pickup indicator when overcurrent exceeds trip-level setting.
3. Lamps to extinguish after operation for relays.

K. Test Jacks to:

1. Simulate proper functioning of three-phase overcurrent relays.
2. Verify pickup and trip levels.
3. Verify proper functioning of current sensors.

L. Overcurrent relays surge withstand capacity in accordance with IEEE C37.90.

2.16 CURRENT TRANSFORMER (CT)

A. Types:

1. Insulated dry indoor.
2. Window type for relaying and ground sensing.

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3. Wound type for metering.

B. Transformer Accuracy in Accordance with IEEE C57.13:

1. Class C20 or greater for relaying.
2. Class 1.2 maximum for imposed burden for metering.

C. [Rating: [5] [8] [15] kV], [[100] [200] [400] [600] [800] [1,200] /5 amperes.]

D. Mechanical Rating: Equal to short-time current carrying capability of circuit breakers.

E. Thermal Rating: Maximum 55 degrees rise above 30 degrees C ambient.

F. Size to operate continuously at rated primary current without insulation damage.

G. Identify polarity with standard mark or symbol.

H. Secondary Wiring: Install in [conduit] [PVC tubing] [or] [wiring trough].

I. Isolate from adjacent components and circuits by removable insulating or metal barriers.

J. Window type CTs accessible for replacement without removing high voltage insulated connections.

2.17 VOLTAGE SENSING DEVICES

A. Constant-current output, solid state devices equipped with secondary protective device and requiring no primary fuses.

B. To directly replace apparatus insulators at the [hinge end of fuses] [and] [lower terminal of interrupting switches].

C. Output voltage directly proportional to line-to-ground voltage with relay accuracy over an ambient temperature range of minus 40 degrees F to plus 60 degrees F.

D. Output connected to nonadjustable secondary burden.

E. Test jacks and adjustment screws for measurement and adjustment of voltage signal inputs.

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2.18 POTENTIAL TRANSFORMER (PT)

A. Type: Insulated dry, indoor.

B. Rating: [2,400] [4,200] [4,800] [7,200] [8,400] [12,000] [13,200] [14,400]/120-volt, single-phase with [60] [75] [110] kV BIL rating.

C. [One] [Two] [Three] transformers connected [phase-to-ground] [phase-to-phase].

D. Thermal Capacity: Minimum 55 degrees rise above 30 degrees C ambient.

E. Mechanical Rating: Equal to short-time current carrying capability of circuit breaker.

F. Accuracy classification in accordance with IEEE C57.13 for connected burden.

G. Primary Protection: Two integral mounted current-limiting fuses.

H. Secondary Protection: Single, separately mounted current-limiting fuse.

I. Identify polarity with standard marking or symbols.

J. [Mount on rollout carriage installed in metering module, complete with secondary wiring.]

K. [Primary and secondary terminals to be disconnected and the primary fuses grounded when rollout carriage is in open position.]

2.19 CONTROL TRANSFORMER

A. Type: Insulated dry indoor.

B. Rating:

1. [2,400] [4,160] [4,800] [7,200] [8,400] [12,000] [13,300] [_____]/240/120-volt, single-phase, three-wire with [60] [95] Kv BIL rating with two 2-1/2 percent taps above, and two 2-1/2 percent taps below, normal voltage.
2. kVA rating for control power, [_____] [and] [space heater] requirements plus 200VA for remote devices and future use.

C. [Stationary] [Drawout carriage] mounted in separate steel compartment.

D. Primary Protection: Two current-limiting fuses mounted on drawout carriage.

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E. Secondary Protection: [Fuses.] [Molded case circuit breakers.]

2.20 TERMINAL BLOCKS

A. Rating: 600 volts, 30-ampere minimum.

B. Type:

1. One-piece barrier, with strap screws.
2. Shorting type for current transformer leads.
3. Pull-apart control wiring terminal boards on all drawout units.

C. Provide for:

1. Conductors connecting to circuits external to switchgear.
2. Internal circuits crossing shipping splits.
3. Equipment parts requiring replacement and maintenance.

D. Spares: Minimum 20 percent spare unused terminals.

E. Grouped together terminal blocks for external circuit wiring leads.

F. 6-inch minimum space between columns of terminal blocks.

G. Permanently identify each terminal and columns of terminal blocks.

H. Manufacturer and Product: General Electric; Type EB-5.

2.21 CONTROL WIRING

A. NFPA 70, Type SIS, single-conductor, Class B, stranded copper, rated 600 volts for control, instrumentation, and power circuits.

B. Individual 7-strand, copper conductors, twisted and covered with a 100 percent aluminum, polyester shield with tinned copper drain wire and overall outer jacket, rated 600 volts, 90 degrees C minimum for transducer output and analog circuits.

C. Conductor Lugs: Pre-insulated, self-locking, spade type with reinforced sleeves.

D. Wire Markers: Each wire individually identified with permanent markers at each end.

E. Internal circuit wiring crossing shipping splits to have plug connectors.

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F. Splices: Not permitted.

2.22 INDICATING METERS

A. Semiflush mounted, square switchboard type.

B. One percent accuracy class in accordance with ANSI C39.1.

C. Anti-parallax scale with convex clear shadow-proof glass covers.

D. White dials with black points and markings.

E. Indicating Scale: Nominal 250-degree circular.

F. Zero Adjustment: External zero capability.

G. Control Switches:

1. Type: Rotary, cam-operated, with two contacts per stage.
2. Silver contacts and maintained positive contact position.
3. Wiping action closing contacts.
4. Adjacent contacts separated by barriers.
5. Contact assembly enclosed in removable cover.
6. Rating: Minimum 20 amperes with 600-volt insulation.
7. Marked escutcheon plates.
8. Operating Handles:
   a. Voltmeter Switches: Four-position, phase-to-phase voltage and OFF.
   b. Ammeter Switches: Four-position three-phase currents and OFF.
   c. Transfer and Auxiliary Switches: Oval type with arrow.

H. ac Voltmeters:

1. Register Size: 6.9-inch scale length, 250-degree arc.
2. Full scale [150] [250]-volt rated movement calibrated for [3,000] [5,250] [15,000] [_____] volts, 60-Hz.
3. Taut suspension type.

I. ac Ammeters:

1. Register Size: 6.9-inch scale length, 250-degree arc.
2. Full scale [5] [6.5]-ampere rated movement.
3. Taut suspension type.

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J. Watthour Meters:

1. Clock register for kilowatt hours.
2. Current rated at 2.5 amperes for three-phase, [three] [four]-wire, [grounded] [ungrounded] neutral.
3. Elements: [Two.] [Two and one-half.] [Three.]

K. Watthour/Demand:

1. Clock register for kilowatt hours and demand.
2. [Secondary] [Primary]-read ratio with [15] [30]-minute intervals.
3. Current rated at 2.5 amperes for three-phase, [three] [four]-wire, [grounded] [ungrounded] neutral.
4. Elements: [Two.] [Two and one-half.] [Three.]

L. Power Factor Meters:

1. Clock register left for lagging power factor and right for leading power factor.
2. Taut suspension type with built-in transducer for dc signal.
3. Current rated at 5 amperes for three-phase, [three] [four]-wire, [grounded] [ungrounded] neutral.

2.23 SURGE PROTECTION

A. Set of three metal oxide type, in accordance with IEEE C62.11 and NEMA LA 1.

B. Connect to line side of main [switch] [with fuses] and ground to switchgear ground bus.

C. Class: [Station.] [Intermediate.] [Distribution.]

D. Rating: [3 kV for 4.16 kv] [6 kV for 6.9 kV] [9 kV for 12 kV] [12 kV for 13.8 kV] [impedance grounded] [ungrounded] system.

2.24 LABELING

A. Nonmetallic, self-sticking with integral lettering and symbols.

B. Warning Labels:

1. Attach to exterior surface of each external door and hinged-bolted panel labels reading “CAUTION-HIGH VOLTAGE-KEEP OUT”.

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2. Attach to internal surface of each protective screen, labels reading "DANGER-HIGH VOLTAGE-KEEP OUT-QUALIFIED PERSONS ONLY."
3. Provide inside each interrupter switch access door, labels reading "SWITCH BLADES MAY BE ENERGIZED IN ANY POSITION."
4. Provide inside each fuse access door, labels reading "FUSES MAY BE ENERGIZED IN ANY POSITION."

2.25 NAMEPLATES

A. Deep etched aluminum riveted to door surface.

B. Integrated Switchgear Assembly Nameplate on External Surface of [Center] Bay Door Indicating:

1. Voltage ratings; kV nominal, maximum, and BIL.
2. Main bus continuous ampere rating.
3. Short-circuit ratings in amperes rms symmetrical and mVA three-phase symmetrical at nominal voltage.
4. Momentary and fault-closing rms symmetrical amperes.
5. Enclosure category.
6. Manufacturer's drawing number.

C. Individual Bay Nameplate on Interior Door Surface Indicating:

1. Switch continuous and interrupting ampere ratings.
2. Maximum fuse rating.
3. Catalog numbers of [fuse units and refill units] [interrupting module] [or control module].
4. Enclosure category.

2.26 FAULT INDICATORS

A. Factory installed with sensing transformer located at cable entrances to each [incoming service] [and] [branch circuit] [interrupter switches] [and] [fuse interrupters].

B. As specified in Section 26 05 05, Conductors.

2.27 ACCESSORIES

A. One fuse handling tool compatible with installed fuses.

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B. [One] [Two] [_____] sets of three grounding jumpers, 3 feet in length, complete with storage bag for each set.

C. One voltage tester with audio and visual signals, batteries, shotgun clamp-stick adapter, and storage case.

D. [Six] [Eight] feet, 5-1/2 inches long, shotgun clamp-stick with canvas storage bag.

E. [Solid material fuse [, end fittings] [, holders] and [fuse] [refill] units for each installed fuse size.]

F. Electronic fuse [, interrupting module,] [and] [control module,] and [fuse] [refill] units for each installed fuse size.

2.28 KEY INTERLOCKS

A. Mechanical-lock cylinder located at each [main] [and] [tie] interrupter switch module.

B. [Superior] [Corbin] [Kirk] type keys and lock cylinders.

C. Keys to be captive when interrupter switches are closed.

D. Two main and [[one] [two] tie] interrupter switch arrangement.

E. [Two] [Three] keys available for each group of [three] [four] locks.

2.29 SOURCE QUALITY CONTROL

A. Switchgear assembly production tested in accordance with IEEE C37.20.3.

B. Fuses production tested in accordance with IEEE C37.46.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install equipment in accordance with manufacturer’s instructions and recommendations.

B. Secure equipment to [floor] [concrete pad] with anchor bolts of sufficient number for specified seismic conditions.

C. Install equipment plumb and in longitudinal alignment with wall.

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A. Tighten current-carrying bolted bus connections and enclosure framing and panel bolts to manufacturer's recommendations.

D. Coordinate terminal connections with installation of secondary feeders.

3.02 MANUFACTURER'S SERVICES

A. Furnish manufacturer's representative [in accordance with Section 01 43 33, Manufacturers' Field Services,] for the following services at Site, for minimum person-days listed below, travel time excluded:

1. [_____] person-days for installation assistance, final adjustment, and initial energization of equipment.
2. [_____] person-days for [functional] [and] [performance] testing and completion of Manufacturer's Certificate of Proper Installation.
3. [_____] person-days for post-startup training.

B. Furnish training of [Owner's] [_____] personnel at such times as requested by [Owner] [_____].

END OF SECTION

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SECTION 26 13.16.02
PAD-MOUNTED SWITCHGEAR

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM):
   a. B117, Standard Practice for Operating for Salt Spray (Fog) Apparatus.
   b. B187, Standard Specification for Copper Bar, Bus Bar, Rod, and Shapes.
   c. B236, Standard Specification for Aluminum Bars for Electrical Purposes (Bus Bars).
   d. D523, Standard Test Method for Specular Gloss.
   e. D543, Standard Practice for Evaluating for Resistance of Plastics to Chemical Reagents.
   f. D570, Standard Test Method for Water Absorption of Plastics.
   g. D635, Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position.
   h. D714, Standard Test Method for Evaluating Degree of Blistering of Paints.
   i. D756, Standard Practice for Determination of Weight and Shape Changes of Plastics under Accelerated Service Conditions.
   j. D790, Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastic and Electrical Insulating Materials.
   k. D1654, Standard Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments.
   l. D2247, Standard Practice for Testing Water Resistance of Coatings in 100 Percent Relative Humidity.
   m. D2794, Standard Test Method for Resistance or Organic Coatings to the Effects of Rapid Deformation.
   n. D3359, Standard Test Methods for Measuring Adhesion by Tape Test.
   o. D4060, Standard Test Method for Abrasion Resistance to Organic Coatings by the Taber Abraser.
   p. D4214, Test Method for Evaluating Degree of Chalking of Exterior Paint Films.
   q. G154, Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials.

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2. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
   a. 386, Standard for Separable Insulated Connector Systems for Power Distribution Systems above 600V.
   b. C37.20.3, Metal Enclosed Interrupter Switchgear.
   c. C37.46, Specifications for Power Fuses and Fused Disconnecting Switches.
   d. C37.57, Metal Enclosed Interrupter Switchgear Assemblies—Conformance Testing.
   e. C37.58, Indoor AC Medium-Voltage Switches for Use in Metal-Enclosed Switchgear—Conformance Test Procedures.
   f. C37.91, Guide for Protective Relay Applications to Power Transformers.
   g. C57.12.28, Switchgear and Transformers, Pad-Mounted Equipment, Enclosure Integrity.
   h. C62.11, Metal-Oxide Surge Arrestors for Alternating-Current Power Circuits (>1 KV).
3. National Electrical Manufacturers Association (NEMA):
   a. C2, National Electrical Safety Code.
   b. C29.9, Wet-Process Porcelain Insulators - Apparatus Post-Type.
   c. C29.10, Wet Process Porcelain Insulators - Indoor Apparatus Type.
   d. LA 1, Surge Arrestors.
   e. SG 2, High Voltage Fuses.
4. National Fire Protection Association (NFPA): 70, National Electrical Code (NEC).

1.02 SUBMITTALS

A. Action Submittals:

1. Descriptive product information.
2. Dimensional drawings.
3. Itemized bill of material.
4. Operational description.
5. Installation instructions.
6. Switchgear configurations.
7. Interrupter switch data.
8. Bus data.
9. Fuse data and time-current characteristics on transparencies.
10. [Power operator [and source transfer controller with voltage sensors] data and circuitry.]
11. [Conduit entrance locations.]
12. [Concrete pad details.]

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13. [Base spacer details.]
14. [Polymer concrete vault details.]
15. [Anchoring details.]
16. Seismic anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Seismic Anchorage and Bracing.

B. Informational Submittals:

1. Seismic anchorage and bracing calculations as required by Section 01 88 15, Seismic Anchorage and Bracing.
2. Component and attachment testing seismic certificate of compliance as required by Section 01 45 33, Special Inspection [, Observation,] and Testing.
3. [Certified] factory test reports.
4. Manufacturer's installation instructions.
5. Operation and Maintenance Data: As specified in Section 01 78 23, Operation and Maintenance Data.
6. [Manufacturer's Certificate of Proper Installation, in accordance with Section 01 43 33, Manufacturers' Field Services.]

1.03 EXTRA MATERIALS

A. Furnish, tag, and box for shipment and storage the following special tools and material:

1. [Fuse handling tool, compatible with installed fuses.]
2. [[One] [Two] [_____] sets of three grounding jumpers 3 feet in length, complete with canvas storage bag for each set.]
3. [Voltage tester with audio and visual signals, batteries, shotgun clamp-stick adapter, and storage case.]
4. [[6] [8] feet 5-1/2 inches long shotgun clamp stick with canvas storage bag.]
5. [Solid material fuse [end fittings,] [holders,] and [fuse,] [refill] units for each installed fuse size.]
6. [Electron fuse [interrupting module] [and] [control module] and [fuse] [refill] units for each installed fuse size.]

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. S&C Co.

B. [_____]

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C. [No “or-equal” or substitute products will be considered.]

D. Provide pad mounted switchgear that is the product of a single manufacturer. Assembled units with component parts of several manufacturers will not be acceptable with the exception that minor items as terminal blacks, test switch, wiring, etc., may be manufactured by others.

2.02 GENERAL

A. Equipment suitable for [4,160] [12,500] [13,200] [13,800] [_____] volts, three-phase, [three-wire] [four-wire] [_____] [solid] [low resistance] [high resistance] [grounded-wye] [ungrounded]] electrical system having an available short-circuit current at line terminals of [_____] amperes rms symmetrical [as shown].

B. Pad mounted switchgear complete with self-supporting enclosure for [elbow-connected encased] [directly operable accessible] components.

C. Switchgear shall be [manually operated] [power operated with [remote supervisory control] [and] [automatic source transfer].]

D. [Radial] [Primary selective] [and] [looped-primary] [_____] interrupter switch configuration as shown on one-line diagram.

E. Design, test, and assemble in accordance to IEEE C37.20.3, IEEE C37.57, and IEEE C57.12.28.

F. Operating Conditions:

1. Ambient Temperature: Maximum [40] [45] [_____] degrees C.
2. Equipment shall be fully rated without derating for these operating conditions.

G. Anchor Bolts: [Galvanized,] [Type 316 stainless steel,] 5/8-inch diameter, length sized by manufacturer, and as specified in Section 05 50 00, Metal Fabrications.

2.03 EQUIPMENT RATINGS

1. Integrated switchgear assembly ratings at 60-Hz.
2. Voltage: 14.4 kV nominal, 17.0 kV maximum.
3. Insulation Level: 95 kV BIL.
4. Bus Current: [200] [and] [600] amperes continuous [, as shown on one-line diagram].

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5. Three-Pole Interrupter Switches:
   a. Current: [200] [and] [600] continuous amperes, [200] [600] load dropping amperes.
   b. Two-Time Duty-Cycle Fault Closing: 22,400 amperes rms asymmetrical.
6. Fuses with Integral Load Interrupter:
   a. Current: [200] [200E] [200K] [400] maximum amperes, [200] [400] load dropping amperes.
   b. Two-Time Duty-Cycle Fault Closing: 13,000 amperes rms asymmetrical.
7. Short-Circuit Rating: [14,000] [12,500] amperes rms symmetrical, [350] [310] mVa three-phase symmetrical at rated nominal voltage.

B. Fault-closing ratings to equal, or exceed, the short-circuit ratings of the pad mounted switchgear with:

1. Momentary and two-time duty-cycle rating of switches.
2. Momentary rating of bus.
3. Interrupting ratings of fuses.
4. [One-time duty-cycle capabilities of fuses with integral load interrupters.]

2.04 ENCLOSURE

A. Monocoque, freestanding, self-supporting construction with welded structural and butt joints having external seams ground flush and smooth.

B. Enclosure sides, doors, roof, bottom flange, [base spacer,] and steel barriers constructed with 11-gauge hot-rolled, pickled, and oiled sheet steel.

C. Tamper resistant with no externally accessible hardware in accordance with security requirements of IEEE C57.12.28.

D. Removable lifting tabs bolted to blind-tapped sockets with resilient anticorrosion material between tabs and enclosure.

E. Enclosure Base:

1. Consisting of continuous 90-degree steel flanges welded to enclosure and turned inward for bolting to [concrete pad] [polymer concrete base] [base spacer].
2. Resilient closed-cell PVC gasket applied between flange bottom and [concrete vault] [polymer concrete vault] [base spacer].
3. Coat enclosure flange with wax-based anticorrosion moisture barrier.

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F. Enclosure Roof:

1. Overlapping edges creating mechanical maze and ventilating openings.
2. Insulating nondrip compound applied to underside.

G. Doors:

1. Constructed with edge flanges overlapping door openings to form mechanical maze.
2. Two extruded-aluminum hinges with Type 316 stainless steel pins, full length of door extruded-aluminum interlocking supports, and stainless steel mounting hardware for each door.
3. Access door to power fuses equipped with storage space for replacement fuse components.
4. Hidden galvanized steel door holders swinging outward when door is in opened position.

H. Door Latch:

1. Automatic positive action, three-point, spring-loaded latching mechanism for each door or set of doors.
2. Pentahead socket wrench to actuate mechanism for unlatching door and recharging spring for next closing operation in same motion.
3. Tamper-proof padlocking shackle coordinated with latches to prevent:
   a. Unlatching mechanism until padlock is removed.
   b. Inserting padlock until mechanism is completely latched closed.

I. Finish:

1. Multistage process applied to interior and exterior surfaces, joints, and blind areas prior to enclosure assembly.
   a. Pretreatment protective film.
   b. Baked epoxy finished coating.
   c. Baked acrylic enamel top coating in accordance with IEEE C57.12.28.
2. Color: [Munsell 7GY3.29/1.5 olive green.] [Gray.] [Manufacturer’s standard.] [_____]
3. Tests:
   a. Salt-spray test in accordance with ASTM B117.
   b. Humidity test in accordance with ASTM D2247 and ASTM D714.
   c. Accelerated weather tests in accordance with ASTM G154, ASTM D4214, and ASTM D523.

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d. Adhesion tests in accordance with ASTM D3359, Method B and ASTM D2794.
e. Corrosion tests in accordance with ASTM D1645.
f. Abrasion tests in accordance with ASTM D4060.
g. Oil resistance testing with no shift in color, streaking, blistering, or loss of hardness.

2.05 BARRIERS

A. In compliance with NEMA C2.

B. Full-length steel barriers separating side-by-side compartments.

C. BIL Rated Fiberglass-Reinforced Polyester Barriers:

1. Fixed interphase and end barriers for each interrupter switch and each set of fuses.
2. Front and rear compartments [and tie bus] isolated by fixed barriers.
3. [Hanging front barriers with window panel, insertable into open gap when switch is opened, for each interrupter switch.]
4. [Hanging front barrier, insertable into open gap when fuse is removed for each fuse.]
5. [Inner barrier panel, secured in place with recessed pentahead bolts, for each high voltage door.]
6. [Hanging front barrier for each door opening.]

2.06 COMPONENT ENCASEMENT

A. In compliance with NEMA C2.

B. Switch and fuse components, and interconnecting bus enclosed in inner air-insulated, grounded, steel compartment bulkheads and 22-gauge galvanized steel floor.

C. Resilient gasketing between compartment bulkheads and enclosure roof and sides.

D. Dense closed-cell gaskets between fuse-handling mechanisms and compartment bulkhead.

E. Full-length steel barriers separating adjoining termination compartments.

F. BIL rated fiberglass-reinforced polyester barriers to isolate interphase bus from components.

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G. Wide-angle viewing window in bulkhead for visual verification of each interrupter switch position.

H. Viewing window in bulkhead adjacent to each fuse-handling mechanism for visual check of blown-fuse indicators.

I. Parking stands adjacent to each 600-ampere rated bushing and 200-ampere rated bushing well.

J. Cable guides at each fuse-handling mechanism.

2.07 GROUND-CONNECTION PADS

A. Provided in each compartment on inside at bottom door stile with momentary rating equal to, or exceeding, short-circuit ratings of switchgear.

B. Constructed of 5/8-inch-thick nickel-plated steel, with oxide inhibitor and sealant coating, welded to enclosure.

C. [Ground studs of each fuse terminal plus one ground stud at ground connection pad in each [fuse compartment] [and] [switch terminals].]

2.08 GROUND RINGS

A. Provide full width in each switch compartment and at each fuse-handling mechanism.

B. Constructed of 3/8-inch-thick copper bolted to the metal enclosure inside at bottom door stile.

C. Cable guides at each fuse-handling mechanism ground ring.

2.09 INSULATORS

A. Interrupter switch and fuse mounting insulators, insulated operating shafts, and push rods constructed of cycloaliphatic epoxy resin in accordance with NEMA C29.9 and NEMA C29.10.

2.10 HIGH VOLTAGE BUS

A. [Copper] [Aluminum] bus bar and bus supports.

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B. [Square-edged, hard-drawn copper bar in accordance with ASTM B187.] [Aluminum bar with minimum 56 percent IACS conductivity of annealed copper in accordance with ASTM B236.]

C. [Silver-plated copper-to-copper bar connection made with 1/2-inch by 13-inch stainless steel bolts with one flat-brass washer under bolthead and one flat washer and stainless steel split washer between flat washer and nut.] [Aluminum-to-aluminum bar connections made with 1/2-inch by 13-inch galvanized steel bolts with Belleview spring washers under bolthead and nut.]

D. Bus rated [600] [1,200]-ampere with provisions for [one] [two]-cable terminations per phase.

2.11 INTERRUPTER SWITCHES

A. External handle-operated, three-pole, nonfused, group-operated with quick-make quick-break mechanism for live, full load, open and close switching in accordance with IEEE C37.58.

B. Single insulated shaft with blades and journals permanently molded in-place for positive and inherently sequenced blade position.

C. One-piece, formed hard-drawn copper blades with silver-clad contact surfaces.

D. Multifinger, convexed, silver-clad copper jaw contacts with stainless steel springs for constant contact pressure.

E. Equip each switchblade assembly with arc compressor, [strain-guard terminals] [600-ampere bushings with removable threaded studs,] and support insulators.

F. Mount each switch assembly [, bushings with adjacent elbow parking stands,] and operator on a rigid, welded steel frame.

G. Switch [and bus compartment] terminals to accommodate [one] [two] cables per phase.

H. [Mounting provisions only for] base mounted metal-oxide type distribution class surge arrests rated [9] [10] [_____] kV at all source switch terminals.]

I. [Bushings, with removable threaded studs, to be constructed of cycloaliphatic epoxy resin and in compliance with IEEE 386.]

J. [Shaft lock for each switch.]

K. [Key interlocks to prevent paralleling of switches in Compartments 1 and 2.]

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L. [Key interlocks to prevent opening of fuse-terminal compartment doors unless all switches are locked open.]

2.12 FUSE INTERRUPTERS

A. Disconnect style interrupter switches suitable for [solid material] [electronic] power fuses, complete with steel base, insulators, [terminal pads,] [loadbreak connector,] mounting contacts, and lower hinge and pull-ring operated latch.

B. Fuse-interrupter mounted on a fuse-handling mechanism with mechanical interlock to prevent fuse access before opening the loadbreak connector at the fuse terminal.

C. Fuse mounting jaw contacts with integral load interrupter for live switching with hookstick.

D. Cycloaliphatic epoxy resin housing for load interrupters.

E. Load interrupters with continuous current path, self-resetting, separate contacts for fault-closing and load currents, and self-guiding fuse hinge.

F. Integral load interrupters to have one-time duty-cycle fault-closing capability equal to interrupting rating of fuse, and two-time duty-cycle fault-closing capability of 13,000-ampere rms asymmetrical at 14.4 kV.

G. Equip each fuse interrupter with [tin-plated copper terminal pads having two-position adapter] [loadbreak connector and 200-ampere bushing well having parking stand mounted adjacent to interrupter].

H. [Bushing wells to be constructed of cycloaliphatic epoxy resin and in compliance with IEEE 386.]

2.13 FUSES

A. Solid Material Power Fuse:

1. In accordance with NEMA SG 2.
2. End fitting, upper end pull ring fitting, blown-fuse target, expendable fuse unit, aluminum-bronze lower end fitting, and silencer.
3. Manufacturer and Product: [S&C Co.; Type SM-20.] [_____]

B. Electronic Power Fuse:

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1. With fuse holder, expendable interrupting module, reusable control module, and blown-fuse target.
2. Interrupting module with main current section and fault-interrupting section arranged coaxially within single housing.
3. Control module with factory-sealed, cylindrical cast aluminum housing containing self-power electronic components and integrally mounted current transformers with no external control wiring or connections to ground.
4. Manufacturer and Product: [S&C Co.; Fault Filter.] [_____]

2.14 AUTOMATIC SOURCE TRANSFER

A. Source transfer control for primary selective system with transfer on loss and return of source voltage via voltage sensors.

B. Complete with switch operators and source transfer controller, voltage sensors, switch operational counters, and accessories.

C. Installed in low voltage, steel-enclosed, grounded control compartment having fully gasketed door openings.

D. Interrupter Switch Operators:

1. Stored energy, motor-charged operators with automatic solenoid trip-open and trip-closed operation.
2. Operators to automatically charge when voltage is present on associated source.
3. Quick-make quick-break mechanism to operate within 10 cycles, excluding any intentional time delay.
4. Complete with decoupler without affecting position of switch.
5. Open/close pushbuttons for tripping quick-make quick-break mechanism.
6. Manual handle for charging and tripping quick-make quick-break mechanism.
7. Operator Targets to Indicate:
   a. Quick-Make Quick-Break Mechanism:
      1) Charged.
      2) Discharged.
   b. Operator Position:
      1) Switch-open.
      2) Switch-closed.
8. Interrupter switch target to indicate open or closed positions.
9. Three-Position Operation Selector:
   a. Operating Position for:
      1) Electrical and manual operation of switch.

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2) Exercising and testing operator with stored energy operator is decoupled without opening or closing interrupter switch.

b. Lock position to prevent electrical and manual operation when padlocked.

c. Charging position permits manual charging of quick-make quick-break mechanism while prohibiting electrical and manual tripping.

E. [Equip switch with mechanical antiparalleling device to prevent both source switches from being closed.]

F. Voltage Sensors:

1. Constant current output device producing output voltage directly proportional to line-to-ground voltage for three-phase signal sensing voltage, control power, and motor charging and tripping power.
2. Three sensors for each source, replacing the lower apparatus insulators of the interrupter switch, and having BIL and dielectric characteristics equivalent to replaced insulators.
3. Relay accuracy ambient temperature range of minus 40 degrees F to plus 160 degrees F.
4. Voltage sensor's secondary conductors shielded from medium voltage and directly connected to variable burden resistors for field adjustment of voltage sensor outputs.

G. Return of normal voltage to affected source shall initiate retransfer to original configuration if in automatic mode, or await manual retransfer if in hold return mode.

H. Control to automatically initiate retransfer to preferred source if alternate source fails when in window mode.

I. Control to provide [open] [closed] transition on retransfer, as field programmed, when in automatic mode.

J. Control to continuously monitor negative-sequence voltage and initiate automatic switching when system unbalance exceeds predetermined value.

K. Solid state, microprocessor control modules located in grounded, metal-enclosed low voltage compartment in switchgear stile, behind hinged padlockable cover doors equipped with windows and gasketing between cover door and mounting surface.

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L. Control Modules Complete with:

1. Liquid Crystal Display with Backlighting for:
   a. Operating characteristics.
   b. Operating parameters.
   c. Operational information menu.
   d. Selected diode lamp status messages.
   e. System events.
   f. Present status of discrete control input and outputs.
   g. Present voltage and current inputs.
2. Code Accessible Keypad for:
   a. Programming source transfer control operating characteristics and its voltage, current, and time-related operating parameters.
   b. Automatic calibration of known voltage on each source.
   c. Examining, by dedicated examine key, inputs and outputs.
   d. Analyzing, by dedicated event key, system events.
3. Light-Emitting Diode Lamps Indicating:
   a. Presents of acceptable high voltage on each source.
   b. Switch operator coupling and position status.
   c. Control automatic mode status.
   d. Access door closed and latched status.
   e. Control circuitry status.
   f. Built-in diagnostics status.
   g. Lockout condition.
4. Selector Switch for Manual or Automatic Operating Mode:
   a. Pushbuttons for electric trip-open and -closed operations when in manual mode.
   b. Automatic switching inhibited when in manual mode.
5. Built-In Diagnostics for Analyzing System Events to Record for Each:
   a. System status.
   b. Source transfer control status.
   c. Display by dedicated event key.
6. Test Keys to:
   a. Simulate loss of voltage on each source.
   b. Check functioning of lamps, display, and keypad.
7. Simulate overcurrent condition on each source.
8. Overcurrent lockout to prevent automatic transfer into a fault, complete with reset key [and manual reset from remote location].
9. Remote Indication Provisions for Remote Monitoring:
   a. Presence or absence of preferred and alternate source voltage.
   b. Operating mode of source transfer mode.
   c. Status of selected diode lamps.
   d. Overcurrent lockout.

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10. Supervisory control provisions for remote switch operations.
11. Test Panel for Checkout of:
    a. Source transfer scheme.
    b. Overcurrent lockout.
    c. Unbalance detection using external, adjustable, and three-phase source.
12. Gold over nickel-plated interconnecting cable connector pins and receptacle contacts and interconnecting cables.

M. Remote control receptacle for each stored-energy operator to permit open/close operation from an adjacent location, including the remote-control station.

N. Source transfer control system surge withstand capacity in accordance with IEEE C37.91.

2.15 CONTROL WIRING

A. NFPA 70, Type SIS, single-conductor, Class B, stranded copper, rated 600 volts for control, instrumentation, and power circuits.

B. Individual seven-strand, copper conductors, twisted and covered with a 100 percent aluminum, polyester shield with tinned copper drain wire and overall outer jacket, rated 600 volts, 90 degrees C minimum for transducer output and analog circuits.

C. Conductor Lugs: Preinsulated, self-locking, spade type with reinforced sleeves.

D. Wire Markers: Each wire individually identified with permanent markers at each end.

E. Internal circuit wiring crossing shipping splits to have plug connectors.

F. Splices: Not permitted.

2.16 SURGE PROTECTION

A. Sets of three metal-oxide, in accordance with IEEE C62.11 and NEMA LA 1.

B. Base mounted at switch terminals and bus terminals in Compartments 1 and 2.

C. Connect to line side of switch terminals and ground to switchgear ground bus.

D. Class: [Intermediate.] [Distribution.]

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E. Rating: [3 kV for 4.16 kV] [6 kV for 6.9 kV] [9 kV for 12 kV] [12 kV for 13.8 kV] [impedance grounded] [ungrounded] system.

2.17 BASE SPACERS

A. Steel [compartmented] [noncompartmented] type bolted to enclosure flange and anchor to on-grade concrete pad.

B. [Spacer height of [6] [12] [18] [24] inches.]

C. Complete with resilient closed-cell gasket between bottom flange and concrete pad.

D. Finish identical to that specified for enclosure finish.

2.18 POLYMER CONCRETE VAULT

A. Precast vault constructed of an aggregate consisting of sand and gravel bound together with polymer and reinforced with continuous woven glass fibers and tested in accordance with ASTM D543, Section 7, Proceed 1; ASTM D756, Proceed E; ASTM G154; ASTM D570; ASTM D790; and ASTM D635.

B. One-piece construction, open top with inward turned flange sized to accommodate switchgear base, with open bottom having tapered footing [anchored] [embedded] in underground, reinforced concrete pad.

C. [Vault Depth: [18] [24] [36] [_____] inches.]

D. Manufacturers:

1. Quazite Corp.
2. Armocast Products Co.

2.19 LABELING

A. Nonmetallic, self-sticking with integral lettering and symbols.

B. Warning Labels:

1. Attach to exterior surface of each external door labels reading CAUTION—HIGH VOLTAGE-KEEP OUT.
2. Attach to internal surface of each external door and on all barriers used to prevent access to live parts, labels reading DANGER—HIGH VOLTAGE—KEEP OUT—QUALIFIED PERSONS ONLY.

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3. Provide inside each interrupter switch access door, labels reading SWITCH BLADES MAY BE ENERGIZED IN ANY POSITION.
4. Provide inside each fuse access door, labels reading FUSES MAY BE ENERGIZED IN ANY POSITION.

C. Rating Labels: Attach inside each door, or set of double doors, labels indicating:

1. Voltage rating.
2. Main bus continuous rating.
3. Short-circuit ratings in amperes rms symmetrical and mVa three-phase symmetrical at rated nominal voltage.
4. Fuse type.
5. Fuse rating, including duty-cycle fault-closing capability.
6. Interrupter switch ratings, including duty-cycle fault-closing and short time momentary, amperes rms asymmetrical and 1 second, amperes rms symmetrical.

D. Connection Labels: Attach inside each door, or set of double doors, and inside each switch-operating hub access cover, labels showing three-line connection diagram for interrupter switches, fuses with integral load interrupter, and bus along with manufacturer's model number.

E. Phase identification numbers 1, 2, and 3 above each phase connection at each fuse unit and interrupter switch.

2.20 NAMEPLATES

A. Deep etched aluminum on outside of each door, or set of double doors, indicating manufacturer's name, catalog number, model number, date of manufacture, and serial number.

B. Riveted to door surface.

2.21 ACCESSORIES

A. [One fuse handling tool compatible with installed fuses.]

B. [[One] [Two] [_____] sets of three grounding jumpers, 3 feet in length, complete with storage bag for each set.]

C. [One voltage tester with audio and visual signals, batteries, shotgun clamp-stick adapter, and storage case.]

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D. [[6] [8] feet, 5-1/2 inches long, shotgun clamp-stick with canvas storage bag.]

E. [Solid material fuse [, end fittings] [, holders] and [fuse] [refill] units for each installed fuse size.]

F. [Electronic fuse [, interrupting module] [and] [control module], and [fuse] [refill] units for each installed fuse size.]

2.22 KEY INTERLOCKS

A. Mechanical lock cylinder located at each [interrupter switch shaft] [fuse termination compartment door] [and] [paralleling switches in compartments one and two] [as shown].

B. Key and Lock Cylinder Type: [Superior.] [Corbin.] [Kirk.]

C. [Two] [Three] [_____] keys available for each group of [three] [four] [_____] locks for loop primary distribution systems.

2.23 FAULT INDICATORS

A. Factory installed with sensing transformer located at cable entrances to each [incoming service] [and] [branch circuit] [interrupter switches] [and] [fuse interrupters].

B. As specified in Section 26 05 05, Conductors.

2.24 SOURCE QUALITY CONTROL

A. Switchgear assembly shall be production tested in accordance with IEEE C37.20.3.

B. Fuses shall be production tested in accordance with IEEE C37.46.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install equipment in accordance with manufacturer’s instructions and recommendations.

B. Secure equipment to [concrete pad] [polymer concrete vault] with anchor bolts of sufficient size and number adequate for specified seismic conditions.

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C. Tighten current-carrying bolted bus connections and enclosure framing and panel bolts to manufacturer's recommendations.

D. Coordinate terminal connections with installation of secondary feeders.

3.02 MANUFACTURER'S SERVICES

A. Furnish manufacturer's representative [in accordance with Section 01 43 33, Manufacturers' Field Services,] for the following services at Site, for minimum person-days listed below, travel time excluded:

1. [_____] person-days for installation assistance, final adjustment, and initial energization of equipment.
2. [_____] person-days for [functional] [and] [performance] testing and completion of Manufacturer's Certificate of Proper Installation.
3. [_____] person-days for post-startup training.

B. Furnish training of [Owner's] [_____] personnel at such times as requested by [Owner] [_____].

END OF SECTION

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SECTION 26 14 13
SWITCHBOARDS

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. National Electrical Manufacturers Association (NEMA):
   a. PB 2, Deadfront Distribution Switchboards.
   b. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
2. National Fire Protection Association (NFPA): 70, National Electrical Code (NEC).
3. Underwriters Laboratories (UL):
   a. 489, Standard for Safety for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit Breaker Enclosures.
   b. 891, Standard for Safety for Switchboards.
   c. 1561, Standard for Safety for Dry-Type General Purpose and Power Transformers.

1.02 SUBMITTALS

A. Action Submittals:

1. Descriptive product information.
2. Itemized Bill of Material.
3. Dimensional drawings.
4. Operational description.
5. One-line, three-line, and control schematic drawings.
6. Connection and interconnection drawings.
7. Circuit Breakers: Copies of time-current characteristics.
8. [Ground Fault Protection: Relay time-current characteristics.]
9. Bus data.
10. Incoming line section equipment data.
11. Transformer section equipment data.
12. Conduit entrance locations.
13. Anchoring instructions and details.
14. Seismic anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Seismic Anchorage and Bracing.

B. Informational Submittals:

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1. Seismic anchorage and bracing calculations as required by Section 01 88 15, Seismic Anchorage and Bracing.
2. Manufacturer's installation instructions.
3. [Certified] Factory Test Report.
4. Component and attachment testing seismic certificate of compliance as required by Section 01 45 33, Special Inspection [, Observation,] and Testing.
5. Operation and Maintenance Data: As specified in Section 01 78 23, Operation and Maintenance Data.
6. [Manufacturer's Certification of Proper Installation in as specified in Section 01 43 33, Manufacturers' Field Services.]

1.03 QUALITY ASSURANCE

A. Authority Having Jurisdiction (AHJ):

1. Provide the Work in accordance with NFPA 70, National Electrical Code (NEC). Where required by the AHJ, material and equipment shall be labeled or listed by a nationally recognized testing laboratory or other organization acceptable to the AHJ in order to provide a basis for approval under NEC.
2. Materials and equipment manufactured within scope of standards published by Underwriters Laboratories, Inc. shall conform to those standards and shall have an applied UL listing mark.

1.04 EXTRA MATERIALS

A. Furnish, tag, and box for shipment and storage [and deliver prior to [_____] percent Project completion] the following spare parts:

1. Fuses: One complete set of spare fuses of each current rating, both power and control.
2. Lights: One complete set of spare indicating lights.
3. Paint: One pint, to match enclosure exterior finish in color and quality.
4. [Indicating Lamp Pullers: Two each.]
5. [Indicating Lamp Resistors and Sockets: Two each.]
6. [_____]

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Materials, equipment, and accessories specified in this section shall be products of:

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1. General Electric.
2. Westinghouse.
3. Siemens.
4. Square D.

B. [No "or-equal" or substitute products will be considered.]

2.02 GENERAL REQUIREMENTS

A. Equipment suitable for [480Y/277] [480] [208Y/120] [_____]-volt, three-phase, [three-wire] [four-wire] [solid] [grounded-wye] [ungrounded] electrical system having available short-circuit current at line terminals of [_____] amperes rms symmetrical [as shown on Drawings].

B. Comply with NEMA PB 2 and UL 891.

C. Switchboard and its major components to be manufactured and assembled by single manufacturer in order to achieve standardization for appearance, operation and maintenance, spare parts replacement, and manufacturer's services.

D. Lifting lugs on equipment and devices weighing over 100 pounds.

E. Operating Conditions:

1. Ambient Temperature: Maximum [40] [45] [_____] degrees C.
2. Equipment shall be fully rated without derating for the above operating conditions.

2.03 STATIONARY STRUCTURE

A. Type: NEMA PB 2 construction, dead front, completely metal enclosed, self-supporting.

B. Sections bolted together to form one rigid assembly capable of being moved into position and bolted directly to floor without use of floor sills.

2.04 ENCLOSURE

A. Equipment Finish: Baked enamel applied over rust-inhibiting phosphated base coating.

1. Color:

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a. Exterior: [Gray] [_____] finish as approved by [Owner] [Engineer].
b. Interior: White.
c. Unpainted Parts: Plated for corrosion resistance.
d. Indoor Enclosure: NEMA 250, Type 1:

2. Rear, full-height, bolt-on panels for each enclosure section.
3. Cable Termination Access: Padlock provision.
4. Front Access:
   a. Service line and load terminations, internal devices, device and bolted bus connections, and protective device removal, serviceable from front only.
   b. Sections aligned across back to permit placement flush against wall.
   c. Working Space: As required by NFPA 70.
5. Front and Rear Access:
   a. With service line and load terminations, internal devices, and device and bolted bus connections serviceable from rear and protective devices serviceable from front.
   b. Align sections across back and front with NFPA 70 required working space in front, back, and sides.
6. Transition sections as required or shown.
7. Side [, Rear,] and Top Covers: Removable, captive, screw-on plates with formed edges on each side.
8. Front Cover: Hinged door with formed edges.

B. Aisle-less Outdoor Enclosure:

1. NEMA 250, Type 3R enclosing NEMA 250, Type 1, enclosed switchboard.
2. Hinged, full-height doors with three-point latch operated by vault-type handle with multiple padlocking provisions for each front [, and rear,] switchboard section.
3. Minimum 10-inch front access space between exterior door and front of interior switchboard doors.
4. Gasketed doors, [rear panels,] end panels, and sloped roof having 4-inch minimum overhang on all sides.
5. Support assembly on [4-inch modular base] [two 6-inch-high I-beams running parallel to switchboard length].
6. Steel bottom enclosure and support assembly undercoated with coal tar emulsion.
7. Ventilating louvers with filters in front door and rear panels.
8. Space Heaters: Thermostatically controlled [250] [1,000]-watt, [120] [240]-volt, in each switchboard vertical section.

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9. Adjustable thermostat for temperature range of 50 degrees F to 70 degrees F.

C. Walk-In Outdoor Enclosure:

1. NEMA 250, Type 3R enclosing NEMA 250, Type 1, enclosed switchboard.
2. Hinged, full-height doors with three-point latch operated by vault type handle with multiple padlocking provisions for each rear switchboard section.
3. Minimum 42-inch wide front.
4. Access Door: With panic hardware at each end of aisle.
5. Gasketed doors, [rear panels], end panels, and sloped roof having 4-inch minimum overhang on all sides.
6. Lighting: [Fluorescent] [Incandescent], 30-foot-candle minimum aisle lights, three-way light switches, and minimum of two duplex convenience receptacles in aisle.
7. Grounding-type, 20-ampere, 120-volt receptacle at each end of aisle.
8. Space Heaters: Thermostatically controlled [250] [1,000]-watt, [120] [240]-volt, in each switchboard vertical section.
9. Adjustable thermostat for temperature range of 50 degrees F to 70 degrees F.

D. Enclosure Transformer and Panelboards:

1. Transformer, primary and secondary main circuit breakers, and secondary panelboard section enclosed in a NEMA 250, Type [3R] [1] enclosure.
2. Self-cooled, Encapsulated, Dry-type Transformer:
   a. Manufacturer’s standard insulation and temperature rise, in accordance with UL 1561.
   b. Full-capacity, 2-1/2 percent voltage taps, two above and two below normal voltage.
   c. Primary Voltage: [480] [_____] [Single] [Three]-phase with current-limiting fuses in primary circuit.
   d. Secondary Voltage: [208/120] [240/120] [240] volts, [single] [three]-phase, [four] [three]-wire.
   e. kVA Rating: [_____] [As shown.] [As required.]
   f. [Primary circuit extended from branch breaker installed in switchboard.]
3. Panelboard:
   a. Full, short-circuit current rated in accordance with UL 489.
   b. Thermal magnetic, quick-make, quick-break, indicating type, noninterchangeable, molded-case circuit breaker.

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c. Number and breaker ampere rating as [shown in Panel Schedule] [required].

2.05 BUSWORK

A. Material: Phase [noninsulated] [insulated] [isolated and insulated] [copper] [aluminum] [silver-plated copper] [tin-plated copper] [tin-plated aluminum] [throughout entire length] [at junction only] of sufficient cross section to limit temperature rise at rated current to 55 degrees C.

B. Bus Arrangement: A-B-C, left-to-right, top-to-bottom, and front-to-rear, as viewed from front.

C. Brace for short-circuit currents [as shown] [_____] [50,000] [75,000] [100,000] [amperes rms symmetrical].

D. Main Horizontal Bus: Nontapered, continuous current rating [as shown] [800] [1,000] [1,200] [1,600] [2,000] [2,500] [3,000] [amperes].

E. Neutral Bus: Continuous current rating [as shown] [100] [70] [50] [percent of main horizontal bus rating].

F. Ground Bus:

1. [Copper.] [Tin-plated copper.]
2. Rating: [As shown.] [500 amperes.]
3. Bolted to each vertical section.
4. Bus Connections and Joints: Bolted [with Belleville washers].

G. Extend each bus entire length of switchboard [with provisions for extension to future units].

2.06 PROTECTIVE DEVICES

A. Insulated-Case Circuit Breakers:

1. [Main,] [Tie,] [and Feeder] Protective Devices: [Fixed, group mounted,] [Individually mounted draw-out,] [Fixed, individually mounted,] UL 489 listed for 100 percent of continuous ampere rating, suitable for use with 75 degrees C wire at full 75 degrees C ampacity when mounted in switchboard.

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2. Arrangement: [Fully rated main and branch feeder] [Selective coordinated main with [selective] [zone selective] [and] [fully rated] [as shown] branch feeder circuit breakers].]
3. Frame Sizes: As shown with solid-state trip units.
4. Interrupting Rating: [_____] amperes rms symmetrical at rated voltage of [_____] and [_____] amperes rms symmetrical short-time rating.
5. Selective override circuit having short-time adjustment for selectivity up to rated rms short-time rating.
6. Two-step, stored energy mechanism with maximum of five cycle closings.
7. Operation: [Manual] [Electric] with multiple charge/close and antipump provisions.
8. Control Power Voltage: [48] [125] [V dc.] [120V ac.]
9. Operational Sequence: CHARGE-CLOSE-RECHARGE-OPEN-CLOSE-OPEN.
10. Color-Coded Visual Indicators: Contact OPEN and CLOSE, plus mechanism CHARGE and DISCHARGED.
11. Draw-Out Construction:
    a. Individual compartments, sheet steel top, bottom, and sides with padlockable door.
    b. Flame retardant, arc track resistance nonmetallic rear barrier.
    c. CTs, where shown, mounted within appropriate breaker compartment.
    d. Stationary contacts extended to bus through rear barrier.
    e. Secondary contact engagement maintained in CONNECTED and TEST positions.
    f. Draw-out mechanism with disconnecting contacts, wheels, and interlocks.
        1) Equipped with means to rack breaker into CONNECTED, TEST, and DISCONNECTED positions.
        2) Full withdraw position allowing breaker removal [and tilt for inspection].
        3) Door closable with breaker in any position.
    g. External visual breaker position indicator.
    h. Each compartment designed for specific breaker frame size.
    i. Each breaker compartment fully equipped with electrical connections, bolted metal barrier across compartment face and compartment door.
12. Breaker Control: Charge pushbutton, control switch, and red and green indicating lights.
13. Provisions for blocking local, manual closing, and padlocking breaker in OPEN position.
14. Test Facilities:
    a. Breakers with integral external test points for portable test kit.

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b. One, handheld test kit for functional testing of trip circuitry.
c. [Separately mounted panel to test ground fault by [tripping] [not tripping] breaker.]

15. Mechanical interlock to prevent opening compartment door while breaker is in closed position.

B. Molded-Case Circuit Breakers:

1. [Main,] [Tie,] [and Branch Feeder] Protective Devices: [Group] [Individually] mounted, suitable for use with 75 degree C wire at full 75 degree C ampacity when mounted in switchboard.
2. Arrangement: [Fully rated main and branch feeder] [Selective coordinated main with [selective] [zone selective] [and] [fully rated] [as shown] branch feeder circuit breakers].]
3. Breakers 225-Ampere Frame and Above: Continuously adjustable magnetic pickups five to ten times trip rating.
4. [Breakers [600] [_____]-Ampere Frame and Above: Solid-state trip unit.]
5. Interrupting Rating: [_____] amperes rms symmetrical at rated voltage of [_____] and [_____] amperes rms symmetrical short-time rating.
6. Breakers 2,000-Ampere through 3,000-Ampere Frame: UL 489 listed and labeled 100 percent application in accordance with NFPA 70.
7. Mechanical interlock to prevent opening compartment door while breaker is in closed position.

C. Breaker with Limiter:

1. [Main,] [Tie,] [and Feeder] Protective Devices: [Group] [Individually] mounted, molded-case with integral current limiters in accordance with UL 489, suitable for use with 75 degree C wire at full 75 degree C ampacity when mounted in switchboard.
2. Arrangement: [Fully rated main and branch feeder] [Selective coordinated main with [selective] [zone selective] [and] [fully rated] [as shown] branch feeder circuit breakers].]
3. Breakers 200-Ampere Frame and Above: Continuously adjustable magnetic pickups five to ten times trip rating.
4. [Breakers [600] [_____]-Ampere Frame and Above: Solid-state trip unit.]
5. Interrupting Rating: [_____] amperes rms symmetrical at rated voltage of [_____] and [_____] amperes rms symmetrical short-time rating.
6. Breakers 2,000-Ampere through 3,000-Ampere Frame: UL 489 Listed and labeled 100 percent application in accordance with NFPA 70.

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7. Mechanical interlock to prevent opening compartment door while breaker is in closed position.
8. Padlockable operating handles with ON/OFF position indicator.

D. Current Limiting Circuit Breakers:

1. [Main,] [Tie,] [and Feeder] Protective Devices: [Group] [Individually] mounted, molded-case with ultra-high blow-apart contacts in accordance with UL 489, suitable for use with 75 degree C wire at full 75 degree C ampacity when mounted in switchboard.
2. Arrangement: [Fully rated main and branch feeder] [Selective coordinated main with] [selective] [zone selective] [and] [fully rated] [as shown] branch feeder circuit breakers.
3. Breakers 200-Ampere Frame and Above: Continuously adjustable magnetic pickups five to ten times trip rating.
4. [Breakers [600] [_____]-Ampere Frame and Above: Solid-state trip unit.]
5. Interrupting Rating: [_____] amperes rms symmetrical [as shown] at rated voltage of [_____] and [_____] amperes rms symmetrical short-time rating.
6. Mechanical interlock to prevent opening compartment door while breaker is in closed position.
7. Padlockable operating handles with ON/OFF position indicator.

E. Fusible Switches:

1. [Main,] [Tie,] [and Feeder] Protective Devices: Individually fixed-mounted, quick-make, quick-break, manually operated mechanism.
2. Suitable for use with 75 degrees C wire at full 75 degrees C when mounted in switchboard.
3. Switches 30 through 600 Amperes: Class RK-1 fuse clips with interrupting rating of [100,000] [200,000] amperes rms symmetrical.
4. Switches 800 Through 1,200 Amperes: Class L fuse clips with interrupting rating of 200,000 amperes rms symmetrical.
5. Rejection-type clips for all fuse sizes.
6. Safety cover interlocks with defeater for authorized personnel.
7. Padlockable operating handles with ON/OFF position indicator.
8. Padlockable front covers in closed position.
9. Fuses: As specified in Section 26 05 04, Basic Electrical Materials and Methods.

F. Ground Fault Protection:

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1. Ground sensor encircling phase conductors and neutral conductor, where used.
2. Solid-state sensing relay and monitor/test panel.
3. Zero sequence current detection, adjustable over range shown.
4. Monitor panel with fault detection indicating light, test, and reset buttons.
5. Control Power Source: Suitable to operate circuit protective device when connected to faulted phase conductor.

G. Breaker Accessories:

1. Shunt trip for [mains] [, ties,] [and feeders].
2. Undervoltage trip for [_____].
3. Auxiliary switches for [_____].
4. Alarm switch for [_____].
5. Ground fault shunt trip for [_____].
6. Electrical operator for remote control of [_____].
7. Breaker lifter, travel rail on top of switchboard.
8. Portable breaker lifter.

2.07 SOLID-STATE TRIP UNIT

A. Flux-shift trip and current sensors.

B. Protective Programmers:

1. Self-powered, automatic rms sensing micro-electronic processor.
2. No external relays or accessories.
3. Printed circuit cards with gold-plated contacts.
4. Programmable Controls:
   a. Fixed-point, with repetitive accuracy and precise unit settings.
   b. Trip adjustments made by nonremovable, discrete step switching.
5. Field-Installable Rating Plugs:
   a. Long-time pickup LED indicator and test receptacle.
   b. Matching load and cable requirements.
   c. Interlocked with tripping mechanism.
   d. Breaker to remain trip-free with plug removed.
   e. Keyed rating plugs to prevent incorrect application.
6. Long-time pickup light.
7. Selective Coordination Time/Current Curve Shaping Adjustable Functions:
   a. Current setting.
   b. Long-time pickup.
   c. Long-time delay.

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d. Instantaneous pickup [with] [without] short-time for [main] [tie] [and] [feeders].
e. [Short-time pickup for [main] [tie] [and] [feeders].]
f. [Short-time delay for [main] [tie] [and] [feeders] with I2T function, and IN-OUT switch.]
g. [Ground fault pickup.]
h. [Ground fault delay with I2T function.]
i. [High instantaneous pickup with short-time delay.]
j. [Zone selective interlock.]

8. [Fixed, instantaneous pickup for [main] [tie] [and] [feeders].]
9. Fault Trip Indicators: Mechanical push-to-reset type for overload and short-circuit overload [plus ground fault] trip.
10. Rejection Pins: For each programmer frame size.

C. Phase Current Sensors:

1. [Single] [Multi]-ratio type.
2. Fixed, mounted on breaker frame.
3. Molded epoxy construction.
4. One toroidal type for each phase.

D. Ground Fault Sensor:

1. Neutral bar single-ratio CT mounted in cable compartment.
2. Molded epoxy construction.
3. Shorting bar.

E. [Portable Test Set: ac/dc static, full function unit for checking programmer's time-current characteristics of programmer.]

2.08 CONTROL WIRING

A. Control, Instrumentation, and Power/Current Circuits: NFPA 70, Type SIS, single-conductor, Class B, stranded copper, rated 600 volts.

B. Transducer Output/Analog Circuits: Shielded cable rated 600 volts, 90 degrees C minimum.

C. Conductor Lugs: Preinsulated, self-locking, spade-type, with reinforced sleeves.

D. Identification: Individually, with permanent wire markers at each end.

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E. Enclose in top and vertical steel wiring troughs, and front-to-rear in nonmetallic wiring troughs.

F. Splices: Not permitted in switchboard wiring.

2.09 TERMINAL BLOCKS

A. Enclosed in steel wiring troughs.

B. Rated 600 volts, 30 amperes minimum, one-piece barrier type with strap screws.

C. Shorting type for current transformer leads.

D. Provide terminal blocks for:

1. Conductors connecting to circuits external to switchboard.
2. Internal circuits crossing shipping splits.
3. Equipment parts requiring replacement and maintenance.

E. Spare Terminals: Not less than 20 percent.

F. Group terminal blocks for external circuit wiring leads.

G. Maintain 6-inch minimum space between columns of terminal blocks.

H. Identification: Permanent, for each terminal and columns of terminal blocks.

I. Manufacturer: General Electric; Type EB-5.

2.10 INSTRUMENTATION AND METERING

A. As specified in Section 26 09 13, Power Measurement and Control.

2.11 POWER METER

A. As specified in Section 26 09 13, Power Measurement and Control.

2.12 KEY INTERLOCK

A. Mechanical lock cylinder within [main and tie] breaker compartments [as shown on Drawings].

B. Key and Lock Cylinder Type: [Superior.] [Corbin.] [Kirt.]

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C. Keys to be captive when breakers are closed.

D. Two main and [two] [three] tie breaker arrangements.

2.13 IDENTIFICATION

A. Nameplates:

1. Master:
   a. Deep-etched aluminum, with manufacturer's name and model number.
   b. Riveted to main vertical section.
2. Circuit Breaker Cubicle and Door-Mounted Device:
   a. Engraved, [acrylic] [phenolic].
   b. Color: [Black with white.] [White with black.]
   c. Characters: Block-type, [3/16] [1/4]-inch high.
   d. Size: [Manufacturer's standard.] [As required for three lines, with 15 characters per each line.] [_____]
   e. Inscription: As shown on one-line diagram.
   f. Blank plates for future spaces.
   g. Attachment Screws: [Self-tapping.] [Stainless steel panhead.]

B. Section Identification:

1. [Stamped] [Engraved] metallic, riveted to each vertical section.
2. Serial number, bus rating, and section reference number.
3. Size: [Manufacturer's standard.] [6 inches by 2 inches.] [As required.]

C. Cubicle Labels:

1. Nonmetallic, applied inside each cubicle compartment.
2. Device serial number, rating, and description.

D. Metering Instruments: Meter type identified on meter face below pointer or dial.

E. Control Switches: Deep etched, aluminum escutcheon plate.

F. Relays and Devices:

1. Stamped metallic, riveted to instrument case.
2. Manufacturer's name, model number, relay type, and rating data.

G. Switchboard Sign:

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1. Two signs each on front [and back] of switchboard.
2. Engraved, [acrylic] [phenolic].
3. Size: [Manufacturer's standard.] [8 inches by 4 inches, with three lines each.] [As required.]
4. Color: [Red with white.] [Orange with black.]
5. Characters: Gothic-type, [1] [2] [_____] inch(es) high.
6. Inscription: DANGER/HIGH VOLTAGE/KEEP OUT.
7. Attachment: Four rivets each sign.

2.14 FACTORY TESTING

A. Performance tests in accordance with UL 891 and production tests in accordance with NEMA PB-2.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install in accordance with manufacturer's instructions and recommendations.

B. Secure to mounting pads with anchor bolts of sufficient size and number adequate for specified seismic conditions.

C. Install plumb and in longitudinal alignment with pad or wall.

D. Coordinate terminal connections with installation of secondary feeders.

3.02 MANUFACTURER'S SERVICES

A. Furnish manufacturer's representative [in accordance with Section 01 43 33, Manufacturers' Field Services,] for the following services at Site, for minimum person-days listed below, travel time excluded:

1. [_____] person-days for installation assistance, final adjustment, and initial energization of equipment.
2. [_____] person-days for [functional] [and] [performance] testing.
3. [_____] person-days for adjustment of relay settings.

B. Furnish startup services and training of [Owner's] [_____] personnel at such times as requested by [Owner] [_____].

END OF SECTION

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SECTION 26 18 39
MEDIUM-VOLTAGE MOTOR CONTROL

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
   a. C37.20.3, Metal-Enclosed Interrupter Switchgear.
   b. C37.32, American National Standard for Switchgear - High Voltage Air Switches, Bus Supports, and Switch Accessories – Schedules of Preferred Ratings Manufacturing Specifications, and Application Guide.
   c. C37.33, Switchgear High-Voltage Air Switches - Rated Control Voltages and Their Ranges.
   d. C37.40, High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches and Accessories, Service Conditions and Definitions.
   e. C37.46, American National Standard Specifications for Power Fuses and Fuse Disconnecting.
2. National Electrical Manufacturers Association (NEMA):
   a. C37.06, AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis Preferred Ratings and Related Required Capabilities.
   b. ICS 2, Industrial Control and Systems: Controllers, Contactors, and Overload Relays Rated Not More Than 2000 Volts AC Or 750 Volts DC.
   c. ICS 6, Enclosures for Industrial Control and Systems.
3. National Fire Protection Association (NFPA): 70, National Electrical Code (NEC).
4. Underwriters Laboratories, Inc. (UL): 347, Standard for Safety High Voltage Industrial Control Equipment.

1.02 SUBMITTALS

A. Action Submittals:

1. Itemized Bill-of-Material.
2. Descriptive information.
3. Dimensional Drawings.
4. Conduit entrance locations.
5. Bus data.

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6. Protective Devices: Copies of time-current characteristics.
7. [Operational description.]
8. Typed Tabulation:
    a. Motor name; tag (equipment) numbers as shown on Drawings.
    b. Motor horsepower.
    c. Nameplate full load current.
    d. Measured load current and voltage.
    e. Heater catalog number.
    f. Protective device trip settings.
    g. Attach above typed, tabulated data to a copy of starter manufacturer's overload heater selection tables for the starters provided.
9. Control Diagrams:
    a. NEMA ICS 2, Section 322.08, Type [I] [II] [IS] [IIS].
    b. Wiring, Type [A] [B] [C].
    c. [Remote control devices.]
    d. [Remote indication and pilot lights.]
    e. [Interconnections and interlocking circuits between starter and remote equipment.]
    f. [Remote sensors.]
    g. [Tag numbers associated with all control devices and equipment.]
10. One-line diagrams.
11. Schematic (elementary) diagrams.
12. Outline diagrams.
13. [Wireless unit connection diagrams.]
14. [Interconnection diagrams.]
15. Anchoring instructions and details.
16. Seismic anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Seismic Anchorage and Bracing.

B. Informational Submittals:

1. Seismic anchorage and bracing calculations as required by Section 01 88 15, Seismic Anchorage and Bracing.
2. Manufacturer's installation instructions.
3. [Factory test reports] [, certified.]
4. Component and attachment testing seismic certificate of compliance as required by Section 01 45 33, Special Inspection [, Observation,] and Testing.
5. Operation and Maintenance Data: As specified in Section 01 78 23, Operation and Maintenance Data.

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1.03 QUALITY ASSURANCE

A. Authority Having Jurisdiction (AHJ):

1. Provide the Work in accordance with NFPA 70, National Electrical Code (NEC). Where required by the AHJ, material and equipment shall be labeled or listed by a nationally recognized testing laboratory or other organization acceptable to the AHJ in order to provide a basis for approval under NEC.
2. Materials and equipment manufactured within the scope of standards published by Underwriters Laboratories, Inc. shall conform to those standards and shall have an applied UL listing mark.

1.04 PACKING AND SHIPPING

A. Shipping Splits: [As shown] [Established by Contractor] to facilitate ingress of equipment to final installation location within the building.

1.05 EXTRA MATERIALS

A. Furnish, tag, and box for shipment and storage the following [spare parts,] [special tools,] [and] [materials:]

Item	**Quantity**
Spare fuses, both power and control, of every size and type used	1 complete set per unit
Indicating lamps.	10 per unit
Indicating lamp pullers	2 per unit
Lamp sockets for indicating lamps	1 per unit

B. Delivery: [In accordance with Section 01 61 00, Common Product Requirements.] [_____]

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. General Electric.

B. Eaton.

C. Siemens.

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D. Square D.

E. Allen Bradley.

F. [No "or-equal" or substitute products will be considered.]

2.02 GENERAL

A. Products specified herein are based on motors specified in Section 26 20 00, Low-Voltage AC Induction Motors.

B. Make adjustments as necessary to wiring, conduit, disconnect devices, motor starters, branch circuit protection, and other affected material or equipment to accommodate motors actually provided.

C. Equipment suitable for [2,400] [4,160] [7,200] [_____] volts, three-phase, [three-wire,] [four-wire,] [_____] [solid] [low-resistance] [high-resistance] grounded-wye] [ungrounded] electrical system having an available short-circuit current at line terminals of [_____] amperes rms symmetrical [as shown].

D. Designed, tested, and assembled in accordance with NEMA ICS 2 and UL 347.

E. Like items of equipment shall be end products of one manufacturer in order to achieve standardization for appearance, operation and maintenance, spare parts and replacement, and manufacturer's services.

F. Removable lifting lugs on all equipment and devices weighing over 100 pounds.

G. Anchor Bolts: [Galvanized,] [Type 316 stainless steel,] [sized by equipment manufacturer,] [1/2-inch minimum diameter,] and as specified in Section 05 50 00, Metal Fabrications.

H. Operating Conditions: Equipment to be fully rated without any derating for operating conditions.

I. Equipment Finish: Electrocoating process applied over rust-inhibiting phosphated base coating.

1. Color:
   a. Exterior Color: [Gray] [_____] finish as approved by [Owner] [Engineer].
   b. Interior: Surfaces of Medium Voltage Motor Control: White.

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2.03 ENCLOSURE

A. In accordance with NEMA 250 and ICS 6 Standards.

B. Type: NEMA 250, Type [1] [1, gasketed] [12].

C. Construction:

1. Sheet steel, reinforced with channel or angle iron.
2. Butt sections flush, end-to-end with similar sections.
3. Freestanding.
4. [Steel bottom cover plates.]
5. [Front] [Front and rear] accessible with segregated high and low voltage sections.
6. Low voltage control compartment with separate door.
7. High voltage compartment with separate interlocked door.
8. Bus compartment with protective barriers and cable entrance compartments.
9. Equip with defeater to allow intentional access only to qualified personnel.

B. [Air-Break Starter Unit Enclosures: [One] [Two] [Three]-high.]

C. [Vacuum Starter Unit Enclosures: [One] [Two] [Three]-high.]

D. Vertical Section: 100 inches maximum height, 30 inches deep, [26] [36] [40] [_____] inches wide.

2.04 INCOMING SERVICE SECTION

A. General:

1. Height and depth to match motor controller.
2. Width as required for cable stress cones.
3. [Top] [Bottom] service cable entrance.
4. Surge Protection: [Distribution] [Intermediate] [Station] class arrestors and capacitors, rated [_____] kV, mounted in incoming line compartment.
5. Incoming Cable Terminations: [Clamp type.] [Pothead.] [Roof bushing.] [Elbow connectors.]
6. Upper space to accommodate metering.

B. Cable Entrance Cubicle:

1. Separate, gasketed [compartment] [vertical section].
2. Voltage and Short-Circuit Ratings: Match ratings specified for integrated assembly.

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C. Load-Break Air Switch:

1. Manually operated, three-pole, single-throw disconnecting type in accordance with IEEE C37.32 and IEEE C37.40.
2. [Stationary] [Nonfused] [Fused] air interrupter switch with stored energy spring and external operating handle.
3. Load-break rated 5 kV, [600] [1,200] amperes, 60 kV BIL, with a fault-closing rating of 61,000 amperes rms symmetrical.
4. Switch and fuse combination short-circuit interrupting rating of [200] [350] [400] mVA, three-phase symmetrical at [2,400] [4,800] volts.
5. Fuses: Current-limiting, ANSI C37.46, Class E, [clip-on] [bolt-on] type.

D. Vacuum Circuit Interrupter Switch:

1. Manually operated, three-pole, single-throw interrupting type in accordance with IEEE C37.20.3.
2. [Fused,] [Nonfused,] fixed mounted with quick-make, quick-break, blade disconnects in series with vacuum interrupters, external control switch, and manual crank operator.
3. Rated [5] [8] [15] kV, [60] [95] [200] [400] [800] kV BIL.
4. Switch and fuse combination short-circuit interrupting rating of 40,000 amperes rms symmetrical.
5. Fuses: Current-limiting, IEEE C37.46, Class E.
6. Trip Mechanism:
   a. 120V ac shunt trip.
   b. Capacitor trip.

E. Air-Break Contactor:

1. Electrically operated, three-pole, single-break high pressure type in accordance with NEMA ICS 2, Section 324 and UL 347.
2. [Fused,] [Nonfused,] drawout type.
3. Rated [5] [7.2] kV, [400] [700] [330] amperes, 60 kV BIL.
4. [Contactor and fuse combination interrupting rating of [200] [400] [500] mVA, three-phase symmetrical at [2,400] [4,800] [7,200] volts.]
5. [Nonfused contactor interrupting rating [50] [80] mVA, three-phase symmetrical at [2,400] [4,800] [7,200] volts.]
6. Fuses: Current-limiting, IEEE C37.46, Class E, [clip-on] [bolt-on] type.

F. Vacuum Circuit Breaker:

1. Electrically charged, mechanically and electrically stored energy type in accordance with IEEE C37.06.

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2. Drawout type with manual charging of mechanism for maintenance and inspection.
3. Continuous rated [4,160 volts, 60 kV BIL,] [7,200 volts, 95 kV BIL,] [1,200] [_____] amperes.
4. Interrupting Rating: [250] [350] [_____] mVA, three-phase symmetrical at [4,160] [7,200] volts.
5. Equipped with secondary disconnecting contacts automatically engaged in connected position.
6. Breaker compartment with mechanism to move breaker between operating and disconnect position.
7. Interlocks to prevent breaker movement from operating position unless contacts are in OPEN position.
8. Operating springs to discharge automatically when breaker is inserted into compartment or moved to disconnect position.
9. Padlockable racking mechanism for breaker in either connected or disconnected position.

G. Protective Relays:

1. Ground fault device 51 GS.
2. Overcurrent device 51.

H. Bus transition section isolated from main bus section.

2.05 BUS

A. [Copper] [Aluminum] [Silver-plated copper] [Tin-plated copper] [Tin-plated aluminum] [throughout entire length.] [at joints only.]

B. Horizontal Bus: [Isolated] [or] [Insulated], [1,200] [2,200]-ampere, three-phase, extending entire length of control center lineup [with provisions for extension to future starter sections].

C. Vertical Bus: Insulated, three-phase with rating [of 800 amperes] [as required by connected motor load].

D. Ground Bus: Extend continuous throughout all sections of control center lineup without cable connections between sections.

E. Bus Bracing: 80,000 amperes rms asymmetrical.

F. Connections and Joints: Bolted [with Belleville washers].

G. Potential Bus:

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1. 600-volt insulated copper conductors.
2. Maximum current rating determined by application.
3. Connected to terminal boards mounted inside enclosure.

H. All bus sized for present and anticipated future loads as indicated on one-line diagram [with provisions for extension to future starter sections].

2.06 MOTOR STARTER UNIT

A. General:

1. NEMA ICS 2, Section 524, Class E2 combination controller with current-limiting IEEE C37.46, Class R fuses and three-pole [air-break] [vacuum] contactor.
2. [Drawout Type Construction:
   a. [Air-break] [Vacuum] contactor and clip-on fuse assembly.
   b. External, sequentially operated, isolating mechanism.
   c. Mechanically interlocked to prevent:
      1) Operation of isolating mechanism underload.
      2) Opening high voltage compartment door without isolating starter.
      3) Closing contactor with compartment door open.]
3. Mechanically driven shutters to isolate starter from high voltage in OFF position.
4. Automatic grounding of all three phases when isolating switch is open.
5. [Fixed Type Construction:
   a. Bolt-on fuse and support assembly.
   b. Externally operated disconnect switch.
   c. Vacuum contactor.
   d. Mechanically interlocked to prevent:
      1) Opening disconnect when contactor is energized.
      2) Opening door when contactor is closed.
      3) Closing contactor with disconnect in intermediate position.
      4) Closing disconnect when high voltage door is open.
   e. Magnet coil removable without removing contactor from its mounts.]
6. Antisingle phase trip mechanism and blown fuse indicator to be integral part fuse support system.
7. Control power transformer with [120] [240]-volt secondary and two primary and [one] [two] secondary current-limiting fuses.
8. Current transformers installed on each phase.
9. [Zero sequence ground fault current transformer.]
10. Terminals for incoming feeder and motor cable connections.

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B. Control circuitry.

1. Pushbutton and indicating lights.
2. Nonreversing Starter: Single contactor and fused isolation switch.
3. Reactor Type Starter:
   a. One main contactor, one run contactor, and fused isolation switch.
   b. Three reactors with 50, 65, and 80 percent voltage taps.
   c. Close circuit transition.
4. Adjustable timers for start-run sequence.
   a. Autotransformer Starter:
   b. One main contactor, one start contactor, one run contactor, and fused isolation switch.
   c. [Two] [Three] autotransformers connected open delta with 50, 65, and 80 percent voltage taps.
   d. Close circuit transition and autotransformer thermal overtemperature protection.

C. Contactors: Electrically operated, three-pole, single-break type in accordance with NEMA ICS 2, Section 324, and UL 347.

1. Air-Break Type:
   a. Fused, magnetically held drawout contactor.
   b. Rated [5.5] [7.2] kV, [400] [700] [330] amperes, 60 kV BIL.
   c. Combination fuse and contactor interrupting rating [200] [400] [500] mVA, three-phase symmetrical at [2,400] [4,800] [7,200] volts.
   d. Main Contacts: Weld-resistant, silver alloy with three-phase interrupting capacity of 50,000 kVA rms symmetrical.
   e. Removable arc shoots.
2. Vacuum Type:
   a. Fused, magnetically held [fixed] [drawout] contactor.
   b. Rated [5] [7.2] kV, [400] [800] amperes, 60 kVA BIL.
   c. Combination Fuse and Contactor Interrupting Rating: [200] [400] [600] mVA, three-phase symmetrical at [2,400] [4,800] [7,200] volts.
   d. Main Contacts:
      1) Weld-resistant, copper alloy.
      2) Constructed for low chopping currents.
      3) Three-phase interrupting capacity of 50 mVA rms symmetrical.
3. Auxiliary Contacts:
   a. Rated 10 amperes, [115] [230] [600] volts.
   b. Two normally open and two normally closed.

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D. Disconnect Switch:

1. Fixed mounted, nonfused, nonload-break, externally operated quick-make, quick-break in accordance with IEEE C37.33.
2. Rated 5 kV, [400] [800] amperes, 60 kV BIL.
3. Switch contacts barriered and visible through viewing window.
4. Lockable operating handle.

E. Motor Protector Relay: As specified in Section 26 09 13, Power Measurement and Control.

F. Surge Protection: Surge capacitors and station class surge arrestors.

G. Space Heaters:

1. Space heater rated for [120] [240] volts, sized for prevention of condensation in each vertical section.
2. Adjustable thermostat with temperature range of 50 to 70 degrees F.
3. Power supply from [starter] [separate] [control transformer] [circuit breaker panel].

H. Current Transformer (CT): As specified in Section 26 09 13, Power Measurement and Control.

I. Potential Transformer (PT): As specified in Section 26 09 13, Power Measurement and Control.

J. Control Transformers:

1. Type: Insulated dry indoor.
2. Rating:
   a. [2,400] [4,160] [7,200]/240/120-volt, single-phase, three-wire with 60 kV BIL rating with two 2-1/2 percent taps above, and two 2-1/2 percent taps below normal voltage.
   b. kVA rating for control power, [motor heater] [and] [space heater] requirements plus 200VA for remote devices and future use.
3. [Stationary] [Drawout carriage] mounted in separate steel compartment.
4. Primary Protection: Two current-limiting fuses mounted on drawout carriage.
5. Secondary Protection: [Fuses.] [Molded case circuit breakers.]
6. Provisions for test control power.

K. Terminal Blocks:

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1. Rating: 600 volts, 30-ampere minimum.
2. Type:
   a. One-piece barrier with strap screws.
   b. Shorting type for current transformer leads.
3. Pull-apart unit control wiring terminal boards:
   a. As required by NFPA 70 for disconnecting externally powered control circuits.
   b. On drawout units as required.
4. Provide for:
   a. Conductors connecting to circuits external to motor control.
   b. Internal circuits crossing shipping splits [with plug connectors].
   c. Equipment parts requiring replacement and maintenance.
5. Spares: Minimum 20 percent spare unused terminals.
6. Grouped together terminal blocks for external circuit wiring leads.
7. 6-inch minimum space between columns of terminal blocks.
8. Permanently identify each terminal and columns of terminal blocks.
9. Manufacturer and Product: G.E.; Type EB-5.

L. Control Wiring:

1. NFPA 70, Type SIS, single conductor, Class B, stranded copper, rated 600 volts for control, instrumentation, power and circuits.
2. Individual seven-strand, copper conductors, twisted and covered with a 100 percent aluminum, polyester shield with tinned copper drain wire and overall outer jacket, rated 600 volts, 90 degrees C minimum for transducer output and analog circuits.
3. Conductor Lugs: Preinsulated, self-locking, spade type with reinforced sleeves.
4. Wire Markers: Each wire individually identified with permanent markers at each end.
5. Splices: Not permitted.

M. Pushbutton, Indicating Light, and Selector Switches: As specified in Section 26 05 04, Basic Electrical Materials and Methods.

N. Elapsed Time Meters: As specified in Section 26 05 04, Basic Electrical Materials and Methods.

O. Time Delay Relays: As specified in Section 26 05 04, Basic Electrical Materials and Methods.

P. Control Relays: As specified in Section 26 05 04, Basic Electrical Materials and Methods.

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Q. Reset Timers: As specified in Section 26 05 04, Basic Electrical Materials and Methods.

R. Load Cable Connections:

1. Two-hole cable lugs for [copper] [aluminum] conductors.
2. Cable lugs sized for [MCM] conductors.
3. Provide space for cable stress cones.
4. Cable Entrance: [Top] [and] [bottom].

2.07 TIE SWITCH

A. General:

1. Voltage, Bus, and Short-Circuit Ratings: Match ratings specified for integrated assembly.
2. Height and depth to match motor controller depth.
3. Width of tie switch and transition section as required.
4. Back access not required.

B. Load-Break Air Switch:

1. Manually operated, three-pole, single-throw disconnecting type in accordance with IEEE C37.32 and IEEE C37.40.
2. Stationary nonfused air interrupter switch with stored energy spring and external operating handle.
3. Load-break rated 5 kV, [600] [1,200] amperes, 60 kV BIL, with a fault-closing rating of 61,000 amperes rms symmetrical.
4. Switch short-circuit interrupting rating of [200] [350] [400] mVA, three-phase symmetrical at [2,400] [4,800] volts.

C. Vacuum Circuit Interrupter Switch:

1. Manually operated, three-pole, single-throw interrupting type in accordance with IEEE C37.20.3.
2. Nonfused, fixed mounted with quick-make, quick-break blade disconnects in series with vacuum interrupters, external control switch, and manual crank operator.
3. Rated [5] [8] [15] kV, [200] [400] [800] amperes, [60] [95] kV BIL.
4. Switch short-circuit interrupting rating of 40,000 amperes rms symmetrical.

2.08 KEY INTERLOCKS1

A. Mechanical lock cylinder within [main and tie] breaker compartments.

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B. [Superior] [Corbin] [Kirk] type keys and lock cylinders.

C. Keys to be captive when breakers are closed.

D. Between main and bus tie fused switches to prevent paralleling transformers in double-ended configurations.

2.09 EQUIPMENT IDENTIFICATION

A. Master Nameplate:

1. Deep etched aluminum with manufacturer's name and model number.
2. Riveted to main vertical section.

B. Section Identification:

1. [Stamped] [Engraved] metallic, riveted to each vertical section.
2. Serial number, bus rating, and section reference number.
3. Size: [Manufacturer's standard.] [6 inches by 2 inches.] [As required.]

C. Nameplate:

1. Engraved, [acrylic] [phenolic] for each incoming service section, motor starter unit, and tie switch cubicle and door mounted device.
2. [Black with white] [White with black] block type characters.
3. Character Height: [3/16] [1/4]-inch.
4. Size: [Manufacturer's standard.] [As required for 3 lines, with 15 characters each line.] [_____]
5. Inscriptions: As shown on one-line diagram.
6. Blank plates for future spaces.
7. Attachment Screws: [Self-tapping.] [Stainless steel panhead.]

D. Cubicle Labels:

1. Nonmetallic, applied inside each cubicle compartment.
2. Device serial number, rating, and description.

E. Motor Data Label:

1. Provide typed, self-adhesive label attached inside each motor starter enclosure door displaying the following information:
   a. Motor served by tag number and equipment name.
   b. Nameplate horsepower.
   c. Motor code letter.

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d. Full load amperes.
e. Service factor.
f. Installed overload relay heater catalog number.

F. Metering Instruments: Meter type identified on meter face below pointer or dial.

G. Control Switches: Deep etched, aluminum escutcheon plate.

H. Signs:

1. Two signs each on [front] [and back] of motor control center.
2. Size: [Manufacturer's standard.] [8 inch by 4 inch, with 3 lines each.] [As required.]
3. Engraved, [acrylic] [phenolic].
4. Color: [Red with white.] [Orange with black.]
5. Inscription: DANGER/HIGH VOLTAGE/KEEPOUT.
6. Characters: Gothic type, [1] [2] [_____]-inch high.
7. Attachment: Four rivets each sign.

2.10 FACTORY TESTS

A. Test in accordance with UL 347.

PART 3 - EXECUTION

3.01 INSTALLATION

A. General:

1. Install in accordance with manufacturer's instructions and recommendations.
2. Secure equipment to floor with anchor bolts of sufficient size and number for seismic conditions.
3. Install equipment plumb and in longitudinal alignment with wall.
4. Tighten current-carrying bus bolted connections and enclosure framing and panel bolts to manufacturer's recommendations.
5. Coordinate terminal connections with installation of secondary feeders.

B. Key Interlocks: Two main and one tie breaker arrangement:

1. Two keys available for each group of three locks.
2. Two out of three breakers closed at any time.

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3.02 MANUFACTURER'S SERVICES

A. Furnish manufacturer's representative [in accordance with Section 01 43 33, Manufacturers' Field Services,] for the following services at Site or classroom as designated by [Owner,] [_____,] for minimum person-days listed below, travel time excluded:

1. [_____] person-days for installation assistance and inspection, and certification of installation.
2. [_____] person-days for [functional] [and] [performance] testing.
3. [_____] person-days for plant startup.

END OF SECTION

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SECTION 26 22 00
LOW-VOLTAGE TRANSFORMERS

PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes:

1. Two-winding transformers.
2. Shielded transformers.
3. Autotransformers.
4. Buck-and-boost transformers.

B. Related Requirements:

1. Section 03 30 00, Cast-In-Place Concrete: Housekeeping pads.
2. Section 26 05 26, Grounding and Bonding for Electrical Systems.
3. Section 26 05 29, Hangers and Supports for Electrical Systems.
4. Section 26 05 33, Raceway and Boxes for Electrical Systems.
5. Section 26 05 53, Identification for Electrical Systems.
6. Section 26 22 03, Low-Voltage Transformers For Nonlinear Loads.
7. Section 26 22 06, Low-Voltage Transformer Load Centers.

1.02 REFERENCE STANDARDS

A. National Electrical Manufacturers Association:

1. NEMA ST 1, Specialty Transformers (Except General Purpose Type).
2. NEMA ST 20, Dry Type Transformers for General Applications.

B. International Electrical Testing Association:

1. NETA ATS, Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems.

1.03 SUBMITTALS

A. Section 01 33 00, Submittal Procedures: Submittal procedures.

B. Product Data: Submit outline and support point dimensions of enclosures and accessories, unit weight, voltage, kVA, and impedance ratings and characteristics, tap configurations, insulation system type, and rated temperature rise.

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C. Test and Evaluation Reports: Indicate loss data, efficiency at 25, 50, 75 and 100 percent rated load, and sound level.

D. Source Quality Control Submittals: Indicate results of [shop] [factory] tests and inspections.

E. Field Quality Control Submittals: Indicate results of Contractor furnished tests and inspections.

1.04 CLOSEOUT SUBMITTALS

A. Section 01 70 00, Execution and Closeout Requirements: Closeout procedures.

B. Record Documentation: Record actual locations of transformers.

1.05 QUALIFICATIONS

A. Manufacturer: Company specializing in manufacturing products specified in this section with minimum three years [documented] experience.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Section 01 60 00, Product Requirements: Product storage and handling requirements.

B. Store in clean, dry space. Maintain factory wrapping or provide additional canvas or plastic cover to protect units from dirt, water, construction debris, and traffic.

C. Handle in accordance with manufacturer's written instructions. Lift only with lugs provided. Handle carefully to avoid damage to transformer internal components, enclosure, and finish.

PART 2 - PRODUCTS

2.01 TWO-WINDING TRANSFORMERS

A. Manufacturer List:

1. [_____] Model [_____] [as basis of design].
2. [Cutler-Hammer] Model [_____].
3. [General Electrical] Model [_____].
4. [Olsun Electric Corporation] Model [_____].
5. [Schneider Electric] Model [_____].
6. [Sola Hevi Duty] Model [_____].
7. [_____] Model [_____].

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B. Substitution Limitations:

1. Section 01 60 00, Product Requirements: Requirements for substitutions for other manufacturers and products.

****** [OR] ******

2. No substitutions permitted.

****** [OR] ******

C. Furnish materials in accordance with [State] [Municipality] of [_____] [Highways] [Public Work's] standards.

D. Description: NEMA ST 20, factory-assembled, air-cooled, dry type transformers [, ratings as indicated on Drawings].

E. Operation:

1. Primary Voltage: As shown on Drawings. [480 volts, 3 phase] [_____].
2. Secondary Voltage: As shown on Drawings. [208Y/120 volts, 3 phase] [_____].
3. Insulation system and average winding temperature rise for rated kVA as follows:
4. 1-15 kVA: Class 185 with [80] [115] degrees C rise.
5. 16-500 kVA: Class 220 with [80] [115] [150] degrees C rise.
6. Case temperature: Do not exceed [35] [_____] degrees C rise above ambient at warmest point at full load.
7. Winding Taps:
   a. Transformers Less than 15 kVA: Two 5 percent below rated voltage, full capacity taps on primary winding.
   b. Transformers 15 kVA and Larger: NEMA ST 20.
8. Sound Levels: [NEMA ST 20.] [Maximum sound levels are as follows:]
   a. 1-5 kVA: [_____] dB.
   b. 6-25 kVA: [_____] dB.
   c. 26-150 kVA: [_____] dB.
   d. 151-225 kVA: [_____] dB.
   e. 226-300 kVA: [_____] dB.
   f. 301-500 kVA: [_____] dB.
9. Basic Impulse Level: [10 kV] [10 kV for transformers less than 300 kVA, 30 kV for transformers 300 kVA and larger].
10. Mounting:
    a. 1-15 kVA: Suitable for wall mounting.

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b. 16-75 kVA: Suitable for [wall] or[, floor] [, or] [trapeze] mounting, in accordance with Manufacturer instructions.
c. Larger than 75 kVA: Suitable for [floor] [or] [trapeze] mounting.

F. Materials:

1. Ground core and coil assembly to enclosure by means of visible flexible copper grounding strap.
2. Coil Conductors: Continuous [copper] [aluminum] windings with terminations brazed or welded.
3. Enclosure: NEMA ST 20, [Type 1] [Type 3R [ventilated] [non-ventilated]]. Furnish lifting eyes or brackets.

G. Fabrication:

1. Isolate core and coil from enclosure using vibration-absorbing mounts.
2. Nameplate: Include transformer connection data [and overload capacity based on rated allowable temperature rise].

2.02 SHIELDED TRANSFORMERS

A. Manufacturer List:

1. [_____] Model [_____] [as basis of design].
2. [Cutler-Hammer] Model [_____].
3. [General Electric] Model [_____].
4. [Olsun Electric Corporation] Model [_____].
5. [Sola Hevi Duty] Model [_____].
6. [Schneider Electric] Model [_____].
7. [_____] Model [_____].

B. Substitution Limitations:

1. Section 01 60 00, Product Requirements: Requirements for substitutions for other manufacturers and products.
2. No substitutions permitted.

C. Furnish materials in accordance with [State] [Municipality] of [_____] [Highways] [Public Work's] standards.

D. Description: NEMA ST 20, factory-assembled, air-cooled, dry type shielded isolation transformers [, ratings as indicated on Drawings].

E. Operation:

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1. Primary Voltage: [480 volts, 3 phase] [_____].
2. Secondary Voltage: [208Y/120 volts, 3 phase] [_____].
3. Insulation system and average winding temperature rise for rated kVA as follows:
   a. 10-15 kVA: Class 185 with 115 degrees C rise.
   b. 16-500 kVA: Class 220 with 150 degrees C rise.
4. Case temperature: Do not exceed [50] [_____] degrees C rise above ambient at warmest point at full load.
5. Winding Taps:
   a. Transformers Less than 15 kVA: Two 5 percent below rated voltage, full capacity taps on primary winding.
   b. Transformers 15 kVA and Larger: NEMA ST 20.
6. Sound Levels: [NEMA ST 20.] [Maximum sound levels are as follows:]
   a. 1-5 kVA: [_____] dB.
   b. 6-25 kVA: [_____] dB.
   c. 26-150 kVA: [_____] dB.
   d. 151-225 kVA: [_____] dB.
   e. 226-300 kVA: [_____] dB.
   f. 301-500 kVA: [_____] dB.
7. Basic Impulse Level: [10 kV] [10 kV for transformers less than 300 kVA, 30 kV for transformers 300 kVA and larger].
   a. Winding Shield: Electrostatic, with separate insulated grounding connection.
8. Mounting:
   a. 1-15 kVA: Suitable for wall mounting.
   b. 16-75 kVA: Suitable for [wall] [, floor] [, or] [trapeze] mounting.
   c. Larger than 75 kVA: Suitable for [floor] [or] [trapeze] mounting.

F. Materials:

1. Ground core and coil assembly to enclosure with visible flexible copper grounding strap.
2. Coil Conductors: Continuous [copper] [aluminum] windings with terminations brazed or welded.
3. Enclosure: NEMA ST 20, [Type 1] [Type 3R [ventilated] [non-ventilated]]. Furnish lifting eyes or brackets.

G. Fabrication:

1. Isolate core and coil from enclosure using vibration-absorbing mounts.
2. Nameplate: Include transformer connection data.

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2.03 AUTOTRANSFORMERS

A. Manufacturer List:

1. [_____] Model [_____] [as basis of design].
2. [Cutler-Hammer] Model [_____].
3. [General Electric] Model [_____].
4. [Olsun Electric Corporation] Model [_____].
5. [Schneider Electric] Model [_____].
6. [_____] Model [_____].

B. Substitution Limitations:

1. Section 01 60 00, Product Requirements: Requirements for substitutions for other manufacturers and products.
2. No substitutions permitted.

C. Furnish materials in accordance with [State] [Municipality] of [_____] [Highways] [Public Work's] standards.

D. Description: NEMA ST 20, factory-assembled, air-cooled, dry type autotransformers [, ratings as indicated on Drawings].

E. Operation:

1. Primary Voltage: [480 volts, 3 phase] [_____].
2. Secondary Voltage: [208Y/120 volts, 3 phase] [_____].
3. Insulation system and average winding temperature rise for rated kVA as follows:
   a. 10-15 kVA: Class 185 with 115 degrees C rise.
   b. 16-500 kVA: Class 220 with 150 degrees C rise.

F. Case temperature: Do not exceed [35] [_____] degrees C rise above ambient at warmest point at full load.

1. Winding Taps:
   a. Transformers Less than 15 kVA: Two 5 percent below rated voltage, full capacity taps on primary winding.
   b. Transformers 15 kVA and Larger: NEMA ST 20.
2. Sound Levels: [NEMA ST 20.] [Maximum sound levels are as follows:]
   a. 1-5 kVA: [_____] dB.
   b. 6-25 kVA: [_____] dB.
   c. 26-150 kVA: [_____] dB.
   d. 151-225 kVA: [_____] dB.

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e. 226-300 kVA: [_____] dB.
f. 301-500 kVA: [_____] dB.

3. Use three-legged core construction.
   a. Mounting:
   b. 1-15 kVA: Suitable for wall mounting.
   c. 16-75 kVA: Suitable for [wall] [, floor] [, or] [trapeze] mounting.
   d. Larger than 75 kVA: Suitable for [floor] [or] [trapeze] mounting.

G. Materials:

1. Ground core and coil assembly to enclosure by means of visible flexible copper grounding strap.
2. Coil Conductors: Continuous [copper] [aluminum] windings with terminations brazed or welded.
3. Enclosure: NEMA ST 20, [Type 1] [Type 3R [ventilated] [non-ventilated]]. Furnish lifting eyes or brackets.

H. Fabrication:

1. Isolate core and coil from enclosure using vibration-absorbing mounts.
2. Nameplate: Include transformer connection data.

2.04 BUCK-AND-BOOST TRANSFORMERS

A. Manufacturer List:

1. [_____] Model [_____] [as basis of design].
2. [Cutler-Hammer] Model [_____].
3. [General Electric] Model [_____].
4. [Olsun Electric Corporation] Model [_____].
5. [Schneider Electric] Model [_____].
6. [Sola Hevi Duty] Model [_____].
7. [_____] Model [_____].

B. Substitution Limitations:

1. Section 01 60 00, Product Requirements: Requirements for substitutions for other manufacturers and products.
2. No substitutions permitted.

C. Furnish materials in accordance with [State] [Municipality] of [_____] [Highways] [Public Work's] standards.

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D. Description: NEMA ST 1, factory-assembled, dry type two winding buck and boost transformers [, ratings as indicated on Drawings].

E. Operation:

1. Insulation system and average winding temperature rise for rated kVA as follows:
   a. 0.25-2 kVA: Class 185 with 80 degrees C rise.
   b. 3-7.5 kVA: Class 220 with [80] [115] degrees C rise.
2. Primary Voltage: 120 x 240 volts, single phase.
3. Secondary Voltage: [12/24] [16/32] volts.

F. Materials:

1. Coil Conductors: [copper] [aluminum] Continuous windings.
2. Lugs: Suitable for terminating conductors sized for full load ampacity of transformer unit when operating in buck-and-boost configuration shown.
3. Enclosure: NEMA ST 1, Type 1.

G. Fabrication:

1. Isolate core and coil from enclosure using vibration-absorbing mounts.
2. Nameplate: Include transformer connection data.

2.05 SOURCE QUALITY CONTROL

A. Section 01 40 00, Quality Requirements: Testing, inspection and analysis requirements.

B. Production test each unit according to NEMA ST20.

PART 1 - EXECUTION

3.01 EXAMINATION

A. Section 01 70 00, Execution and Closeout Requirements: Requirements for installation examination.

B. Verify mounting supports are properly sized and located including concealed bracing in walls.

3.02 PREPARATION

A. Section 01 70 00, Execution and Closeout Requirements: Requirements for installation preparation.

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B. Provide concrete pads under provisions of Section 03 30 00.

3.03 DEMOLITION

A. Disconnect and remove abandoned transformers.

B. Maintain access and adequate ventilation to existing transformers and other installations remaining active and requiring access and ventilation. Modify installation or provide access panel or ventilation grilles.

3.04 INSTALLATION

A. Set transformer plumb and level.

B. Use flexible conduit, in accordance with Section 26 05 33, 2 feet minimum length, for connections to transformer case. Make conduit connections to side panel of enclosure.

C. Support transformers in accordance with Section 26 05 29.

1. Mount wall-mounted transformers using integral flanges or accessory brackets furnished by manufacturer.
2. Mount floor-mounted transformers on vibration isolating pads suitable for isolating transformer noise from building structure.
3. Mount trapeze-mounted transformers as indicated on Drawings.

D. Provide seismic restraints.

E. Install grounding and bonding in accordance with Section 26 05 26.

3.05 [REPAIR] [RESTORATION]

A. Repair existing transformers to remain or to be reinstalled.

3.06 FIELD QUALITY CONTROL

A. Section [01 40 00, Quality Requirements] Requirements for inspecting and testing.

B. Section 01 70 00, Execution and Closeout Requirements: Requirements for testing, adjusting, and balancing.

C. Inspect and test in accordance with NETA ATS, except Section 4.

D. Perform inspections and tests listed in NETA ATS, Section 7.2.1.

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3.07 ADJUSTING

A. Section 01 70 00, Execution and Closeout Requirements: Testing, adjusting, and balancing.

B. Measure primary and secondary voltages and make appropriate tap adjustments.

3.08 CLEANING

A. Section 01 70 00, Execution and Closeout Requirements: Requirements for cleaning.

B. Clean existing transformers to remain or to be reinstalled.

END OF SECTION

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SECTION 26 24 16
PANELBOARDS

PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes:

1. Distribution and branch circuit panelboards.
2. Electronic grade branch circuit panelboards.
3. Load centers.

B. Related Requirements:

1. Section 26 05 26, Grounding and Bonding for Electrical Systems.
2. Section 26 05 53, Identification for Electrical Systems.
3. Section 26 28 13, Fuses.

1.02 REFERENCE STANDARDS

A. Institute of Electrical and Electronics Engineers: IEEE C62.41, Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits.

B. National Electrical Manufacturers Association:

1. NEMA FU 1, Low Voltage Cartridge Fuses.
2. NEMA ICS 2, Industrial Control and Systems: Controllers, Contactors, and Overload Relays, Rated Not More Than 2000 Volts AC or 750 Volts DC.
3. NEMA ICS 5, Industrial Control and Systems: Control Circuit and Pilot Devices.
4. NEMA KS 1, Enclosed and Miscellaneous Distribution Equipment Switches (600 Volts Maximum).
5. NEMA PB 1, Panelboards.
6. NEMA PB 1.1, General Instructions for Proper Installation, Operation, and Maintenance of Panelboards Rated 600 Volts or Less.

C. International Electrical Testing Association: NETA ATS, Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems.

D. National Fire Protection Association: NFPA 70, National Electrical Code.

E. Underwriters Laboratories Inc.:

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1. UL 50, Cabinets and Boxes
2. UL 67, Safety for Panelboards.
3. UL 489, http://www.nssn.org/search/DetailResults.aspx?docid=521368&selnode=Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures.
4. UL 1283, Electromagnetic Interference Filters.
5. UL 1449, Transient Voltage Surge Suppressors.
6. UL 1699, Arc-Fault Circuit Interrupters.

1.03 SUBMITTALS

A. Section 01 33 00, Submittal Procedures: Requirements for submittals.

B. Product Data: Submit catalog data showing specified features of standard products.

C. Shop Drawings: Indicate outline and support point dimensions, voltage, main bus ampacity, integrated short circuit ampere rating, circuit breaker and fusible switch arrangement and sizes.

D. Source Quality control submittals: Indicate results of [shop] [factory] tests and inspections.

E. Field Quality Control Submittals: Indicate results of Contractor furnished tests and inspections.

1.04 CLOSEOUT SUBMITTALS

A. Section 01 70 00, Execution and Closeout Requirements: Requirements for submittals.

B. Project Record Documents: Record actual locations of panelboards and record actual circuiting arrangements.

C. Operation and Maintenance Data: Submit spare parts listing; source and current prices of replacement parts and supplies; and recommended maintenance procedures and intervals.

1.05 MAINTENANCE MATERIAL SUBMITTALS

A. Section [01 70 00, Execution and Closeout Requirements]: Requirements for maintenance products.

B. Extra Stock Materials: Furnish twoof each panelboard key. Panelboards keyed alike.

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1.06 QUALITY ASSURANCE

A. Qualifications:

1. Manufacturer: Company specializing in manufacturing products specified in this section with minimum three years [documented] experience.

PART 2 - PRODUCTS

2.01 DISTRIBUTION PANELBOARDS

A. Manufacturer List:

1. Cutler-Hammer.
2. General Electric.
3. Schneider Electric.
4. Siemens.

B. Substitution Limitations:Section 01 60 00, Product Requirements: Requirements for substitutions for other manufacturers and products.

C. Description: NEMA PB 1, [circuit breaker type] [fusible switch type] panelboard. [Furnish combination controllers as indicated on Drawings].

D. Operation:

1. Service Conditions:
   a. Temperature: 0 to 130 degrees F.
   b. Altitude: 475 feet above sea level.
2. Minimum integrated short circuit rating: 22,000 amperes rms symmetrical for 240 or 208 volt panelboards; 65,000 amperes rms symmetrical for 480 volt panelboards, or as indicated on Drawings.

E. Materials:

1. Panelboard Bus: Copper,current carrying components, ratings as indicated on Drawings. Furnish copper ground bus in each panelboard.
2. Fusible Switch Assemblies: NEMA KS 1, quick-make, quick-break, load interrupter enclosed knife switch with externally operable handle. Furnish interlock to prevent opening front cover with switch in ON position. Handle lockable in OFF position. Fuse clips: Designed to accommodate NEMA FU 1, Class Rfuses.

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3. Molded Case Circuit Breakers: UL 489, circuit breakers with integral thermal and instantaneous magnetic trip in each pole. Furnish circuit breakers UL listed as Type HACR for air conditioning equipment branch circuits.
4. Molded Case Circuit Breakers with Current Limiters: UL 489, circuit breakers with replaceable current limiting elements, in addition to integral thermal and instantaneous magnetic trip in each pole.
5. Current Limiting Molded Case Circuit Breakers: UL 489, circuit breakers with integral thermal and instantaneous magnetic trip in each pole, coordinated with automatically resetting current limiting elements in each pole. Interrupting rating 100,000 symmetrical amperes, let-through current and energy level less than permitted for same size NEMA FU 1, Class RK-5 fuse.
6. Controllers: NEMA ICS 2, AC general-purpose Class A magneticcontroller for induction motors rated in horsepower.
   a. Control Voltage: 120volts, 60 Hertz.
   b. Overload Relay: NEMA ICS 2; bimetal or melting alloy.
   c. Auxiliary Contacts: NEMA ICS 2, normally open and normally closed contacts in addition to seal-in contact.
   d. Cover Mounted Pilot Devices: NEMA ICS 5, heavy duty oiltight type.
   e. Pilot Device Contacts: NEMA ICS 5, Form Z, rated A150.
   f. Pushbuttons: Coveredtype.
   g. Indicating Lights: LEDtype.
   h. Selector Switches: Rotary type.
   i. Relays: NEMA ICS 2.
   j. Control Power Transformers: [120] [_____] volt secondary, [[_____] VA minimum, in each motor starter.] [as indicated on Drawings.] Furnish fused [primary and] secondary, and bond unfused leg of secondary to enclosure.
7. Circuit Breaker Accessories: Trip units and auxiliary switches as indicated on Drawings.
8. [Surge Suppressers: Integrated in panelboard, refer to Section 26 35 53.]
9. Enclosure: NEMA PB 1, Type or 201or 3R20 inches deep,6 inches wide, cabinet box.
10. Cabinet Front: Surface type, fastened [hinged door with flush lock.

F. Finishes: Manufacturer's standard [gray] [_____] enamel.

2.02 BRANCH CIRCUIT PANELBOARDS

A. Manufacturer List:

1. Cutler-Hammer.
2. General Electric.
3. Schneider Electric.

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4. Siemens.

B. Substitution Limitations:

1. Section 01 60 00, Product Requirements: Requirements for substitutions for other manufacturers and products.

C. Description: NEMA PB1, circuit breaker type, lighting and appliance branch circuit panelboard.

D. Materials:

1. Panelboard Bus: Copper,current carrying components, ratings as indicated on Drawings. Furnish copper ground bus in each panelboard[; furnish insulated ground bus as indicated on Drawings].
2. For non-linear load applications subject to harmonics furnish 200 percent rated, plated copper, solid neutral.
3. Minimum Integrated Short Circuit Rating: 22,000amperes rms symmetrical for 240 volt panelboards; 14,00065,000amperes rms symmetrical for 480 volt panelboards[, or as indicated on Drawings].
4. Molded Case Circuit Breakers: UL 489, [bolt-on] [plug-on] type thermal magnetic trip circuit breakers, with common trip handle for all poles, listed as Type SWD for lighting circuits, Type HACR for air conditioning equipment circuits, Class A ground fault interrupter circuit breakers as indicated on Drawings. Provide UL class 760 arc-fault interrupter circuit breakers as indicated on Drawings. Do not use tandem circuit breakers.
5. Current Limiting Molded Case Circuit Breakers: UL 489, circuit breakers with integral thermal and instantaneous magnetic trip in each pole, coordinated with automatically resetting current limiting elements in each pole. Interrupting rating 100,000 symmetrical amperes, let-through current and energy level less than permitted for same size NEMA FU 1, Class RK-5 fuse.
6. [Surge Suppresser: Integrated in panelboard, refer to Section 26 35 53.]
7. Enclosure: NEMA PB 1, Type or1or Type as3Ras shown on Drawings.
   a. Cabinet Box: 6 inches deep, 20 inches inches wide for 240 volt and less panelboards, 20 inches6 inches wide for 480 volt panelboards.
   b. Cabinet Front:
      1) Surface cabinet front with concealed trim clamps, concealed hinge, metal directory frame, and flush lock keyed alike.
      2) Finishes: Finish in manufacturer's standard [gray] [_____] enamel.

2.03 ELECTRONIC GRADE PANELBOARD

A. Description:

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1. Integral Surge Suppresser: Component recognized in accordance with UL 1449 and UL 1283.
2. Panelboard: UL 67 listed and TVSS device UL 1449 Component Recognized. TVSS device meets UL 1449. Furnish panelboard markings with clamp voltage at TVSS terminals and clamp voltage at panelboard line terminals.

B. Performance:

1. Integral Surge Suppressers:
   a. Meet or exceed the following criteria:
      1) Maximum single impulse current rating not less than [80 kA] [120 kA] [160 kA] [200 kA] [_____] for each phase.
      2) Pulse Lift Test: Capable of protecting against and surviving 5000 IEEE C62.41 Category C transients without failure or degradation.
      3) Clamping voltage not exceeding the following:

Voltage	L-N	N-G	L-G
208Y/120	500 V	500 V	500 V
480Y/277	1000 V	1000 V	1000 V

C. Fabrication:

1. Integral Surge Suppresser:
   a. Furnish copper bus bars for surge current path.
   b. Construct using surge current modules (MOV based). Each module fused with user replaceable 200,000 AIR rated fuses. Status of each module monitored on front cover of panelboard enclosure and on module.
   c. Furnish with audible alarm activated when one of surge current modules has failed. Furnish alarm on/off to silence alarm and alarm push-to-test switch to test alarm. Locate switches and alarm on front cover of panelboard enclosure.
   d. Furnish response time no greater than five nanoseconds for individual protection modes.
   e. Designed to withstand maximum continuous operating voltage (MCOV) of not less than 115 percent of nominal RMS voltage.
   f. Furnish visible indication of proper suppresser connection and operation. Lights indicate operable phase and module.
   g. Furnish minimum EFI/RFI filtering of 34 dB at 100 kHz with insertion loss ratio of 50: 1 using Mil Std. 220A methodology.
2. Panelboards
   a. Top or bottom feed as indicated on Drawings. Furnish circuit directory inside door.
   b. Construct box of galvanized steel. Box size as indicated on Drawings.

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c. Main bus constructed of copper and rated for load current.
d. Furnish interior with branch circuit breakers. Furnish one 60amp circuit breaker, with appropriate number of poles, as dedicated disconnect for TVSS.
e. Furnish standard ratedneutral assembly with [copper neutral bus.
f. Furnish with insulated ground bus and safety ground bus.
g. Furnish wiring gutters in accordance with NEC.
h. Field connections to panelboard: main breaker type.
i. Construct with surfacemounted trim and NEMA Type 1or 3R enclosure, as shown on Drawings.
j. Furnish with branch breaker positions and nominal current rating as indicated on Drawings.

2.04 LOAD CENTERS

A. Manufacturer List:

1. Cutler-Hammer.
2. General Electric.
3. Schneider Electric.
4. Siemens.

B. Substitution Limitations: Section 01 60 00, Product Requirements: Requirements for substitutions for other manufacturers and products.

C. Description: Circuit breaker load center, with bus ratings as indicated on Drawings.

D. Performance: Minimum Integrated Short Circuit Rating: 10,000 amperes rms symmetrical.

E. Materials:

1. Molded Case Circuit Breakers: UL 489, plug-on type thermal magnetic trip circuit breakers, with common trip handle for poles, listed as Type SWD for lighting circuits, Class A ground fault interrupter circuit breakers [as indicated on Drawings]. Do not use tandem circuit breakers.
2. Enclosure: [General Purpose] [Rainproof].

F. Box: [Flush] [Surface] type [without door] [with door, and [pull ring and latch] [lock] on door].

G. Finishes: Finish in manufacturer's standard [gray] [_____] enamel.

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2.05 SOURCE QUALITY CONTROL

A. Section 01 40 00, Quality Requirements: Testing, inspection and analysis requirements.

B. Independently test integral surge suppressers with category C3 high exposure waveform (20 kV-1.2/50us, 10kA-8/20 us) per IEEE C62.41.

PART 3 - EXECUTION

3.01 DEMOLITION

A. Disconnect abandoned panelboards [and load centers]. [Remove] [Install blank cover for] abandoned panelboards [and load centers].

B. Maintain access to existing panelboard [and load centers] remaining active and requiring access. Modify installation or provide access panel.

3.02 INSTALLATION

A. Install panelboards [and load centers] in accordance with NEMA PB 1.1.

B. Install panelboards [and load centers] plumb.

C. Install recessed panelboards [and load centers] flush with wall finishes.

D. Height: 6 feet to top of panelboard [and load center]; install panelboards taller than 6 feet with bottom no more than 4 inches above floor.

E. Install filler plates for unused spaces in panelboards.

F. Provide typed [or neatly handwritten] circuit directory for each branch circuit panelboard [and load center]. Revise directory to reflect circuiting changes to balance phase loads. Identify each circuit as to its clear, evident and specific purpose of use.

G. Install engraved plastic nameplates in accordance with Section 26 05 53.

H. Install spare conduits out of each recessed panelboard to accessible location [above ceiling] [below floor]. Minimum spare conduits: [5] [_____] empty [1 inch] [[_____] inch]. Identify each as SPARE.

I. Ground and bond panelboard enclosure according to Section 26 05 26. Connect equipment ground bars of panels in accordance with NFPA 70.

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3.03 [REPAIR] [RESTORATION]

A. Repair existing panelboards [and load centers] to remain or to be reinstalled.

3.04 FIELD QUALITY CONTROL

A. Section 01 40 00, Quality Requirements: Requirements for inspecting, testing.

B. Section 01 70 00, Execution and Closeout Requirements: Requirements for testing, adjusting, and balancing.

C. Inspect and test in accordance with NETA ATS, except Section 4.

D. Perform circuit breaker inspections and tests listed in NETA ATS, Section 7.6.

E. Perform switch inspections and tests listed in NETA ATS, Section 7.5.

F. Perform controller inspections and tests listed in NETA ATS, Section 7.16.1.

3.05 ADJUSTING

A. Section 01 70 00, Execution and Closeout Requirements: Requirements for starting and adjusting.

B. Measure steady state load currents at each panelboard feeder; rearrange circuits in panelboard to balance phase loads to within 10 percent of each other. Maintain proper phasing for multi-wire branch circuits.

3.06 CLEANING

A. Section 01 70 00, Execution and Closeout Requirements: Requirements for cleaning.

B. Clean existing panelboards [and load centers] to remain or to be reinstalled.

END OF SECTION

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SECTION 26 24 19
MOTOR-CONTROL CENTERS

PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes: Motor control centers.

B. Related Requirements:

1. Section 03 30 00, Cast-In-Place Concrete: Housekeeping pads.
2. Section 26 05 26, Grounding and Bonding for Electrical Systems.
3. Section 26 05 53, Identification for Electrical Systems.
4. Section 26 28 13, Fuses.

1.02 REFERENCE STANDARDS

A. Institute of Electrical and Electronics Engineers: IEEE C62.41, Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits.

B. National Electrical Manufacturers Association:

1. NEMA FU 1, Low Voltage Cartridge Fuses.
2. NEMA ICS 2, Industrial Control and Systems: Controllers, Contactors, and Overload Relays, Rated Not More Than 2000 Volts AC or 750 Volts DC.
3. NEMA ICS 2.3, Instructions for the Handling, Installation, Operation, and Maintenance of Motor Control Centers.
4. NEMA ICS 3, Industrial Control and Systems: Factory Built Assemblies.
5. NEMA ICS 5, Industrial Control and Systems: Control Circuit and Pilot Devices.
6. ,NEMA KS 1, Enclosed and Miscellaneous Distribution Equipment Switches (600 Volts Maximum).

C. International Electrical Testing Association: NETA ATS, Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems.

D. Underwriters Laboratories Inc.:

1. UL 198E, Class R Fuses.
2. UL 489, http://www.nssn.org/search/DetailResults.aspx?docid=521368&selnode=Mold

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ed-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures.
3. UL 508, Industrial Control Panels.
4. UL 845, Motor Control Centers.

1.03 SUBMITTALS

A. Section 01 33 00, Submittal Procedures: Submittal procedures.

B. Product Data: Submit electrical characteristics including voltage, frame size and trip ratings, fault current withstand ratings, and time-current curves of equipment and components.

C. Shop Drawings: Indicate front and side views of enclosures with overall dimensions shown; conduit entrance locations and requirements; nameplate legends; size and number of bus bars for each phase, [neutral,] and ground; electrical characteristics including voltage, frame size and trip ratings, withstand ratings, and time and current curves of equipment and components.

D. Test and Evaluation Reports: Indicate field test and inspection procedures and test results.

E. Source Quality Control Submittals: Indicate results of [shop] [factory] tests and inspections.

F. Field Quality Control Submittals: Indicated results of Contractor furnished tests and inspections.

1.04 CLOSEOUT SUBMITTALS

A. Section 01 70 00, Execution and Closeout Requirements: Closeout procedures.

B. Operation and Maintenance Data: Submit replacement parts list for controllers.

C. Project Record Documents: Record actual locations, configurations, and ratings of motor control centers and major components.

1.05 QUALIFICATIONS

A. Manufacturer: Company specializing in manufacturing products specified in this section with minimum three years [documented] experience.

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1.06 DELIVERY, STORAGE, AND HANDLING

A. Section 01 60 00, Product Requirements: Product storage and handling requirements.

B. Deliver in [60] [_____] inch maximum width shipping splits, individually wrapped for protection, and mounted on shipping skids.

C. Store in clean, dry space. Maintain factory wrapping or provide additional canvas or plastic cover to protect units from dirt, water, construction debris, and traffic.

D. Handle in accordance with NEMA ICS 2.3. Lift only with lugs provided. Handle carefully to avoid damage to motor control center components, enclosure, and finish.

1.07 AMBIENT CONDITIONS

A. Section 01 50 00, Temporary Facilities and Controls: Ambient conditions control facilities for product storage and installation.

B. Conform to NEMA ICS 2 service conditions during and after installation of motor control centers.

1.08 EXISTING CONDITIONS:

A. Verify field measurements prior to fabrication. Indicate field measurements on shop drawings.

PART 2 - PRODUCTS

2.01 MOTOR CONTROL CENTER

A. Manufacturer List:

1. Allen-Bradley.
2. Cutler-Hammer.
3. General Electric Company.
4. Schneider Electric.
5. Siemens Energy & Automation, Inc.

B. Substitution Limitations:

1. Section 01 60 00, Product Requirements: Requirements for substitutions for other manufacturers and products.

C. Description: NEMA ICS 3, Class [I] [II], Type [A] [B] [C] motor control center.

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1. Main Overcurrent Protection: [Molded case circuit breaker] [Fusible switch].
2. Feeder Tap Units: [Molded case thermal-magnetic circuit breakers] [Fusible switches].

D. Operation:

1. Service Conditions: NEMA ICS 2.
   a. Temperature: 0 to 130 degrees F.
   b. Altitude: 475 feet.
   c. Voltage Rating: 277/480volts, three phase, [four] wire, 60 Hertz.
   d. Integrated Equipment Short Circuit Rating: 65,000 amperes rms symmetrical at 480 volts.

E. Materials:

1. Horizontal Bus: Copper, with continuous current rating of 600] amperes. Include copper ground bus entire length of control center.
2. Vertical Bus: Copper.

F. Fabrication:

1. Configuration: Units front mounting only, accessible from front only.
2. Enclosure: NEMA ICS 6, Type 3R, non-walk-in or12, as shown on Drawings.

G. Finishes: [Manufacturer's standard gray enamel] [_____].

2.02 FULL-VOLTAGE NON-REVERSING CONTROLLERS

A. Manufacturer List:

1. Allen Bradley.
2. Cutler-Hammer.
3. General Electric.
4. Square D.

B. Substitution Limitations: Section 01 60 00, Product Requirements: Requirements for substitutions for other manufacturers and products.

C. Description: NEMA ICS 2, AC general-purpose Class A [magnetic] [solid-state] controller for induction motors rated in horsepower.

D. Operation: Control Voltage: 120volts, 60 Hertz.

E. Materials:

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1. Overload Relay: NEMA ICS 2; bimetalormelting alloy.
2. Product Options and Features:
   a. Auxiliary Contacts: NEMA ICS 2, [normally open and normally closedcontacts in addition to seal-in contact.
   b. Cover Mounted Pilot Devices: NEMA ICS 5, heavy duty oiltight type.
   c. Pilot Device Contacts: NEMA ICS 5, Form Z, rated A150.
   d. Pushbuttons: Coveredtype.
   e. Indicating Lights: LEDtype.
   f. Selector Switches: Rotary type.
   g. Relays: NEMA ICS 5.
   h. Control Power Transformers: 120volt secondary, [[_____] VA minimum, in each motor controller.] [as scheduled.] Furnish fused primary and secondary, and bond unfused leg of secondary to enclosure.

2.03 FUSIBLE SWITCH ASSEMBLIES

A. Manufacturer List:

1. Cutler Hammer.
2. General Electric.
3. Square D.

B. Substitution Limitations: Section 01 60 00, Product Requirements: Requirements for substitutions for other manufacturers and products.

C. Description: NEMA KS 1, Type HD, load interrupter knife switch. Handle lockable in OFF position.

D. Materials: Fuse clips: Designed to accommodate NEMA FU 1, Class [R] [J] fuses.

2.04 MOLDED CASE CIRCUIT BREAKER

A. Manufacturer List:

1. Allen Bradley.
2. Cutler Hammer.
3. General Electric.
4. Square D.

B. Substitution Limitations: Section 01 60 00, Product Requirements: Requirements for substitutions for other manufacturers and products.

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2.05 DESCRIPTION: UL 489, MOLDED-CASE CIRCUIT BREAKER.

A. Operation:

1. Field-Adjustable Trip Circuit Breaker: Circuit breakers with frame sizes [200] [_____] amperes and larger have mechanism for adjusting [long time] [short time] [continuous current] [[short time] [long time] pickup current] setting for automatic operation. Range of Adjustment: [_____] [seconds.] [amperes.] [percent.]
2. Field-Changeable Ampere Rating Circuit Breaker: Circuit breakers with frame sizes [200] [_____] amperes and larger have changeable trip units.

2.06 TRANSIENT VOLTAGE SUPPRESSION DEVICES

A. Manufacturer List:

1. [_____] Model [_____] [as basis of design].
2. [_____] Model [_____].
3. [_____] Model [_____].

B. Substitution Limitations:

1. Section 01 60 00, Product Requirements: Requirements for substitutions for other manufacturers and products.
2. No substitutions permitted.

C. Furnish materials in accordance with [State] [Municipality] of [_____] [Highways] [Public Work's] standards.

D. Description: IEEE C62.41, factory-mounted transient voltage surge suppressor, selected to meet requirements for [low] [medium] [high] exposure and to coordinate with system circuit voltage.

2.07 SOURCE QUALITY CONTROL

A. Section 01 40 00, Quality Requirements: Testing, inspection and analysis requirements.

B. Shop inspect and perform standard productions tests for each controller in accordance with manufacturer's standards.

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C. Make completed motor control center available for inspection at manufacturer's factory prior to packaging for shipment. Notify [Owner] [Architect/Engineer] at least seven days before inspection is allowed.

D. Allow witnessing of factory inspections and tests at manufacturer's test facility. Notify [Owner] [Architect/Engineer] at least seven days before inspections and tests are scheduled.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Section 01 70 00, Execution and Closeout Requirements: Requirements for installation examination.

B. Verify surfaces are suitable for motor control center installation.

3.02 DEMOLITION

A. Disconnect and remove abandoned motor control centers.

B. Maintain access to existing motor control centers and other installations remaining active and requiring access.

3.03 INSTALLATION

A. Furnish housekeeping pads under the provision of Section 03 30 00 }.

B. Install in accordance with NEMA ICS 2.3 [and NEMA 7.1].

C. Tighten accessible bus connections and mechanical fasteners after placing motor control center.

D. Install fuses in fusible switches.

E. Select and install heater elements in motor controllers to match installed motor characteristics.

F. Install engraved plastic nameplates in accordance with Section 26 05 53.

G. Neatly type label inside each motor controller door identifying motor served, nameplate horsepower, full load amperes, code letter, service factor, voltage rating, and phase rating. Place label in clear plastic holder. Indicate method of identifying phase conductors.

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H. Ground and bond motor control centers in accordance with Section 26 05 26.

3.04 [REPAIR] [RESTORATION]

A. Repair existing motor control centers to remain or are to be reinstalled.

3.05 FIELD QUALITY CONTROL

A. Section 01 40 00, Quality Requirements: Requirements for inspecting, testing.

B. Section 01 70 00, Execution and Closeout Requirements: Requirements for testing, adjusting, and balancing.

C. Inspect and test in accordance with NETA ATS, except Section 4.

D. Perform inspections and tests listed in NETA ATS, Section 7.16.

E. Inspect and test variable frequency controllers according to NEMA ICS 7.1.

3.06 CLEANING

A. Section 01 70 00, Execution and Closeout Requirements: Requirements for cleaning.

B. Clean existing motor control centers to remain or are to be reinstalled.

END OF SECTION

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SECTION 26 27 26
WIRING DEVICES

PART 1 - GENERAL

1.01 SUMMARY

A. Section includes wall switches; wall dimmers; receptacles; multioutlet assembly; and device plates and decorative box covers.

B. Related Sections:

1. Section 26 05 21, Undercarpet Cable.
2. Section 26 05 33, Raceway and Boxes for Electrical Systems: Outlet boxes for wiring devices.
3. Section 26 05 34, Floor Boxes for Electrical Systems: Service fittings for receptacles installed on floor boxes.
4. Section 26 05 34, Floor Boxes for Electrical Systems: Poke-through receptacles.
5. Section 26 05 39, Underfloor Raceways for Electrical Systems: Service fittings for receptacles installed in underfloor raceways.

1.02 REFERENCES

A. National Electrical Manufacturers Association:

1. NEMA WD 1, General Requirements for Wiring Devices.
2. NEMA WD 6, Wiring Devices-Dimensional Requirements.

1.03 SUBMITTALS

A. Section 01 33 00, Submittal Procedures: Submittal procedures.

B. Product Data: Submit manufacturer's catalog information showing dimensions, colors, and configurations.

C. Samples: Submit two samples of each wiring device and wall plate illustrating materials, construction, color, and finish.

1.04 QUALIFICATIONS

A. Manufacturer: Company specializing in manufacturing products specified in this section with minimum three years [documented] experience.

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1.05 EXTRA MATERIALS

A. Section 01 70 00, Execution and Closeout Requirements: Spare parts and maintenance products.

B. Furnish [two] [_____] of each style, size, and finish wall plate.

PART 2 - PRODUCTS

2.01 WALL SWITCHES

A. Manufacturers:

1. Cooper Wiring Devices Model [_____].
2. Harvey Hubbell, Inc. Model [_____].
3. Leviton Manufacturing Company. Model [_____].
4. Substitutions: Section 01 60 00, Product Requirements.

B. Single Pole Switch:

1. [Cooper Wiring Devices] Model [_____].
2. [Harvey Hubbell, Inc.] Model [_____].
3. [Leviton Manufacturing Company.] Model [_____].
4. Substitutions: Section 01 60 00, Product Requirements.

C. Double Pole Switch:

1. [Cooper Wiring Devices] Model [_____].
1. [Harvey Hubbell, Inc.] Model [_____].
2. [Leviton Manufacturing Company.] Model [_____].
3. Substitutions: Section 01 60 00, Product Requirements.

D. Three-way Switch:

1. [Cooper Wiring Devices] Model [_____].
2. [Harvey Hubbell, Inc.] Model [_____].
3. [Leviton Manufacturing Company.] Model [_____].
4. Substitutions: Section 01 60 00, Product Requirements.

E. Four-way Switch:

1. [Cooper Wiring Devices] Model [_____].
2. [Harvey Hubbell, Inc.] Model [_____].
3. [Leviton Manufacturing Company.] Model [_____].
4. Substitutions: Section 01 60 00, Product Requirements.

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F. Color: [_____].

1. Product Description: NEMA WD 1, Heavy-Duty, AC only general-use snap switch.

G. Body and Handle: Ivory plastic with togglehandle.

H. Ratings: Match branch circuit and load characteristics.

2.02 RECEPTACLES

A. Single Convenience Receptacle:

1. [Cooper Wiring Devices] Model [_____].
2. [Harvey Hubbell, Inc.] Model [_____].
3. [Leviton Manufacturing Company.] Model [_____].
4. [_____] Model [_____].
5. Substitutions: [Section 01 60 00, Product Requirements] [Not Permitted].

B. Duplex Convenience Receptacle:

1. [Cooper Wiring Devices] Model [_____].
2. [Harvey Hubbell, Inc.] Model [_____].
3. [Leviton Manufacturing Company.] Model [_____].
4. [_____] Model [_____].
5. Substitutions: [Section 01 60 00, Product Requirements] [Not Permitted].

C. GFCI Receptacle:

1. [Cooper Wiring Devices] Model [_____].
2. [Harvey Hubbell, Inc.] Model [_____].
3. [Leviton Manufacturing Company.] Model [_____].
4. [_____] Model [_____].
5. Substitutions: [Section 01 60 00, Product Requirements] [Not Permitted].

D. Hospital Use Receptacle:

1. [Cooper Wiring Devices] Model [_____].
2. [Harvey Hubbell, Inc.] Model [_____].
3. [Leviton Manufacturing Company.] Model [_____].
4. [_____] Model [_____].
5. Substitutions: [Section 01 60 00, Product Requirements] [Not Permitted].

E. [_____] Receptacle:

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1. [Cooper Wiring Devices] Model [_____].
2. [Harvey Hubbell, Inc.] Model [_____].
3. [Leviton Manufacturing Company.] Model [_____].
4. [_____] Model [_____].
5. Substitutions: [Section 01 60 00, Product Requirements] [Not Permitted].

F. Color: [_____].

G. Product Description: NEMA WD 1, Heavy-duty general use receptacle.

H. Device Body: Ivory plastic.

I. Configuration: NEMA WD 6, type as indicated on Drawings.

J. Convenience Receptacle: Type 5-20.

K. GFCI Receptacle: Convenience receptacle with integral ground fault circuit interrupter to meet regulatory requirements.

1.2 WALL PLATES

A. Manufacturers:
1. Cooper Wiring Devices Model [_____].
2. Harvey Hubbell, Inc. Model [_____].
3. Leviton Manufacturing Company. Model [_____].
4. Substitutions: Section 01 60 00, Product Requirements.

B. Decorative Cover Plate: Ivory,nylon.]

C. Jumbo Cover Plate: Ivory,nylon.

D. Weatherproof Cover Plate: Stainless steel plate withhinged and gasketed device cover.

E. [_____] Cover Plate: [_____].

PART 3 - EXECUTION

3.01 EXAMINATION

A. Section 01 30 00, Administrative Requirements: Coordination and project conditions.

B. Verify outlet boxes are installed at proper height.

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C. Verify wall openings are neatly cut and completely covered by wall plates.

D. Verify branch circuit wiring installation is completed, tested, and ready for connection to wiring devices.

3.02 PREPARATION

A. Clean debris from outlet boxes.

3.03 EXISTING WORK

A. Disconnect and remove abandoned wiring devices.

B. Modify installation to maintain access to existing wiring devices to remain active.

C. Clean and repair existing wiring devices to remain or to be reinstalled.

3.04 INSTALLATION

A. Install devices plumb and level.

B. Install switches with OFF position down.

C. Install wall dimmers to achieve full rating specified and indicated after derating for ganging as instructed by manufacturer.

D. Do not share neutral conductor on load side of dimmers.

E. Install receptacles with grounding pole on [top] [bottom].

F. Connect wiring device grounding terminal to [outlet box with bonding jumper] [and] [branch circuit equipment grounding conductor].

G. Install wall plates on flush mounted switches, receptacles, and blank outlets.

H. Install decorative plates on switch, receptacle, and blank outlets in finished areas.

I. Connect wiring devices by wrapping solid conductor around screw terminal. Install stranded conductor for branch circuits 10 AWG and smaller. When stranded conductors are used in lieu of solid, use crimp on fork terminals for device terminations. Do not place bare stranded conductors directly under device screws.

J. Use jumbo size plates for outlets installed in masonry walls.

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K. Install galvanized steel plates on outlet boxes and junction boxes in unfinished areas, above accessible ceilings, and on surface mounted outlets.

3.05 INTERFACE WITH OTHER PRODUCTS

A. Coordinate locations of outlet boxes provided under Section 26 05 33 to obtain mounting heights [as specified and] as indicated on drawings.

B. Install wall switch 48 inches above finished floor.

C. Install convenience receptacle 18 inches above finished floor.

D. Install convenience receptacle 6 inches above [counter] [back splash of counter].

E. Coordinate installation of wiring devices with underfloor raceway service fittings provided under Section 26 05 39, <<insert title>>.

F. Coordinate installation of wiring devices with floor box service fittings provided under Section 26 05 34, <<insert title>>.

3.06 FIELD QUALITY CONTROL

A. Section [01 40 00, Quality Requirements] [01 70 00, Execution and Closeout Requirements]: Field inspecting, testing, adjusting, and balancing.

B. Inspect each wiring device for defects.

C. Operate each wall switch with circuit energized and verify proper operation.

D. Verify each receptacle device is energized.

E. Test each receptacle device for proper polarity.

F. Test each GFCI receptacle device for proper operation.

3.07 ADJUSTING

A. Section 01 70 00, Execution and Closeout Requirements: Testing, adjusting, and balancing.

B. Adjust devices and wall plates to be flush and level.

3.08 CLEANING

A. Section 01 70 00, Execution and Closeout Requirements: Final cleaning.

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B. Clean exposed surfaces to remove splatters and restore finish.

END OF SECTION

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SECTION 26 29 23
LOW-VOLTAGE ADJUSTABLE FREQUENCY DRIVE SYSTEM

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. Electronic Industries Alliance (EIA): 359-A-1, Special Colors.
2. Hydraulic Institute Standards (HIS).
3. Institute of Electrical and Electronics Engineers (IEEE):
   a. 112, Standard Test Procedure for Polyphase Induction Motors and Generators.
   b. 519, Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems.
   c. C62.41, Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits.
4. National Electrical Manufacturer's Association (NEMA):
   a. 250, Enclosures for Electrical Equipment (1,000 Volts Maximum).
   b. CP 1, Shunt Capacitors.
   c. MG 1, Motors and Generators.
   d. WC 57, Standard for Control, Thermocouple Extensions, and Instrumentation Cables.
5. National Fire Protection Association (NFPA): 79, Electrical Standard for Industrial Machinery.

1.02 DEFINITIONS

A. Terms that may be used in this section:

1. AFD: Adjustable frequency drive.
2. CMOS: Complementary metal oxide semiconductor.
3. CSI: Current source inverter.
4. EMU: Energy monitoring unit.
5. GTO: Gate turn-off thyristor.
6. MPR: Motor protection relay.
7. MTBF: Mean time between failure.
8. PWM: Pulse width modulation.
9. ROM: Read only memory.
10. RTD: Resistance temperature detector.
11. RTU: Remote Telemetry Unit.

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12. Rated Load: Load specified for equipment.
13. Rated Speed: Nominal rated (100 percent) speed specified for equipment.
14. TDD: Total demand distortion.
15. THD: Total harmonic distortion.
16. TTL: Transistor transistor logic.

1.03 SYSTEM DESCRIPTION

A. Performance Requirements:

1. Composite drive/motor efficiency (CE) is defined as ratio of motor shaft kW to drive input kW. AFD system minimum requirements:
   a. At 60-Hz drive output and 100 percent load, CE equals 92 percent.
   b. At 50-Hz drive output and 60 percent load CE equals 89 percent.
   c. At 40-Hz drive output and 30 percent load CE equals 84 percent.
   d. At 30-Hz drive output and 12.5 percent load CE equals 77 percent.
2. Rated Continuous Operation Capacity: Not less than 1.15 times full load current rating of driven motor, as indicated on motor nameplate, and suitable for continuous operation at continuous overload which may be imposed on motor by driven pump operating over specified speed range.
3. Basis for Harmonic Computations: Using Simplified Plant One-Line Diagram for current and voltage distortion computations, furnish harmonic filters, line reactors, isolation transformers, or higher pulse converter arrangements required to meet current/voltage distortion [and line notching] limits.
4. Normal Source Current Harmonic Distortion:
   a. Compute normal source individual and total current harmonic distortion at location identified as [PCC1,] [_____,] in accordance with IEEE 519.
   b. Individual current harmonic distortion and total demand distortion expressed as percent of maximum demand load current I_L shall not exceed values specified in Table 1 below:

Table 1

Individual Harmonic Order (Odd Harmonics)	Harmonic Current Distortion Percent of Max. Demand Load Current IL
h <11	[_____]
11 h <17	[_____]
17 h <23	[_____]

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Table 1	
Individual Harmonic Order (Odd Harmonics)	**Harmonic Current Distortion Percent of Max. Demand Load Current IL**
23 h <35	[_____]
35 h	[_____]
Total Demand Distortion (TDD)	[_____]

c. Limits specified in Table 1 are for drives utilizing 6-pulse rectifiers. Should manufacturer propose 12-pulse rectifiers, limits for characteristic harmonics can be increased by a factor of 1.41 times values listed in Table 1.

5. [Standby Source Current Harmonic Distortion:]

a. [Compute standby source individual and total current harmonic distortion at location identified as] [PCC2,] [_____] [in accordance with IEEE 519. Individual current harmonic distortion and total demand distortion expressed as percent of maximum demand load current IL shall not exceed values specified in Table 2 below.]

Table 2	
Individual Harmonic Order (Odd Harmonics)	**Harmonic Current Distortion Percent of Max. Demand Load Current IL**
h <11	[_____]
11 <h <17	[_____]
17 <h <23	[_____]
23 <h <35	[_____]
35 <h	[_____]
Total Demand Distortion (TDD)	[_____]

b. Limits specified in Table 2 are for drives utilizing 6-pulse rectifiers. Should manufacturer propose 12-pulse rectifiers, limits for characteristic harmonics can be increased by a factor of 1.41 times values listed in Table 2.

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6. Normal Source Voltage Harmonic Distortion: Compute normal source voltage harmonic distortion at location identified as [PCC3.] [_____] THD shall not exceed [5] [_____] percent, and individual voltage harmonic distortion shall not exceed [3] [_____] percent.
7. [Standby Source Voltage Harmonic Distortion: Compute standby source voltage harmonic distortion at location identified as [PCC3.] [_____] THD shall not exceed [5] [_____] percent, and individual voltage harmonic distortion shall not exceed [3] [_____] percent.]
8. Furnish isolating transformers or series reactors, harmonic filters, or other devices necessary for proper system operation. Furnish necessary devices and circuits to prevent operation of one drive from adversely affecting operation of other drives supplied from same transformer or same bus.
9. When isolation transformers are used, design to meet K-factor requirements of drive(s) connected.

B. Design Requirements:

1. Drive system consisting of adjustable frequency controller, drive motor, auxiliary items, and components necessary for complete operating system.
2. Other equipment is being powered from same bus as adjustable frequency drives. Ensure proper operation of drives and other loads under normal and emergency conditions.
3. Furnish AFDs rated on basis of actual motor full load nameplate current rating times the service factor.
4. Drive System: Convert incoming three-phase, 60-Hz ac power to variable voltage, adjustable frequency output for adjustable speed operation of a standard ac induction squirrel-cage motor, using pulse-width-modulation (PWM) technique to produce adjustable frequency output.
5. System rated for continuous industrial duty and suitable for use with NEMA MG 1, Design B motors.
6. Incoming Line Circuit Breaker: Provide positive means of disconnecting incoming power, and overcurrent protection for drive system.
7. Incoming Line Reactor: Design to minimize harmonic distortion on incoming power feeder.

1.04 SUBMITTALS

A. Action Submittals:

1. Overall drive system operating data, including efficiencies, input currents, and power factors, at driven equipment actual load and rated system input voltage, at 0, 40, 60, 80, 100, and 110 percent of rated speed.

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2. Individual and total harmonic content (voltage and current) reflected in system normal source supply at driven equipment actual load at 70 percent and 100 percent of rated speed at locations specified in Simplified Plant One-Line Diagram and load conditions specified. Normal source system short-circuit available at drive shall be calculated from data furnished in Supplements to this section. Use TDD and THD factors as defined in IEEE 519 to designate total harmonic content.
3. [Individual and total current and voltage harmonic content reflected in standby power source, at locations specified in Supplements to this section, at driven equipment actual load at 70 percent and 100 percent of rated speed determined by using actual size and subtransient reactance of standby system obtained from standby source manufacturer. Use TDD and THD factors as defined in IEEE 519 to designate total harmonic content.]
4. AFD output pulse maximum peak voltage, pulse rise time, and pulse rate of rise including justification for proposed deviation from specified values. Include motor manufacturer's certification motor insulation will withstand long-term overvoltages caused at motor terminals due to specified output pulse data or proposed deviation from this data.
5. Data on shelf life of "dc link" capacitor.
6. Complete system rating, including nameplate data, continuous operation load capability throughout speed range of 0 percent to 120 percent of rated speed.
7. Complete adjustable frequency controller rating coordinated with motor full load nameplate current rating; list controller special features being supplied.
8. Controller, reactor, harmonic filter, and isolating transformer (if applicable) dimensional drawings; information on size and location of space for incoming and outgoing conduit.
9. Maximum heat dissipation from enclosure.
10. [Should separate enclosures and equipment be necessary for [filter elements] [or] [power factor correction equipment,] provide complete dimensional information including location of space for incoming and outgoing conduit, weight, maximum heat loss, and minimum current carrying capacity and recommended wire size for required interconnecting circuits.]
11. Layout of controller face showing pushbuttons, switches, instruments, and indicating lights.
12. Complete system operating description.
13. Complete system schematic (elementary) wiring diagrams.
14. Complete system interconnection diagrams between controller, drive motor, and related components or controls external to system, including wire numbers and terminal board point identification.

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15. One-line diagram of system, including component ratings.
16. Description of diagnostic features being provided.
17. Descriptive literature for control devices such as relays and timers.
18. Itemized bill-of-materials listing system components.
19. [Specific description of provisions, such as filtering and harmonic suppression, being made to ensure proper system operation when [power factor correction capacitors are included in system] [and] [system is supplied from standby engine generator].]
20. [Description of EMU and MPR being furnished or how these functions are accomplished within drive system.]
21. Seismic anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Seismic Anchorage and Bracing.

B. Informational Submittals:

1. Statement of Supplier qualifications.
2. Seismic anchorage and bracing calculations as required by Section 01 88 15, Seismic Anchorage and Bracing.
3. Special shipping, storage and protection, and handling instructions.
4. Manufacturer's printed installation instructions.
5. Factory functional test reports.
6. Certified copy of test report for identical motor tested in accordance with NEMA MG 1-12.53a and IEEE 112, Test Method B, showing rated load, rated speed efficiency meeting or exceeding specified values; motors not as specified will be rejected.
7. Field test reports.
8. Component and attachment testing seismic certificate of compliance as required by Section 01 45 33, Special Inspection [, Observation,] and Testing.
9. Suggested spare parts list to maintain equipment in service for period of [1 year] [and] [5 years.] Include list of special tools required for checking, testing, parts replacement, and maintenance with current price information.
10. List special tools, materials, and supplies furnished with equipment for use prior to and during startup and for future maintenance.
11. Operation and Maintenance Data: As specified in Section 01 78 23, Operation and Maintenance Data.
12. Manufacturer's Certificate of Proper Installation, in accordance with Section 01 43 33, Manufacturers' Field Services.

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1.05 QUALITY ASSURANCE

A. Supplier: Minimum 5 years' experience in furnishing similar size and type adjustable frequency, controlled speed, drive systems.

1.06 EXTRA MATERIALS

A. Furnish for each drive unit:

1. [Complete set of components likely to fail in normal service.]
2. [Plug-in subassemblies.]
3. [Printed circuit boards.]
4. [SCRs.]
5. [Potentiometers.]
6. [Integrated circuits.]
7. [One complete power bridge and one spare printed circuit card for each modular, plug-in type card in controller.]

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Components and accessories specified in this section shall be products of:

1. Eaton Cutler Hammer.
2. Danfoss.
3. Siemens Robicon.
4. Allen-Bradley.
5. ABB.
6. Toshiba.
7. Square D.

B. [No "or-equal" or substitute products will be considered.]

2.02 SUPPLEMENTS

A. Some specific requirements are attached to this section as supplements.

2.03 SERVICE CONDITIONS

A. Ambient Operating Temperature: 32 degrees F to 104 degrees F.

B. Storage Temperature: Minus 40 degrees F to 158 degrees F.

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C. Humidity: 0 percent to 95 percent relative (noncondensing).

D. Altitude: [0 foot to 3,300 feet] [_____].

E. Frequency Stability: Plus or minus 0.1 percent of maximum frequency.

2.04 COMPONENTS

A. Drive Units:

1. Incorporate switching power supply operating from dc bus, to produce PWM output waveform simulating sine wave and providing power loss ride through of 2 milliseconds at full load, full speed.
2. Current-limiting semiconductor fuses for protection of internal power semiconductors.
3. Employ diode bridge rectifier providing constant displacement power factor of 0.95 minimum at all operating speeds and loads.
4. Use transistors for output section, providing a minimum 97 percent drive efficiency at full speed, full load.
5. Employ dc power discharge circuit so that after removal of input power dc link capacitor voltage level will decay below 50 volts dc within 1 minute after de-energizing following NEMA CP 1 and NFPA 79. Design dc link capacitor for a MTBF of [5] [_____] years.
6. Operate with open circuited output.
7. Input Voltage: [480V] [_____] ac plus or minus [10] [_____] percent.
8. Output Voltage: 0 to [480] [_____] volts, three-phase, 0 to [66] [_____]-Hz, minimum.
9. Maximum peak voltage of PWM AFD output pulse of [1,000] [_____] volts, with pulse rise time of not less than 2 microseconds, and maximum rate of rise of [500] [_____] volts per microsecond. Maximum frequency of PWM AFD output pulse (carrier) frequency of [3,000] [_____]-Hz. Should magnitudes of these characteristics be more stressful to motor insulation than specified values, furnish insulation systems on motors suitable for proposed values.
10. Motor Audible Noise Level: When operating throughout speed range of PWM AFD, no more than [3] [_____] dBA above that designated in NEMA MG 1 for same motor operated at constant speed with a 60-Hz supply voltage.
11. Short-Time Overload Capacity: [125] [_____] percent of rated load in rms current for 1 minute following full load, full speed operation.

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12. Equipment Short-Circuit Rating: Suitable for connection to system with maximum source three-phase, bolted fault, short-circuit available of [42,000] [_____] amps rms symmetrical at [480] [_____] volts.
13. Furnish drives with output current-limiting reactors mounted within equipment enclosure.
14. Diagnostics: Comprehensive for drive adjustment and troubleshooting:
    a. Memory battery backup; 100-hour minimum during power loss.
    b. Status messages will not stop drive from running but will prevent it from starting.
    c. Fault Condition Messages and History: First fault protection function to be activated, ability to store six successive fault occurrences in order. Minimum faults numerically:
        1) Overcurrent (time and instantaneous).
        2) Overvoltage.
        3) Undervoltage (dc and ac).
        4) Overtemperature (drive, motor windings, motor bearing, pump bearing).
        5) Serial communication fault.
        6) Short-circuit/ground fault (motor and drive).
        7) Motor stalled.
        8) Semiconductor fault.
        9) Microprocessor fault.
        10) Single-phase voltage condition.
15. Drive Protection:
    a. Fast-acting semiconductor fuses.
    b. Overcurrent, instantaneous overcurrent trip.
    c. Dc undervoltage protection, 70 percent dropout.
    d. Dc overvoltage protection, 130 percent pickup.
    e. Overtemperature, drive, inverter, converter, and dc link components.
    f. Overtemperature, motor, and pump.
    g. Single-phase protection.
    h. Reset overcurrent protection (manual or automatic reset).
    i. Active current limit/torque limit protection.
    j. Semiconductor fault protection.
    k. Short-circuit/ground fault protection.
    l. Serial communication fault protection.
    m. Microprocessor fault.
    n. Surge protection for transient overvoltage (6,000 volts, 80 joule surge, tested per IEEE C62.41).
    o. Visual display of specific fault conditions.
16. Operational Features:

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a. Use manufacturer's standard unless otherwise indicated.
b. Sustained power loss.
c. Momentary power loss.
d. Power interruption.
e. Power loss ride through (0.1 second).
f. Start on the fly.
g. Electronic motor overload protection.
h. Stall protection.
i. Slip compensation.
j. Automatic restart after power return (ability to enable/disable function).
k. Critical frequency lockout (three selectable points minimum, by 1.5-Hz steps in 10-Hz bands, to prevent resonance of system).
l. Drive maintenance system software for complete programming and diagnostics.
m. Ground fault protection, drive, and motor.
n. Operate with no motor connected to output terminals.

B. Rectifier: Three-phase [6-pulse] [12-pulse] full wave diode bridge rectifier to provide constant dc voltage to drive's dc bus.

C. Furnish series choke and capacitors on dc bus to reduce ripple in rectifier output and to reduce harmonic distortion reflected into incoming power feeders.

D. Controller: Microprocessor-controller PWM inverter to convert to dc voltage to variable voltage, adjustable frequency, three-phase ac output. Output voltage shall vary proportionally with frequency to maintain constant ratio of volts to hertz up to 60-Hz; above 60-Hz, voltage shall remain constant with drive operating in constant horsepower output mode.

E. Enclosure:

1. NEMA 250, Type 1, gasketed, freestanding, enclosure for mounting against wall, completely front accessible, and hinged doors. Properly sized to dissipate heat generated by controller within limits of specified operating conditions (including ambient temperature and ambient airflow). Enclosure not to exceed dimensions shown on Drawings.
2. Cable termination compartment door interlocked main circuit breaker, defeatable (lockable in the open position), emergency stop pushbutton, alphanumeric keypad and display, and operator's controls. [Components and controls specified in Section 26 05 04, Basic Electrical Materials and Methods.]

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3. Wire drive from [below] [and] [above] for power and control wiring.
4. Size forced-ventilation for periodic operation to cool each unit with maximum room ambient temperature of 95 degrees F. Furnish redundant fans such that if one fan fails remaining fans furnish adequate ventilation for drive when operating at maximum capacity. Furnish filters on ventilation intakes.
5. Wiring:
    a. Bundle stranded copper wiring neatly with nylon tie wraps or with continuous plastic spiral binding.
    b. Label each terminal for permanent identification of leads.
    c. Identify each wire at each end with imprinted mylar adhesive-back wire markers.
    d. Incorporate in as-installed wiring diagrams for wire and terminal numbers shown.
    e. Wiring across door hinge, use 19-strand, NEMA WC 57 Class C stranding looped for proper twist rather than bending at hinge.
    f. Wire connections internal to panels by crimp-on terminal types.
    g. For multiple enclosure systems, complete interconnection wiring with gasketed enclosure openings for wiring.
    h. Multipoint plug receptacles for control wiring crossing equipment shipping splits.
6. Selector switches, indicating lights, potentiometers, instruments, protective devices, and major system components identified by means of mechanically attached, engraved, laminated nameplates.

F. Operator Interface:

1. Controls: Mount drive local control on front door of enclosure and include control switch and membrane type keypad for the following operator functions:
    a. Start (when in local mode).
    b. Stop (when in local mode).
    c. Speed increase (when in local mode).
    d. Speed decrease (when in local mode).
    e. Parameter mode selection (recall programmed parameters).
    f. LOCAL/OFF/REMOTE control selection (in remote, furnish for remote RUN command digital input and speed increase/decrease via remote 4 mA to 20 mA analog signal).
    g. Fault reset, manual for faults, except loss of ac voltage which is automatic upon return.
    h. RUN/preset speed.

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i. Parameter lock, password or key switch lockout of changes to parameters.
j. Start disable, key switch or programmed code.

2. Control circuit disconnect shall de-energize circuits in units that are not de-energized by main power disconnect device [as required by California Administrative Code].
3. 120 volts, single-phase, 60-Hz circuits for control power and operator controls from internal control power transformer. Furnish power for motor space heaters rated 120 volts.
4. Arrange component and circuit such that failure of a single component cannot cause cascading failure(s) of other component(s).
5. Alphanumeric Display: During normal operation and routine test, the following parameters shall be available:
   a. Motor current (percent of drive rated current).
   b. Output frequency (Hertz).
   c. Output voltage.
   d. Running time.
   e. Local/remote indicator.
   f. Status of digital inputs and outputs.
   g. Analog input and output values.
   h. Output motor current per leg.
   i. All test points.
6. Adjustable Parameters: Set drive operating parameters and indicate in numeric form. Potentiometers may not be used for parameter adjustment. Minimum setup parameters available:
   a. Frequency range, minimum, maximum.
   b. Adjustable acceleration/deceleration rate.
   c. Volts per Hertz (field weakening point).
   d. Active current limit/torque limit, 0 percent to 140 percent of drive rating.
   e. Adjustable voltage boost (IR compensation).
   f. Preset speed (adjustable, preset operating point).
   g. Provision for adjustment of minimum and maximum pump speed to be furnished as function of 4 mA to 20 mA remote speed signal.

G. Signal Interface:

1. Digital Input:
   a. Accept a remote RUN command contact closure input.
   b. High temperature contact closure input from field mounted motor temperature monitoring relay.

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1) Digital Output: Furnish three discrete output dry contact closures rated [5] [_____] amps at [120] [_____] volts [ac.] [dc.]

a. DRIVE RUNNING.
b. DRIVE FAULT (with common contact closure for all fault conditions).
c. DRIVE IN REMOTE MODE.

2. Analog Input: When LOCAL/OFF/REMOTE switch is in REMOTE, control drive speed from remote 4 mA to 20 mA dc signal.
   a. Make provisions for adjustment of minimum and maximum motor speed which shall result from this signal.
   b. Factory set this adjustment to comply with operating speed range designated in driven equipment specifications.
   c. Frequency resolution shall be 0.1 percent of base speed.
   d. [Accept second analog input from speed transmitter located on motor shaft.]
3. Analog Output: Furnish two 4 mA to 20 mA dc signals for actual frequency, actual load.
4. [Serial Communication Interface: RS232/RS 422, compatible with MODBUS as an RTU.]

B. Accessories:
   1. Equipment Identification Plate: 16-gauge stainless steel with 1/4-inch die-stamped equipment tag number securely mounted in readily visible location.
   2. Lifting Lugs: Equipment weighing over 100 pounds.
   3. Anchor Bolts: [Galvanized,] [Type 316 stainless steel,] [sized by equipment manufacturer,] [1/2-inch minimum diameter,] and as specified in Section 05 50 00, Metal Fabrications.
   4. [Motor Protection Relay (MPR): For each drive include a MPR as specified in Section 26 05 04, Basic Electrical Materials and Methods, or furnish functions within drive system. Communications protocol and signal compatibility shall be as required for MPRs.]

C. [Energy Monitoring System: For each drive include an EMU as specified in [_____] or furnish functions within drive system. Communications protocol and signal compatibility shall be as required for EMUs.]

1.2 FACTORY FINISHING

A. Enclosure:
   1. Primer: One coat of rust-inhibiting coating.
   2. Finish:
      a. Interior: One coat white enamel.

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b. Exterior: [One coat manufacturer's standard gray enamel or EIA 359-A-1, No. 61.]

3. [Manufacturer's standard [baked] enamel finish.]

1.3 SOURCE QUALITY CONTROL

A. Factory Inspections: Inspect control panels for required construction, electrical connection, and intended function.

B. Factory Tests and Adjustments: Test [one] [_____] [all] control panels [actually] [identical to that] furnished.

C. Record test data for report.

D. Functional Test: Perform [manufacturer's standard,] [following tests:] [_____]
1. Test diodes, transistors, and GTOs at a thermal level of 125 degrees C.
2. Test TTL and CMOS chips at 70 degrees C.
3. Test printed circuit boards while heat cycled to maximum temperature of 65 degrees C.
4. Test run power sections at maximum 40 degrees C for 12 hours and run with motors for 6 hours.
5. Test assembled drive at maximum 40 degrees C and full load, full speed for 4 hours.
6. Test power capacitors and active components.
7. Operate controller with motor throughout its specified range, and at rated power supply load for 1 hour.
8. Resonance: When harmonic filters are furnished to meet specified harmonic distortion requirements, perform analysis and furnish documentary evidence that filter elements do not resonate with remainder of system parameters at harmonic frequencies present.

E. Motor Test: [See Section 26 20 00, Low-Voltage AC Induction Motors.] [_____]

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install in accordance with manufacturer's printed instructions.

3.02 FIELD QUALITY CONTROL

A. Functional Test:

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1. Conduct on each controller.
2. Inspect controller for electrical supply termination connections, interconnections, proper installation, and quiet operation.
3. Vibration Test:
   a. Complete assembly, consisting of motor, load, and flexible shafting, connected and in normal operation shall not develop amplitudes of vibration exceeding limits recommended by HIS.
   b. Where loads and drives are separated by intermediate flexible shafting, measure vibration both at top motor bearing and at two points on top pump bearing, 90 degrees apart.
4. Record test data for report.

B. Performance Test:

1. Conduct on each controller.
2. Perform under actual or approved simulated operating conditions.
3. Test for continuous [12] [_____]-hour period without malfunction.
4. Demonstrate performance by operating continuous period while varying application load, as input conditions allow, to verify system performance.
5. With plant load connected to normal utility source, measure the following to show parameters within specified limits:
   a. Total and individual current harmonic distortion, up to and including 35th harmonic, at location identified as [PCC1] [_____] in Simplified Plant One-Line Diagram, under following load conditions:
      1) AFDs running at full load and half load.
      2) Half of specified AFDs running at full load and half load.
   b. Power factor at input side of each drive. Documented verification that power factor is maintained at 95 percent as speed of drive goes down from 100 percent to 33 percent.
   c. THD at location identified as [PCC3] [_____] under following conditions:
      1) AFDs running at full load and half load.
      2) Half of specified AFDs running at full load and half load.
6. [With plant load connected to standby power source, measure the following to show parameters within specified limits:
   a. [Total and individual current harmonic distortion, up to and including 35th harmonic, at location identified as [PCC2] [_____] in Simplified Plant One-Line Diagram, with [_____] drives running at:
      1) Full load.
      2) Half load.

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b. [THD at location identified as [PCC3] [_____] in Simplified Plant One-Line Diagram, with [_____] drives running at:
   1) Full load.
   2) Half load.]

7. Record test data for report.

C. Test Equipment:

1. Use Dranetz, Model No. 626-PA, harmonic distortion monitor and Series 626 disturbance analyzer or equivalent instrument to document results.
2. Provide diagnostic plug-in test card complete with instructions, multiposition selector switch, and meters or built-in diagnostic control panel or ROM-based processor for monitoring ac, dc, and digital signals to assist in troubleshooting and startup of drive.

3.03 MANUFACTURERS' SERVICES

A. Manufacturer's Representative: Present at Site or classroom designated by [Owner,] [_____,] for minimum person-days listed below, travel time excluded:

1. [_____] person-days for [installation assistance] [and] [inspection.]
2. [_____] person-days for [functional] [and] [performance] testing and completion of Manufacturer's Certificate of Proper Installation.
3. [_____] person-days for prestartup classroom or Site training.
4. [_____] person-days for facility startup.
5. [_____] person-days for post-startup training [of Owner's personnel.] [Training shall not commence until an accepted detailed lesson plan for each training activity has been reviewed by [Owner] [Engineer] [_____].]

B. See [Section 01 43 33, Manufacturers' Field Services] [and] [Section 01 91 14, Equipment Testing and Facility Startup.]

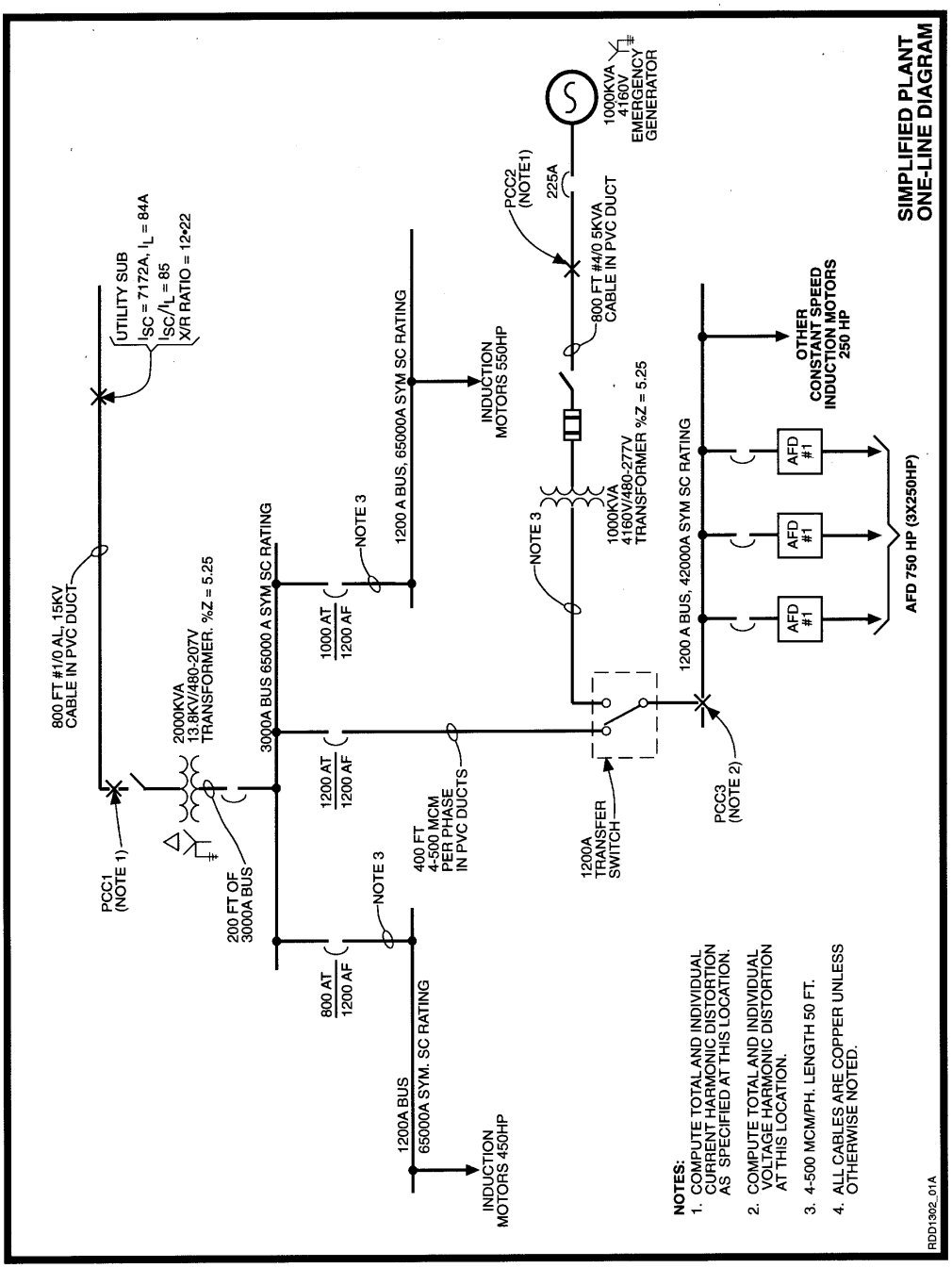
3.04 SUPPLEMENTS

A. The supplements listed below, following "End of Section," are a part of this Specification.

1. Simplified Plant One-Line Diagram.

END OF SECTION

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SECTION 26 43 00
TRANSIENT VOLTAGE SUPPRESSION

PART 1 - GENERAL

1.01 SUBMITTALS

A. Submit product data on each suppressor type, indicating component values, part numbers, and conductor sizes. Include dimensional drawing for each, showing mounting arrangements.

B. Submit manufacturer's UL certified test data and nameplate data for each TVSS.

C. Submit electrical single-line diagram showing location of each TVSS.

1.02 QUALITY ASSURANCE

A. UL Compliance and Labeling:

1. For power and signal circuits, TVSS devices shall comply with UL 1449 (latest edition) and complimentary listed to UL 1283 as an electromagnetic interference filter. Provide units that are listed and labeled by UL.
2. For telephone circuit protection, TVSS devices shall comply with UL 497A.

B. ANSI Compliance: Use TVSS devices in compliance with the recommendations of IEEE C62.41.1, IEEE C62.41.2, and IEEE C62.45.

PART 2 - PRODUCTS

2.01 GENERAL

A. All TVSS devices for power circuits, provided under this section, shall be the product of a single manufacturer.

B. TVSS devices shall be capable of performance at ambient temperatures between minus 40 degrees C and 60 degrees C, at relative humidity ranging from 0 percent to 95 percent, and at altitudes ranging from sea level to 12,000 feet.

C. TVSS devices shall be fused to disconnect the suppressor from the electrical source should the suppressor fail. The fusing shall allow full surge handling capabilities and to afford safety protection from thermal overloads and short circuits.

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D. Design TVSS devices for the specific type and voltage of the electrical service. Single-phase and three-phase wye-configured systems shall have L-N, L-G, and N-G protection. Grounded delta-configured systems shall have L-L and L-G protection.

E. Power Filter: The TVSS shall include a high frequency extended range power filter complimentary listed to UL 1283 as an electromagnetic interference filter.

2.02 MANUFACTURER

A. Innovative Technology, VanGuard Series.

B. Advanced Protection Technologies, Inc.

C. General Electric.

2.03 MAIN DISTRIBUTION TVSS

A. Provide TVSS meeting IEEE C62.41.1 and IEEE C62.41.2 Location in accordance with Category C.

B. Surge current capacity shall be not less than the following:

1. L-N Capacity: 200 kA.
2. L-G Capacity: 120 kA.
3. N-G Capacity: 120 kA.

C. Suppressor housing shall be in an enclosure that has the same NEMA rating as the equipment it protects and painted to match.

D. UL 1449 maximum suppression voltage shall not be more than:

System Voltage	Phase	L-L or L-N Suppression Voltage
120	1	400
208Y/120	3	400
240	3	800
480Y/277	3	800

2.04 PANELBOARD TVSS

A. Provide TVSS meeting IEEE C62.41.1 and IEEE C62.41.2 Location Category B.

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B. Surge current capacity shall be not less than the following:

1. L-L Capacity: 80 kA.
2. L-N Capacity: 80 kA.
3. L-G Capacity: 80 kA.
4. N-G Capacity: 80 kA.

C. Suppressor shall be in an enclosure that has the same NEMA rating as the panel it protects or the TVSS may be integral to a panelboard.

D. UL 1449 maximum clamp voltage shall not be more than:

System Voltage	Phase	L-L or L-N Clamp Voltage
120	1	400
208Y/120	3	400
240	3	800
480Y/277	3	800

2.05 ANNUNCIATION

A. Provide unit or separately mounted LED-type indication lights to show the normal and failed status of each module. Provide one normally open and one normally closed contacts which operate when the unit fails.

2.06 SURGE COUNTER

A. Provide each TVSS rated above 100 kA with a counter displaying the number of voltage transients that have occurred on the unit input. The counter shall be battery backed and retain the count through system power outages.

2.07 PAIRED CABLE DATA LINE INTERIOR SUPPRESSORS

A. Provide units meeting IEEE C62.41, Location Category A.

B. Use bi-polar 1,500-watt silicon avalanche diodes between the protected conductor and earth ground.

C. Provide units with a maximum single impulse current rating of 80 amperes (10 by 1,000 microsecond-waveform).

D. Breakdown voltage shall not exceed 36 volts.

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2.08 PAIRED CABLE DATA LINE EXTERIOR SUPPRESSORS

A. Provide units meeting IEEE C62.41, Location Category A.

B. Suppressors shall be a hybrid design with a minimum of three stages, utilizing solid-state components and operating bi-directionally.

C. Suppressors shall meet or exceed the following criteria:

1. Maximum single impulse current rating of 10,000 amperes (8 by 20 microsecond-waveform).
2. Pulse Life Rating: 3,000 amperes (8 by 20 microsecond-waveform): 2,000 occurrences.
3. Maximum clamping voltage at 10,000 amperes (8 by 20 microsecond current waveform), shall not exceed the peak of the normal applied signal voltage by 200 percent.

PART 3 - EXECUTION

3.01 APPLICATION REQUIREMENTS

A. Install TVSS when indicated on the Drawings and:

1. Main Distribution TVSS in or near each low-voltage switchgear (load center).
2. Main Distribution TVSS in or near each motor control center.
3. Panelboard TVSS In or near each distribution panelboard unless otherwise indicated.

B. Electronic Equipment Paired Cable Conductors: Install data line suppressors at the low voltage input and output of each piece of equipment, including telephone cable entrance.

1. Use secondary protectors on lines that do not exit the structure.
2. Use primary protectors on lines that exit and enter the structure.

3.02 GENERAL INSTALLATION REQUIREMENTS

A. Install suppressors according to manufacturer’s recommendations.

B. Install suppressors directly to the cabinet which houses the circuit to be protected so that the suppressor leads are straight and short, with all conductors laced, running directly to the point of connection within the panel, without loops or

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bends. If bends are unavoidable, no bend may exceed 90 degrees and bending radius may not be less than 6 inches.

C. Connecting wires shall be as short as possible with gently twisted conductors, tied together, to prevent separation. Connecting wires shall not exceed 24 inches in length at any point.

D. Field installed conductors shall be the same as specified for building wire, not smaller than No. 8 AWG and not larger than No. 4 AWG. Device leads shall not be longer than the length recommended by the manufacturer, unless specifically reviewed and approved by the manufacturer.

E. Provide dedicated disconnecting means for TVSS devices installed at main service entrance location, switchgear, and motor control centers. Provide dedicated 30-60-ampere circuit breakers (size dependent upon wire size used) with number of poles as required, as disconnecting means for TVSS devices installed at panelboards. The interrupting capacity of the circuit breakers shall be that specified for the other breakers at that location.

END OF SECTION

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SECTION 26 50 00
LIGHTING

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. Canadian Standards Association (CSA).
2. Certified Ballast Manufacturer (CBM).
3. Federal Communications Commission (FCC).
4. Illuminating Engineering Society of North America (IESNA).
5. Institute of Electrical and Electronics Engineers (IEEE): C62.41, Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits.
6. National Electrical Manufacturers Association (NEMA): 250, Enclosures for Electrical Equipment (1,000 Volts Maximum).
7. National Fire Protection Association (NFPA): 70, National Electrical Code (NEC) – Softbound Version.
8. Underwriters Laboratories, Inc. (UL):
   a. 595, Marine-Type Electric Lighting Fixtures.
   b. 844, Electric Lighting Fixtures for Use in Hazardous (Classified) Locations.
   c. 924, Emergency Lighting and Power Equipment.

1.02 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. Interior Luminaires:
      1) Catalog data sheets and pictures.
      2) Luminaire finish and metal gauge.
      3) Lens material, pattern, and thickness.
      4) Candle power distribution curves in two or more planes.
      5) Candle power chart 0 degree to 90 degrees.
      6) Lumen output chart.
      7) Average maximum brightness data in foot lamberts.
      8) Coefficients of utilization for zonal cavity calculations.
      9) Mounting or suspension details.
      10) [Heat exchange and air handling data.]

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b. Exterior Luminaires:
   1) Catalog data sheets and pictures.
   2) Luminaire finish and metal gauge.
   3) Lens material, pattern, and thickness.
   4) IESNA lighting classification and isolux diagram.
   5) Fastening details to wall or pole.
   6) Ballast type, location, and method of fastening.
   7) For light poles, submit wind loading, complete dimensions, and finish.

c. Lamps:
   1) Voltages.
   2) Colors.
   3) Approximate life (in hours).
   4) Approximate initial lumens.
   5) Lumen maintenance curve.
   6) Lamp type and base.
   7) Copy of lamp order, including individual quantities, for Project.

d. Ballasts:
   1) Type.
   2) Wiring diagram.
   3) Nominal watts and input watts.
   4) Input voltage and power factor.
   5) Starting current, line current, and restrike current values.
   6) Sound rating.
   7) Temperature rating.
   8) Efficiency ratings.
   9) Low temperature characteristics.
   10) Emergency ballasts rating and capacity data.

e. Photo-Time Control:
   1) Wiring diagram.
   2) Contact ratings.

f. Photocells:
   1) Voltage, and power consumption.
   2) Capacity.
   3) Contacts and time delay.
   4) Operating levels.
   5) Enclosure type and dimensions.
   6) Temperature range.

g. Occupancy Sensors:
   1) Type.
   2) Switching capacity.

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3) Coverage.
4) Time delay AUTO/OFF adjustment.

h. Low Voltage Remote Control Wiring System:
1) Type.
2) Switching capacity.
3) Voltage rating.
4) Wiring diagrams.

i. Seismic anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Seismic Anchorage and Bracing.

2. Samples: Submit Samples of each substituted luminaire [if requested by Engineer].

B. Informational Submittals: Seismic anchorage and bracing calculations as required by Section 01 88 15, Seismic Anchorage and Bracing.

1.03 QUALITY ASSURANCE

A. Authority Having Jurisdiction (AHJ):

1. Provide the Work in accordance with NFPA 70, National Electrical Code (NEC). Where required by the AHJ, material and equipment shall be labeled or listed by a nationally recognized testing laboratory or other organization acceptable to the AHJ in order to provide a basis for approval under NEC.
2. Materials and equipment manufactured within the scope of standards published by Underwriters Laboratories, Inc. shall conform to those standards and shall have an applied UL listing mark.
3. [Assembled fixture, complete with lamps, shall be in accordance with California Code of Regulations Title 24 requirements.]

B. Preinstallation Meeting: Occupancy Sensors: Arrange preinstallation meeting with manufacturer’s factory authorized representative at Owner’s facility, to verify placement of sensors and installation criteria.

1.04 EXTRA MATERIALS

A. Furnish, tag, and box for shipment and storage the following [spare parts,] [special tools,] [and] [materials:]

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Item	Quantity
Spare ballast of each type	[One] [Two] [_____] complete set [per unit]
Spare lamps of each type	[One] [Two] [_____] complete set [per unit]
[_____]	[One] [_____] complete set [per unit]

PART 2 - PRODUCTS

2.01 LUMINAIRES

A. [Specific requirements relative to execution of the Work of this section are located in Luminaire Schedule [at end of this section] [on Drawings].]

B. Feed-through type, or separate junction box.

C. Ballasts: Two-lamp when possible.

D. [Tandem wired for three-lamp, fluorescent fixtures.]

E. Wire Leads: Minimum 18 AWG.

F. Component Access: Accessible and replaceable without removing luminaire from ceiling.

G. Soffit Installations:

1. UL Labeled: SUITABLE FOR DAMP LOCATIONS.
2. Ballast: Removable, prewired.

H. Exterior Installations:

1. UL Labeled: SUITABLE FOR WET LOCATIONS.
2. Ballast: Removable, prewired.
3. When factory-installed photocells are provided, entire assembly shall have UL label.

I. Marine Environments:

1. UL Labeled: MARINE, OUTSIDE TYPE.
2. Housing: Copper-free, aluminum in accordance with UL 595.

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J. [Emergency Lighting:

1. Power Pack: Self-contained, 120/277-volt [dual voltage] [selectable input] transformer, inverter/charger, sealed [nickel cadmium] [lead acid] [lead calcium] battery, and indicator switch in accordance with UL 924.
2. Lighted, push-to-test indicator.
3. Capable of providing full illumination for 1-1/2 hours in emergency mode.
4. Capable of full recharge in 24 hours, automatically upon resumption of normal line voltage.
5. Capable of protecting against excess charging and discharging.]
6. [Emergency Self-Diagnostic System:
   a. Solid state device with LED display and audible alarm.
   b. Automatic and manual test unit.
   c. Test for malfunction of lamps, battery, and charger board.
   d. Manufacturer: Lithonia.]

K. Hazardous Classified Areas:

1. UL Labeled: [CLASS I, DIVISION 1, GROUPS C AND D.] [CLASS II, DIVISION 1, GROUPS F AND G.]
2. Fixture Enclosure and Fittings: Copper-free, cast aluminum in accordance with UL 844.

2.02 LAMPS

A. Fluorescent:

1. Type Efficiency: [Energy.] [Standard.]
2. Color: [Cool white.] [White.] [Warm white.] [_____]

B. High Intensity Discharge:

1. Type: [High pressure sodium] [and] [metal halide.]
2. Color: [Color corrected.] [Clear.]

C. Incandescent:

1. Type Efficiency: [Energy.] [Standard.]
2. Color: [Inside frosted.] [Clear.]

D. Incandescent Quartz: [Translucent.] [Clear.]

E. Tungsten Halogen:

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1. Type Efficiency: [Energy.] [Standard.]
2. Color: [Clear.] [Frosted.]

F. Manufacturers:

1. General Electric Co.
2. Osram Sylvania.
3. Phillips Lighting Company.

2.03 BALLASTS

A. General:

1. Meet requirements for fixture light output, reliable starting, radio interference, total harmonic distortion, electromagnetic interference, and dielectric rating.
2. Certified by electrical testing laboratory to conform to CBM specifications.

B. Fluorescent (Electromagnetic):

1. Type: High power factor, energy efficient, [rapid-start] [and] [instant-start] type ballast, compatible with lamps specified.
2. Sound Rating: Minimum A, maximum allowable noise level of 30 decibels measured 2 feet from installed fixture.
3. Class: P.
4. Automatic resetting, thermo-protector to prevent case temperature from exceeding 110 degrees C in event of short circuit.
5. [Dimming ballasts capable of operating two 40-watt rapid-start lamps. Include auxiliary components required for proper control.]
6. [For use in exterior located ballasts to produce reliable starting of lamps at minus 20 degrees F at 90 percent of normal line voltage.]

C. Fluorescent (Electronic):

1. Provide in 1 lamp, 2 lamp, or 3 lamp models.
2. High frequency ballast of 20k Hz or greater; [rapid-start] [instant-start].
3. Meets FCC Part 18.
4. UL listed, Class P, sound rating A.
5. Power factor of [90 percent] [98 percent] or greater.
6. Total harmonic distortion THD shall be less than [20 percent] [10 percent].
7. Shall withstand line transients per IEEE C62.41, Cat A.
8. Shall not contain PCB’s and shall carry a minimum 3-year manufacturer’s warranty.

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9. Ballast shall start lamp at a minimum temperature of [50 degrees F] [0 degree F].
10. [Shall meet Canadian Standards Association (CSA) where applicable.]

D. Metal Halide:

1. High power factor, normal ambient, 180 degrees C insulation class.
2. Types:
   a. Autotransformer with capacitor and ignitor for lamps 150 watts and less.
   b. Constant wattage autotransformer with capacitor for lamps above 150 watts.

E. High Pressure Sodium:

1. High power factor, normal ambient, 180 degrees C insulation class, with capacitor and ignitor.
2. Type:
   a. Autotransformer for 50-watt lamps.
   b. Constant wattage autotransformer for lamps 70 watts and above.

F. Manufacturers:

1. MagneTek Lighting Products.
2. Advance Transformer Co.
3. Motorola Lighting Inc.
4. SLI Inc.
5. General Electric.

2.04 LIGHTING CONTROL

A. [Time Switch:

1. [Time dial shown.] [Plain 24-hour dial.] [7-day dial.] [Astronomic dial.] [and day omitting device.]
2. [Bypass Switch: Prewired, externally operated ON/AUTO/OFF, for each circuit shown.]
3. [Contact configuration and rating for circuits as required.]
4. [Enclosure: NEMA 250, Type [1.] [3R.] [4X.]]
5. [Reserve Power: Spring driven, capable of operating time switch for 16 hours after power failure.]
6. [Wired for use with photocell specified.]
7. Manufacturers:
   a. Tork.

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b. Paragon Electric Company.]

B. [Time Switch:

1. Provide digital electronic time switches with number of channels indicated on Drawings. Each channel shall be independently programmable and shall have a Form C dry contact, output rated for 10 amps at 120V ac. Time switches shall have, as a minimum, the following features:
   a. Selectable am/pm or 24-hour format.
   b. 1-minute time resolution.
   c. Programmable up to 48 events per channel.
   d. Weekly or 365-day capability.
   e. Holiday capability.
   f. User-programmable daylight savings time adjustment option.
   g. Automatic leap year compensation.
   h. Battery backup with rechargeable batteries and 72-hour capacity.
   i. Individual manual ON/OFF override control for each channel.
   j. Manufacturers:
      1) Tork.
      2) Paragon Electric Company.]

C. Photocell:

1. Automatic ON/OFF switching photo control.
2. Housing: Self-contained, die-cast aluminum, unaffected by moisture, vibration, or temperature changes.
3. Setting: ON at dusk and OFF at dawn.
4. Time delay feature to prevent false switching.
5. Field adjustable to control operating levels.
6. Manufacturers:
   a. Tork.
   b. Paragon Electric Company.

D. Dimming System:

1. Fluorescent dimmer capable of dimming from one to ten 40-watt rapid-start lamps.
2. Size: Fit in a single gang wall box.
3. Positive OFF switching and low intensity trim adjustment without removing dimmer from box.
4. Manufacturers:
   a. Lutron Electronics Co., Inc.

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b. Pass and Seymour/LeGrand.
c. Lithonia Lighting Co.

E. Low Voltage Remote Control Wiring System:

1. Provide a complete low-voltage, remote control wiring system for control of lighting fixtures as indicated on Drawings and Schedules. System shall be complete with transformers, rectifiers, relays, switches, master switches, electronic controls, enclosures, wall plates, and wiring. System and components shall be of same manufacturer.
2. Remote control wiring shall be in accordance with Article 725, Class 2 of NFPA 70.
3. Provide for direct-wired connection of:
   a. Standard of pilot light switches for individual control of relays.
   b. Two independent master override inputs, which allow ON/OFF control of all relays while still supporting individual control of each relay.
4. Relay panels shall be configured to allow future addition of up to two master controls of programmable control of all relays.

F. Occupancy Sensors:

1. Passive Infrared:
   a. Wall switch sensors shall be capable of detection of motion at desk top level up to 300 square feet and gross motion up to 1,000 square feet.
   b. Wall switch sensors shall accommodate loads from 0 to 800 watts at 120 volts; 0 to 1,200 watts at 277 volts and shall have 180-degree coverage capability.
   c. Bi-level wall switch sensors shall accommodate up to two loads from 0 to 800 watts at 120 volts; 0 to 1,200 at 277 volts, for each load.
   d. Passive infrared sensors shall have a multiple segmented lens, in a multiple-tier configuration, with grooves-in to eliminate dust and residue build-up.
   e. Wall switches shall be compatible with electronic ballasts.
2. Dual Technology Units:
   a. Unit to be ceiling mounted for 360-degree coverage.
   b. Unit shall utilize both passive infrared and ultrasonic technologies and be easily programmed to accommodate different environmental and architectural conditions.
   c. Unit must detect up to 2,000 square feet with no blind spots.
   d. No audio dual technology units will be accepted.

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3. Circuit Control Hardware—CU Power Packs:
   a. Control Units: Able to mount through a 1/2-inch knock-out in a standard electrical enclosure and be an integrated, self-contained unit consisting internally of an isolated load switching control relay and a transformer to provide low-voltage power. Transformer shall provide power to a minimum of two sensors.
   b. Relay contacts shall have ratings of:
      1) 13A, 120V ac tungsten.
      2) 20A, 120V ac ballast.
4. Wiring: Control wiring between sensors and control units shall be Class II, 14-AWG, stranded, UL Classified, PVC insulated or Teflon jacketed cable approved for use in plenums, where applicable.
5. General:
   a. Sensors shall be capable of operating normally with any electronic ballast and PL lamp systems.
   b. Coverage of sensors shall remain constant after sensitivity control has been set. No automatic reduction shall occur in coverage due to cycling of air conditioner or heating fans.
   c. Sensors shall have readily accessible, user adjustable controls for time delay and sensitivity.
   d. In event of failure, bypass manual OVERRIDE ON key shall be provided on each sensor. When bypass is utilized, lighting shall remain on constantly or control shall divert to a wall switch until sensor is replaced. This control shall be recessed to prevent tampering.
   e. Units shall have an extra Form C (1-NO-1-NC) contact for interface with building system. Units shall be designed to be mountable in standard electrical box.
   f. Units shall have capability of being ordered with integral power pack.
   g. Manufacturers:
      1) Unenco, Inc.
      2) The Watt Stopper, Inc.

2.05 POLES

A. Rating (With Luminaire): [100] [125] mph steady winds, without incurred damage.

B. Material: [Steel] [Extruded aluminum] [Fiberglass (FRP)] [and] [Concrete].

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2.06 EMERGENCY BALLAST

A. In accordance with UL 924.

B. Nickel cadmium battery, charger, and electronic circuitry in metal case [plus ac ballast].

C. Solid state charging indicator monitoring light and double-pole test switch.

D. Capable of operating [one] [two] fluorescent lamps for a period of 90 minutes with output of 1,100 to 1,200 lumens.

E. Manufacturers:

1. MagneTek Lighting Products.
2. The Bodine Co., Inc. [; B50.]
3. Lithonia.

2.07 STANDBY LIGHTING PANEL

A. AC Emergency Power Supply:

1. Rated for [500] [750] [_____] [5,000] VA, [120] [277] volts in accordance with UL 924 Standards.
2. Frequency Regulation: Plus or minus 0.5 Hz.
3. Voltage Regulation: Plus or minus 5 percent.
4. Operation:
   a. In normal operating mode, feed supply power to load and battery charger.
   b. Upon failure (loss or undervoltage) of normal supply, automatically transfer load to alternate power source provided by inverter and battery.
   c. When normal power is restored, retransfer load and battery charger to normal supply.

B. Inverter:

1. Construction: Solid state.
2. Sine Wave Output: [Stepped, not causing abnormal lighting ballast heat rise.] [True, suitable for computer applications.]
3. Self-protected from short circuits and overloads.
4. Switch Type: [Mechanical, capable of transferring from normal to emergency in less than 30 milliseconds.] [Rapid transistorized, that will

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prevent HID light sources from extinguishing during transfer from normal to emergency source.]

C. Batteries:

1. Type: [Lead antimony (lead acid).] [Lead cadmium.]
2. Sized for [90] [_____] minutes operation with a discharge to not less than 87.5 percent of nominal battery voltage.

D. Battery Charger:

1. Type: Solid state SCR.
2. Recharge Time: 12 hours, following a discharge to 87.5 percent of nominal battery voltage.

E. Indicators and Controls:

1. Output voltmeter and output current meter.
2. Charge light indicator.
3. Normal power on light.
4. Test switch to simulate a power failure.
5. [Charge alarm light.]
6. [Battery voltmeter.]
7. [Battery ammeter.]
8. [Electrolyte level alarm light.]

F. Enclosure:

1. Type: Steel, [wall mounted] [freestanding].
2. Finish: Red baked enamel.

G. Manufacturers:

1. Holophane Corp.
2. Siltron Emergency Systems.
3. Chloride.

2.08 IN-LINE FUSE HOLDER AND FUSE

A. Fuse Holder:

1. General: Waterproof, of corrosion-resistant material.
2. Rating: 600 volts.

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B. Fuse:

1. General: Midget, dual element.
2. Rating: 5-amp, voltage as required by application.

C. Manufacturer: Methods Electronics Inc. Network, Buss Div.

2.09 LIGHT FIXTURE LOWERING DEVICE

A. Electrical:

1. Contact:
   a. Material: Silver impregnated/silver plate copper.
   b. Pressure: Supplied by springs remote from current conductors.
   c. Electrical Insulation: Provided by porcelain standoffs.
2. Wire Termination: Crimp type connectors.
3. Lowering Device:
   a. Make and break type, rated for 30 amps at 250V ac so fixture need not be remotely isolated before lowering.
   b. Provide number of contacts as required for specified light fixtures.

B. Mechanical Operation:

1. Use ball and socket design for ease of alignment and to allow for residual building vibration and movement.
2. Maintenance-free design.
3. System:
   a. Support loads of **[A: 80] [B: 200]** pounds maximum.
   b. Operated by manual hand-crank winch.
4. Housing: Cast aluminum.
5. Operation: Slow pull/quick release method.
6. Latching: Single point centered design to facilitate even wear over life of hanger.

C. System:

1. Upper or fixed housing of lowering devices shall contain:
   a. Attached pulley.
   b. Single point latching mechanism.
   c. Guide.
   d. Upper (socket) electrical contacts.
   e. Mast arm for attachment of device to structure.
   f. Termination location for fixture guide line.

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2. Lower or moveable housing of lowering device shall contain:
   a. Operating line termination.
   b. Positioning stem and latch assembly.
   c. Lower (ball) electrical contacts
   d. Fixture adapter.
3. Operating Line: High strength/high flexibility stainless steel.
4. Each turn in the structure shall provide transitional pulley assembly for operating line consisting of pulleys, and flare ends (if enclosed in conduit) to prevent cable rub or snags on conduit runs.
5. Each operating line run shall be encased in conduit, or supported by pulleys placed at intervals recommended by lowering device manufacturer.

D. Manufacturers:

1. Joslyn.
2. Light and Lowering Systems.

PART 3- EXECUTION

3.01 LUMINAIRES

A. General:

1. Install in accordance with manufacturer's recommendations.
2. Provide proper hangers, pendants, and canopies as necessary for complete installation [and meeting specified seismic requirements].
3. Provide additional ceiling bracing, hanger supports, and other structural reinforcements to building [and to concrete pole bases] required to safely mount.
4. Install plumb and level.
5. Install each luminaire outlet box with galvanized stud.

B. Mounting:

1. General:
   a. Mounting, fastening, and environmental conditions shall be coordinated with Section 26 05 02, Basic Electrical Requirements.
   b. Refer to Fastener Schedule in Section 05 50 00, Metal Fabrications.
2. Wall Mounted: Measure mounting heights from center of mounting plate to finished floor or finished grade, whichever is applicable.
3. Pendant Mounted:
   a. Provide swivel type hangers and canopies to match luminaires, unless otherwise noted.

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b. Space single-stem hangers on continuous-row fluorescent luminaires nominally 48 inches apart.
c. Provide twin-stem hangers on single luminaires.
d. Measure mounting heights from bottom of luminaire to finished floor or finished grade, whichever is applicable.

4. Pole Mounted:
   a. Provide [cast-in-place] [precast] concrete base.
   b. [Provide branch circuit in-line fuses in pole base handhole.]

C. Swinging Type: Provide, at each support, safety cable capable of supporting four times vertical load from structure to luminaire.

D. Finished Areas:

1. Install symmetrically with tile pattern.
2. Locate with centerlines either on centerline of tile or on joint between adjacent tile runs.
3. Install recessed luminaires tight to finished surface such that no spill light will show between ceilings and sealing rings.
4. Combustible Low Density Cellulose Fiberboard: Provide spacers and mount luminaires 1-1/2 inches from ceiling surface, or use fixtures suitable for mounting on low density ceilings.
5. Junction Boxes:
   a. Flush and Recessed Luminaires: Locate minimum 1-foot from luminaire.
   b. In concealed locations, install junction boxes to be accessible by removing luminaire.
6. Wiring and Conduit:
   a. Provide wiring of temperature rating required by luminaire.
   b. Provide flexible steel conduit.
7. Provide plaster frames when required by ceiling construction.
8. Independent Supports:
   a. Provide each recessed fluorescent luminaire with two safety chains or two No. 12 soft-annealed galvanized steel wires of length needed to secure luminaire to building structure independent of ceiling structure.
   b. Tensile strength of chain or wire, and method of fastening to structure shall be adequate to support weight of luminaire.
   c. Fasten chain or wire to each end of luminaire.

E. Unfinished Areas: Locate luminaires to avoid conflict with other building systems or blockage of luminaire light output.

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1. Fixture Suspension: Provide [1/4] [3/8]-inch threaded steel hanger rods. Scissor type hangers not permitted.
2. Attachment to Steel Beams: Provide flanged beam clips and straight or angled hangers.

F. Building Exterior: Flush-mounted back box and concealed conduit, unless otherwise indicated.

3.02 LAMPS

A. Provide in each fixture, number and type for which fixture is designed, unless otherwise noted.

3.03 BALLASTS

A. Install in accordance with manufacturer's recommendations.

B. Utilize all ballast-mounting holes to fasten securely within luminaire.

C. Replace noisy or defective ballasts.

3.04 LIGHTING CONTROL

A. Outdoor Luminaires: [Photocells switch lights ON at dusk and OFF at dawn.] [Photocells switch time clock ON at dusk with time clock switching lights OFF at preset time.]

B. Dimming Systems:

1. Install in accordance with manufacturer's recommendations.
2. Do not connect ballasts or equipment to dimming system unless acceptable to dimming system manufacturer.

C. Occupancy Sensors: Locate and aim sensors in correct location required for complete and proper volumetric coverage within range of coverage(s) of controlled areas per manufacturer's recommendations. Rooms shall have 90 to 100 percent coverage to completely cover controlled area to accommodate all occupancy habits of single or multiple occupants at any location within room(s). Locations and quantities of sensors shown on Drawings are diagrammatic and indicate only rooms which are to be provided with sensors. Provide additional sensors if required to properly and completely cover respective room.

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3.05 EMERGENCY BALLAST

A. Install battery, charger, and electronic circuitry metal case inside fluorescent fixture housing [adjacent to ac ballast].

B. Install monitoring light and double-pole switch adjacent to light fixture.

C. Wire in accordance with manufacturer's wiring diagrams.

3.06 EMERGENCY LIGHTING UNIT

A. Install in accordance with manufacturer's recommendations.

B. Provide permanent circuit connections with conduit and wire.

C. Connect to branch circuit feeding normal lighting in area ahead of all local switches.

D. Provide separate circuit wiring to luminaire.

3.07 [STANDBY LIGHTING UNIT

A. Install in accordance with manufacturer's recommendations.

B. Provide separate circuit wiring to luminaire.

C. Provide permanent circuit connections with conduit and wire.]

3.08 LIGHT FIXTURE LOWERING DEVICE

A. Install per manufacturer's recommendations.

B. Mount disconnect base unit plumb on rigid structure.

C. Install mountings using stainless steel hardware.

D. Mounting shall be able to withstand static and dynamic loading for at least five times weight of fixture in all directions.

E. Place winch or motor assembly 6 feet to 30 feet from first pulley or disconnect unit.

F. Use pulley every 6 feet to 30 feet of horizontal straight run.

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G. Align centerline of pulley groove with cable path. Cable path shall be free from interference.

3.09 MANUFACTURER'S SERVICES

A. [Occupancy Sensors:

1. Furnish manufacturer's representative at Job Site [in accordance with Section 01 43 33, Manufacturers' Field Services,] to inspect installation, test unit, and put into service].
2. [Provide, at Owner's facility, training necessary to familiarize Owner's personnel with operation, use, adjustment, and problem solving diagnosis of occupancy sensing devices and systems.]

B. [Standby Lighting Panel: Furnish manufacturer's representative at Job Site [in accordance with Section 01 43 33, Manufacturers' Field Services,] to inspect installation, test unit, and put into service.]

3.10 CLEANING

A. Remove labels and markings, except UL listing mark.

B. Wipe luminaires inside and out to remove construction dust.

C. Clean luminaire plastic lenses with antistatic cleaners only.

D. Touch up painted surfaces of luminaires and poles with matching paint ordered from manufacturer.

E. Replace defective lamps at time of Substantial Completion.

3.11 SUPPLEMENTS

A. The supplement listed below, following "End of Section," is a part of this Specification:

1. [Luminaire Schedules.]

END OF SECTION

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Luminaire Schedule						
Type	**Voltage**	**Description**	**Manufacturer**	**Catalog No.**	**Lamp Type**	**Mounting Type**

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SECTION 26 56 00
EXTERIOR LIGHTING

PART 1 - GENERAL

1.01 SUMMARY

A. Section includes exterior luminaries, poles, and accessories.

1.02 UNIT PRICE - MEASUREMENT AND PAYMENT

A. Exterior Luminaire:

1. Basis of Measurement: Each.
2. Basis of Payment: Includes [concrete base,] [luminaire pole,] [and] [luminaire with lamps and accessories.] [connection to power source.]

1.03 REFERENCES

A. American National Standards Institute:

1. ANSI C82.1 - American National Standard for Lamp Ballast-Line Frequency Fluorescent Lamp Ballast.
2. ANSI C82.4 - American National Standard for Ballasts-for High-Intensity-Discharge and Low-Pressure Sodium Lamps (Multiple-Supply Type).
3. ANSI O5.1 - Wood Poles, Specifications and Dimensions.

1.04 SUBMITTALS

A. Section 01 33 00 - Submittal Procedures: Submittal procedures.

B. Shop Drawings: Indicate dimensions and components for each luminaire not standard Product of manufacturer.

C. Product Data: Submit dimensions, ratings, and performance data.

D. Samples: Submit two color chips 3 x 3 inch in size illustrating luminaire finish color where indicated in luminaire schedule.

1.05 QUALIFICATIONS

A. Manufacturer: Company specializing in manufacturing products specified in this section with minimum three years [documented] experience.

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1.06 MOCK-UP

A. Section 01 40 00 - Quality Requirements: Mock-up requirements.

B. Construct mock-up of [_____] to measure luminaire performance. Include [4] [_____] luminaries.

C. Locate [where directed by Architect/Engineer.] [where indicated on Drawings.]

D. Incorporate accepted mockup as part of Work.

E. Remove mockup [when directed by Architect/Engineer.] [_____].

1.07 DELIVERY, STORAGE, AND HANDLING

A. Section 01 60 00 - Product Requirements: Product storage and handling requirements.

B. Store and handle solid wood poles in accordance with ANSI O5.1.

1.08 COORDINATION

A. Section 01 30 00 - Administrative Requirements: Coordination and project conditions.

B. Furnish bolt templates and pole mounting accessories to installer of pole foundations.

1.09 MAINTENANCE MATERIALS

A. Section 01 70 00 - Execution and Closeout Requirements: Spare parts and maintenance products.

B. Furnish [two] [_____] of each lamp installed.

C. Furnish [two] [_____] gallons of touch-up paint for each different painted finish and color.

D. Furnish [two] [_____] ballasts of each lamp type installed.

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PART 2 - PRODUCTS

2.01 LUMINAIRES

A. Product Description: Complete exterior luminaire assemblies, with features, options, and accessories as scheduled.

B. Refer to Section 01 60 00 - Product Requirements for product options. [Substitutions are not permitted.]

2.02 FLUORESCENT BALLASTS

A. Manufacturers:

1. [Cooper Industries Inc.] Model [_____].
2. [Duro-Test Corp.] Model [_____].
3. [General Electric Co.] Model [_____].
4. [Hubbell Lighting] Model [_____].
5. [Magnetek Inc.] Model [_____].
6. [Pass & Seymour] Model [_____].
7. [Philips Electronic North America] Model [_____].
8. [Thomas Industries, Inc.] Model [_____].
9. [_____] Model [_____].
10. Substitutions: [Section 01 60 00 - Product Requirements] [Not Permitted].

B. Product Description: [High-power-factor type electromagnetic ballast certified by Certified Ballast Manufacturers, Inc. to comply with ANSI C82.1], suitable for lamps and environmental conditions specified, with voltage to match luminaire voltage.

2.03 HIGH INTENSITY DISCHARGE (HID) BALLASTS

A. Manufacturers:

1. [Duro-Test Corp.] Model [_____].
2. [General Electric Co.] Model [_____].
3. [Philips Electronics North America] Model [_____].
4. [Radiant Lamp Co.] Model [_____].
5. [Siemens Corp.] Model [_____].
6. [Venture Lighting International Inc.] Model [_____].
7. [_____] Model [_____].
8. Substitutions: [Section 01 60 00 - Product Requirements] [Not Permitted].

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B. Product Description: ANSI C82.4, [mercury vapor] [metal halide] [low pressure sodium] [high pressure sodium] lamp ballast, suitable for lamp and environmental conditions specified, with voltage to match luminaire voltage.

2.04 LAMPS - GENERAL

A. Minimum Efficacy, Lamps Greater Than 100 Watts: 60 lumens/W, except where otherwise indicated or permitted by applicable code.

2.05 INCANDESCENT LAMPS

A. Manufacturers:

1. [Duro-Test Corp.] Model [_____].
2. [General Electric Co.] Model [_____].
3. [Neo-Ray Products] Model [_____].
4. [Philips Electronics North America] Model [_____].
5. [RCS Industries Co.] Model [_____].
6. [Radiant Lighting] Model [_____].
7. [_____] Model [_____].
8. Substitutions: [Section 01 60 00 - Product Requirements] [Not Permitted].

2.06 FLUORESCENT LAMPS

A. Manufacturers:

1. [Duro-Test Corp.] Model [_____].
2. [General Electric Co.] Model [_____].
3. [Hubbell Inc.] Model [_____].
4. [Philips Electronics] Model [_____].
5. [Siemens Corp.] Model [_____].
6. [_____] Model [_____].
7. Substitutions: [Section 01 60 00 - Product Requirements] [Not Permitted].

2.07 HID LAMPS

A. Manufacturers:

1. [Duro-Test Corp.] Model [_____].
2. [General Electric Co.] Model [_____].
3. [Philips Electronic North America] Model [_____].
4. [RCS Industries North America] Model [_____].
5. [Siemens Corp] Model [_____].
6. [_____] Model [_____].

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7. Substitutions: [Section 01 60 00 - Product Requirements] [Not Permitted].

2.08 METAL POLES

A. Manufacturers:

1. [_____] Model [_____].
2. [_____] Model [_____].
3. [_____] Model [_____].
4. Substitutions: [Section 01 60 00 - Product Requirements] [Not Permitted].

B. Material and Finish: [Steel with prime finish for field painting.] [Aluminum with [natural] [bronze] [_____] anodized finish.] [Concrete with exposed aggregate finish.] [Fiberglass with bronze finish.] [_____.]

C. Section Shape and Dimensions: [Round] [Tapered round] [Square] [_____].

D. Height: [[25] [_____] feet] [As indicated on Drawings.] [As scheduled].

E. Base: [Breakaway,] [Nonbreakaway,] [transformer type.]

F. Base: [Direct embedded type.]

G. Base: [_____].

H. Accessories:

1. Handhole.
2. Anchor bolts.
3. [_____].

I. Loading Capacity Ratings:

1. Luminaire Weight: [_____] pounds
2. Luminaire and Bracket Effective Projected Area: [_____] square feet
3. Steady Wind: [_____] miles per hour, minimum.

2.09 WOOD POLES

A. Manufacturers:

1. [_____] Model [_____].
2. [_____] Model [_____].
3. [_____] Model [_____].

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4. Substitutions: [Section 01 60 00 - Product Requirements] [Not Permitted].

B. Wood Poles: [ANSI O5.1, pressure preservative treated [Douglas fir] [Southern pine] poles, length as indicated on Drawings.] [Laminated decorative wood pole.]

C. Section Shape and Dimensions: [Square] [Rectangular] [Cruciform] [_____].

D. Height: [[25] [_____] feet] [As indicated on Drawings.] [As scheduled].

E. Loading Capacity Ratings:

1. Luminaire Weight: [_____] pounds
2. Luminaire and Bracket Effective Projected Area: [_____] square feet
3. Steady Wind: [_____] miles per hour, minimum.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Section 01 30 00 - Administrative Requirements: Coordination and Project conditions.

B. Verify foundations are ready to receive fixtures.

3.02 EXISTING WORK

A. Disconnect and remove abandoned exterior luminaries.

B. Extend existing exterior luminaire installations using materials and methods [compatible with existing installations, or] as specified.

C. Clean and repair existing exterior luminaries to remain or to be reinstalled.

3.03 INSTALLATION

A. Install concrete bases for lighting poles at locations as indicated on Drawings, in accordance with Section 03 30 00.

B. Install poles plumb. [Install [shims] [double nuts] to adjust plumb. Grout around each base.]

C. Install lamps in each luminaire.

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D. Bond and ground luminaries [,metal accessories] [and] [metal poles] in accordance with Section 26 05 26. [Install supplementary grounding electrode at each pole.]

3.04 FIELD QUALITY CONTROL

A. Section [01 40 00 - Quality Requirements] [01 70 00 - Execution and Closeout Requirements]: Field inspecting, testing, adjusting, and balancing.

B. Operate each luminaire after installation and connection. Inspect for improper connections and operation.

C. Measure illumination levels [to verify conformance with performance requirements].

D. Take measurements during night sky, without moon or with heavy overcast clouds effectively obscuring moon.

3.05 ADJUSTING

A. Section 01 70 00 - Execution and Closeout Requirements: Testing, adjusting, and balancing.

B. Aim and adjust luminaries to provide illumination levels and distribution [as indicated on Drawings].

3.06 CLEANING

A. Section 01 70 00 - Execution and Closeout Requirements: Final cleaning.

B. Clean photometric control surfaces as recommended by manufacturer.

C. Clean finishes and touch up damage.

3.07 PROTECTION OF FINISHED WORK

A. Section 01 70 00 - Execution and Closeout Requirements: Protecting finished work.

B. Relamp luminaries [having failed lamps] at Substantial Completion.

3.08 SCHEDULES

A. Type A Exterior Luminaire:

1. ABC Company Model XYZ.
2. Isocandela Corporation Catalog No. 123A456, with No. 5443 pole.
3. Clunk Luminaire Company Type XY-45.

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4. Description: Roadway type luminaire.
5. Material: Aluminum housing.
6. Photometric Performance: IES RP-8, short vertical and Type III lateral distribution, with cutoff above maximum candlepower.
7. Installation Conditions: Pole height greater than 25 feet.
8. Mounting: Furnish pole mount bracket.
9. Ballast: Manufacturer's standard, rated 208 volts.
10. Lamp: 250 watts, high pressure sodium, clear.
11. Furnish photocell.
12. Pole: 35 foot round aluminum pole with bronze anodized finish.

B. Type B Exterior Luminaire:

1. Church Brass Company Model 80867.
2. Trapp Lighting, Inc. Catalog 703-684-0300.
3. Watson, Ltd. Canadian Series.
4. Description: Area flood type luminaire.
5. Size: 18 inches square by 5 inches deep.
6. Material: Extruded aluminum housing with cast aluminum trim.
7. Enclosure: Clear glass, fully gasketed.
8. Photometric Control: Anodized specular aluminum reflector.
9. Installation Conditions: Wet Location.
10. Mounting: Wall mounting.
11. Ballast: Manufacturer's standard, matched to lamp characteristics, rated 208 volts.
12. Lamp: 150 watts, metal halide type coated lamp.

END OF SECTION

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SECTION 31 10 00
SITE CLEARING

PART 1 - GENERAL

1.01 DEFINITIONS

A. Interfering or Objectionable Material: Trash, rubbish, and junk; trees, stumps, brush, roots and shrubs; vegetation and other organic matter, whether alive, dead, or decaying; topsoil.

B. Clearing: Removal of interfering or objectionable material lying on or protruding above ground surface.

C. Grubbing: Removal of vegetation and other organic matter including stumps, buried logs, and roots greater than 2-inch caliper to a depth of 6 inches below subgrade.

D. Scalping: Removal of sod without removing more than upper 3 inches of topsoil.

E. Stripping: Removal of topsoil remaining after applicable scalping is completed.

F. Project Limits: Areas, as shown or specified, within which Work is to be performed.

1.02 SUBMITTALS

A. Action Submittals:

1. Shop Drawings clearly showing clearing, grubbing, and stripping limits.
2. Plan for removing trees and other large vegetation not explicitly shown or indicated for removal in the Contract Documents.

1.03 QUALITY ASSURANCE

A. Prior to commencing clearing, grubbing, and stripping, obtain ENGINEER’s approval of staked clearing, grubbing, and stripping limits.

1.04 SCHEDULING AND SEQUENCING

A. Protection:

1. Throughout the Project, protect existing site improvements, including streets, drives, and Underground Facilities to remain, if any and adjacent

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property and structures. Repair damage caused by CONTRACTOR to original condition or replace in kind, to satisfaction of Engineer, at no additional cost to OWNER.

2. Protect trees, shrubs, vegetation, and grassed areas to remain by providing temporary fencing, barricades, wrapping, or other methods shown, specified, or accepted by Engineer. Correct at Contractor's expense damage caused by CONTRACTOR outside the limits of clearing Work.
3. Do not remove trees without approval of Engineer, unless shown or indicated for removal.
4. Do not locate construction equipment, stored materials, or stockpiles within drip line of trees and vegetation to remain.

B. Site Preparation:

C. Prepare Site only after adequate erosion and sediment controls are in place.

1. Delineation of Clearing and Grubbing Limits:
   a. Locate and clearly flag trees and vegetation to remain, and other materials to remain in the clearing and grubbing limits. Locate and clearly flag salvable vegetation to be relocated.
   b. Provide flagging to delineate limits of areas to be cleared or grubbed. Review at Site with ENGINEER before commencing removal of trees, vegetation, and other materials to be removed.
   c. Replace flagging that is lost, removed, or destroyed, until clearing and grubbing Work is complete and ENGINEER allows removal of flagging.

PART 2 - PRODUCTS (NOT USED)

PART 3 -EXECUTION

3.01 GENERAL

A. Clear, grub, and strip areas actually needed for waste disposal, borrow, or Site improvements within limits shown or specified.

B. Do not injure or deface vegetation that is not designated for removal.

3.02 LIMITS

A. As follows, but not to extend beyond Project limits.

1. Excavation [Excluding Trenches:] 5 feet beyond top of cut slopes.
2. Fill:

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a. Clearing and Grubbing: 5 feet beyond toe of permanent fill.
b. Stripping and Scalping: 2 feet beyond toe of permanent fill.

3. Waste Disposal:
   a. Clearing: 5 feet beyond perimeter.
   b. Scalping and Stripping: Not required.
   c. Grubbing: Around perimeter as necessary for neat finished appearance.
4. Structures: 15 feet outside of new structures.
5. Roadways: Clearing, grubbing 30 feet from centerline.
6. Overhead Utilities:
   a. Clearing and Grubbing: Entire width of easements and rights-of-way.
   b. Scalping and Stripping: Wherever grading is required.
7. Other Areas: As shown.

B. Remove rubbish, trash, and junk from entire area within Project limits.

3.03 TEMPORARY REMOVAL OF INTERFERING PLANTINGS

A. Remove and store, as specified in Section 32 93 00, Plants**,** shrubs and trees that are not designated for removal but do interfere with construction or could be damaged by construction activities.

B. Photograph and document location, orientation, and condition of each plant prior to its removal. Record sufficient information to uniquely identify each plant removed and to assure accurate replacement.

3.04 CLEARING

A. Clear areas within limits shown or specified.

B. Fell trees so that they fall away from facilities and vegetation not designated for removal.

C. Cut stumps not designated for grubbing flush with ground surface.

D. Cut off shrubs, brush, weeds, and grasses to within 2 inches of ground surface.

3.05 GRUBBING

A. Grub areas within limits shown or specified.

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3.06 SCALPING

A. Do not remove sod until after clearing and grubbing is completed and resulting debris is removed.

B. Scalp areas within limits shown or specified.

3.07 STRIPPING

A. Do not remove topsoil until after scalping is completed.

B. Strip areas within limits to minimum depths shown or specified. Do not remove subsoil with topsoil.

C. Stockpile strippings, meeting requirements of Section 32 91 13, Soil Preparation, for topsoil, separately from other excavated material.

3.08 MERCHANTABLE TIMBER

A. Trees classified as merchantable timber will be marked by ENGINEER. Saleable logs will remain property of OWNER.

B. Exercise care in cutting and felling to prevent damage to saleable logs. Cut, trim, and handle logs in such manner that will ensure best sale value.

C. Cut logs in increments of 2 feet between minimum length of 8 feet and maximum length of 24 feet, plus 8 inches for trim. Cut limbs off flush with trunks. Saleable logs shall each have a minimum top diameter of 8 inches, and minimum of 50 board feet.

D. Stockpile saleable logs in neat, orderly piles at location shown or approved by ENGINEER.

3.09 TREE REMOVAL OUTSIDE CLEARING LIMITS

A. Remove Within Project Limits:

1. Dead, dying, leaning, or otherwise unsound trees that may strike and damage Project facilities in falling.
2. Trees designated by the ENGINEER.

B. Cut stumps off flush with ground, remove debris, and if disturbed, restore surrounding area to its original condition.

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3.10 TREE TOPPING

A. Top trees designated by the ENGINEER so remaining portion will not strike facilities in falling. Where topping will remove more than 1/2 of a tree's crown, remove entire tree.

B. Treat wounds resulting from topping as specified in Section 32 93 00, Plants, Article Pruning.

3.11 PRUNING

A. Remove branches below the following heights:

1. 20 feet above roadways and shoulders.
2. 9 feet above sidewalks.
3. 6 feet above roofs.

B. Prune as specified in Section 32 93 00, Plants.

3.12 SALVAGE

A. Saleable log timber may be sold to CONTRACTOR's benefit. Promptly remove from Project Site.

B. Sod with commercial value may be sold to CONTRACTOR's benefit. Promptly remove from Project Site.

C. Trees, shrubs, and other vegetation requiring removal to facilitate the Work, and that will be transplanted elsewhere at the Site, shall be carefully balled and burlapped or placed in temporary pots, and stored at the Site in an acceptable area. Work involving removing and relocating trees, shrubs, and other vegetation shall be under the direction the ENGINEER, or other professional acceptable to ENGINEER, hired by CONTRACTOR.

3.13 DISPOSAL

A. Clearing and Grubbing Debris:

1. Dispose of debris offsite.
2. Debris may be buried in designated onsite disposal areas to minimum depth of 3 feet below final grade. In lieu of onsite burial, dispose of debris offsite.
3. Burning of debris onsite will not be allowed.

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4. When onsite burning is not prohibited by federal, state, or local authorities, debris may be burned onsite. Control burning to prevent fire from spreading.
5. During periods when burning is prohibited by federal, state, or local authorities, debris may be stockpiled until burning ban is rescinded, provided stockpiled material does not constitute a fire hazard or interfere with or delay Work.
6. Dispose of unburned and noncombustible debris offsite.
7. Woody debris may be chipped. Chips may be sold to CONTRACTOR's benefit or used for landscaping onsite as mulch or uniformly mixed with topsoil, provided that resulting mix will be fertile and not support combustion. Dispose of chips that are unsaleable or unsuitable for landscaping or other uses with unchipped debris.
8. Limit offsite disposal of clearing and grubbing debris to locations that are approved by federal, state, and local authorities, and that will not be visible from Project.

B. Scalpings: As specified for clearing and grubbing debris.

C. Strippings:

1. Dispose of strippings that are unsuitable for topsoil or that exceed quantity required for topsoil in waste disposal areas shown or approved by ENGINEER.
2. Stockpile topsoil in sufficient quantity to meet Project needs. Dispose of excess strippings as specified for clearing and grubbing.

END OF SECTION

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SECTION 31 23 13
SUBGRADE PREPARATION

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM):
   a. D698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lb/ft^3 (600 kN-m/m^3)).

1.02 DEFINITIONS

A. Optimum Moisture Content: As defined in Section 31 23 23, Fill and Backfill.

B. Prepared Ground Surface: Ground surface after completion of clearing and grubbing, scalping of sod, stripping of topsoil, excavation to grade, and scarification and compaction of subgrade.

C. Relative Compaction: As defined in Section 31 23 23, Fill and Backfill.

D. Relative Density: As defined in Section 31 23 23, Fill and Backfill.

E. Subgrade: Layer of existing soil after completion of clearing, grubbing, scalping of topsoil prior to placement of fill, roadway structure or base for floor slab.

F. Proof-Rolling: Testing of subgrade by compactive effort to identify areas that will not support the future loading without excessive settlement.

1.03 SEQUENCING AND SCHEDULING

A. Complete applicable Work specified in Section 02 41 00, Demolition; Section 31 10 00, Site Clearing; and Section 31 23 16, Excavation, prior to subgrade preparation.

1.04 QUALITY ASSURANCE

A. Notify ENGINEER when subgrade is ready for compaction or proof-rolling or whenever compaction or proof-rolling is resumed after a period of extended inactivity.

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1.05 ENVIRONMENTAL REQUIREMENTS

A. Prepare subgrade when unfrozen and free of ice and snow.

PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.01 GENERAL

A. Keep subgrade free of water, debris, and foreign matter during compaction or proof-rolling.

B. Bring subgrade to proper grade and cross-section and uniformly compact surface.

C. Do not use sections of prepared ground surface as haul roads. Protect prepared subgrade from traffic.

D. Maintain prepared ground surface in finished condition until next course is placed.

3.02 COMPACTION

A. Under Earthfill: Three passes with three-wheeled power roller weighing approximately 10 tons.

B. Under Earthfill: Compact upper 6 inches to minimum of 100 percent relative compaction as determined in accordance with ASTMD698

C. Under Pavement Structure, Floor Slabs On Grade, or Granular Fill Under Structures: Three passes with a loaded dump truck or similar heavy-wheeled vehicle.

D. Under Pavement Structure, Floor Slabs On Grade, orGranular Fill Under Structures: Compact the upper 6inches to minimum of 100 percent relative compaction as determined in accordance with ASTM D698

3.03 MOISTURE CONDITIONING

A. Dry Subgrade: Add water, then mix to make moisture content uniform throughout.

B. Wet Subgrade: Aerate material by blading, discing, harrowing, or other methods, to hasten drying process.

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3.04 TESTING

A. Proof-roll subgrade with equipment specified in Article Compaction to detect soft or loose subgrade or unsuitable material, as determined by ENGINEER.

3.05 CORRECTION

A. Soft or Loose Subgrade:

1. Adjust moisture content and recompact.
2. Over excavate as specified in Section 31 23 16, Excavation, and replace with suitable material from the excavation, as specified in Section 31 23 23, Fill and Backfill.

B. Unsuitable Material: Over excavate as specified in Section 31 23 16, Excavation, and replace with suitable material from the excavation, as specified in Section 31 23 23, Fill and Backfill.

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SECTION 31 23 16
EXCAVATION

PART 1 - GENERAL

1.01 DEFINITIONS

A. Common Excavation: Removal of material not classified as rock excavation.

B. Rock Excavation:

1. General: Removal of solid material which by actual demonstration cannot, in ENGINEER's opinion, be reasonably loosened or ripped by single-tooth, hydraulically operated ripper mounted on crawler tractor in good condition and rated at minimum 300 flywheel horsepower; and which must be systematically drilled and blasted or broken by power-operated hammer, hydraulic rock breaker, expansive compounds, or other similar means prior to removal.
2. Trench: Removal of solid material which by actual demonstration cannot, in ENGINEER's opinion, be reasonably excavated with minimum 135 -horsepower backhoe in good condition and equipped with manufacturer's standard boom, two rippers, and rock points or similar approved equipment; and which must be systematically drilled and blasted or broken by power-operated hammer, hydraulic rock breaker, expansive compounds, or other similar means prior to removal.
3. Term "rock excavation" indicates removal of solid material, as specified above, and does not necessarily correspond to "rock" as implied by names of geologic formations.
4. Removal of boulders larger than 1/2 cubic yard will be classified as rock excavation, if drilling and blasting or breaking them apart with power-operated hammer, hydraulic rock breaker, expansive compounds, or other similar means is both necessary and actually used for their removal.

1.02 REFERENCES

A. OSHA 29 CFR Part 1926.650

1.03 SUBMITTALS

A. Action Submittals: Submit the following:

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1. Shop Drawings: Modifications to the Work proposed due to design of sheeting, shoring, bracing, cofferdams, and similar excavation supports.

B. Informational Submittals:

1. Excavation Plan, Prior to starting excavation operations, submit written plan to demonstrate compliance with OSHA 29 CFR Part 1926.650. As a minimum, excavation plan shall include:
   a. Name of Contractor's "competent person" in responsible charge of excavation and fill Work.
   b. Methods and sequencing of excavation.
   c. Proposed locations of stockpiled excavated material.
   d. Proposed onsite and offsite spoil disposal sites.
   e. Numbers, types, and sizes of equipment proposed to perform excavations.
   f. Anticipated difficulties and proposed resolutions.
   g. Reclamation of onsite spoil disposal areas.

1.04 QUALITY ASSURANCE

A. Provide adequate survey control to avoid unauthorized overexcavation.

1.05 WEATHER LIMITATIONS

A. Material excavated when frozen or when air temperature is less than 32 degrees F shall not be used as fill or backfill until material completely thaws.

B. Material excavated during inclement weather shall not be used as fill or backfill until after material drains and dries sufficiently for proper compaction.

1.06 SEQUENCING AND SCHEDULING

A. Demolition: Complete applicable Work specified in Section 02 41 00, Demolition, prior to excavating.

B. Clearing, Grubbing, and Stripping: Complete applicable Work specified in Section 31 10 00, Site Clearing, prior to excavating.

C. Dewatering: Conform to applicable requirements of Section 31 23 19.01, Dewatering, prior to initiating excavation.

D. Excavation Support: Install and maintain, as specified in Section 31 41 00, Shoring, as necessary to support sides of excavations and prevent detrimental

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settlement and lateral movement of existing facilities, adjacent property, and completed Work.

PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.01 GENERAL

A. Excavate to lines, grades, and dimensions shown and as necessary to accomplish Work. Excavate to within tolerance of plus or minus 0.1 foot, except where dimensions or grades are shown or specified as maximum or minimum. Allow for forms, working space, granular base, topsoil, and similar items, wherever applicable. Trim to neat lines where concrete is to be deposited against earth.

B. Do not overexcavate without written authorization of ENGINEER.

C. Remove or protect obstructions as shown and as specified in Section 01 50 00, Temporary Facilities and Controls, Article Protection of Work and Property.

3.02 UNCLASSIFIED EXCAVATION

A. Excavation is unclassified. Complete all excavation regardless of the type, nature, or condition of the materials encountered.

3.03 CLASSIFIED EXCAVATION

A. Excavation is classified; see Article Definitions for classifications. Notify ENGINEER whenever rock is encountered.

B. Before beginning rock excavation, comply with following requirements:

1. Remove overlying material as common excavation and expose rock surface for examination by ENGINEER.
2. Demonstrate that removal of remaining material classifies as rock excavation unless waived by ENGINEER.
3. Assist ENGINEER with measurement and documentation of rock excavation.

C. Predrilling and blasting may be allowed prior to removal of overburden if, in ENGINEER’s opinion, top-of-rock line can be clearly defined after excavation. Acceptance of this method will be based on the following demonstration:

1. Predrill, blast, and excavate initial 100-foot long test section.

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2. Excavate minimum of two 20-foot long trenches to apparent rock line immediately adjacent to predrilled section for comparison.

B. In event of disputed quantities, excavate additional correlation trenches to apparent rock as considered necessary by ENGINEER to resolve dispute. ENGINEER reserves right to stop predrilling and blasting if, in ENGINEER's opinion, experience indicates that accurate determination of rock quantities is not possible by this method.

3.04 TRENCH WIDTH

A. Minimum Width of Trenches:

1. Single Pipes, Conduits, Direct-Buried Cables, and Duct Banks:
   a. Less than 4-inch Outside Diameter or Width: 18 inches.
   b. Greater than 4-inch Outside Diameter or Width: 18 inches greater than outside diameter or width of pipe, conduit, direct-buried cable, or duct bank.
2. Multiple Pipes, Conduits, Cables, or Duct Banks in Single Trench: 18 inches greater than aggregate width of pipes, conduits, cables, duct banks, plus space between.
3. Increase trench widths by thicknesses of sheeting.

B. Maximum Trench Width: Unlimited, unless otherwise shown or specified, or unless excess width will cause damage to existing facilities, adjacent property, or completed Work.

3.05 PIPE BEDDING GROOVES FOR NONPERFORATED DRAIN LINES

A. Semicircular, trapezoidal, or 90-degree-V.

B. Excavated or plowed into trench bottom. Forming groove by compaction will not be acceptable.

3.06 EMBANKMENT AND CUT SLOPES

A. Shape, trim, and finish cut slopes to conform with lines, grades, and cross-sections shown, with proper allowance for topsoil or slope protection, where shown.

B. Remove stones and rock that exceed 3-inch diameter and that are loose and may roll down slope. Remove exposed roots from cut slopes.

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C. Round tops of cut slopes in soil to not less than a 6-foot radius, provided such rounding does not extend offsite or outside easements and rights-of-way, or adversely impacts existing facilities, adjacent property, or completed Work.

3.07 STOCKPILING EXCAVATED MATERIAL

A. Stockpile excavated material that is suitable for use as fill or backfill until material is needed.

B. Post signs indicating proposed use of material stockpiled. Post signs that are readable from all directions of approach to each stockpile. Signs should be clearly worded and readable by equipment operators from their normal seated position.

C. Confine stockpiles to within easements, rights-of-way, and approved work areas. Do not obstruct roads or streets.

D. Do not stockpile excavated material adjacent to trenches and other excavations, unless excavation side slopes and excavation support systems are designed, constructed, and maintained for stockpile loads.

E. Do not stockpile excavated materials near or over existing facilities, adjacent property, or completed Work, if weight of stockpiled material could induce excessive settlement.

3.08 DISPOSAL OF SPOIL

A. Dispose of excavated materials, which are unsuitable or not needed for fill or backfill, in designated spoil disposal areas.

B. Dispose of debris resulting from removal of organic matter, trash, refuse, and junk as specified in Section 31 10 00, Site Clearing, for clearing and grubbing debris.

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SECTION 31 23 23
FILL AND BACKFILL

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM):
   a. C117, Standard Test Method for Materials Finer Than 75-Micrometers (No. 200) Sieve in Mineral Aggregates by Washing.
   b. C136, Standard Method for Sieve Analysis of Fine and Coarse Aggregates.
   c. D75, Standard Practice for Sampling Aggregates.
   d. D698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3)).
   e. D1556, Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method.
   f. D1557, Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3)).
   g. D4253, Standard Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table.
   h. D4254, Standard Test Method for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density.
   i. D6938, Standard Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth).

1.02 DEFINITIONS

A. Relative Compaction:

1. Ratio, in percent, of as-compacted field dry density to laboratory maximum dry density as determined in accordance with ASTM D698.
2. Apply corrections for oversize material to either as-compacted field dry density or maximum dry density, as determined by ENGINEER.

B. Optimum Moisture Content:

1. Determined in accordance with ASTM Standard specified to determine maximum dry density for relative compaction.
2. Determine field moisture content on basis of fraction passing 3/4-inch sieve.

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C. Relative Density: Calculated in accordance with ASTM D4254 based on maximum index density determined in accordance with ASTM D4253 and minimum index density determined in accordance with ASTM D4254.

D. Prepared Ground Surface: Ground surface after completion of required demolition, clearing and grubbing, scalping of sod, stripping of topsoil, excavation to grade, and subgrade preparation.

E. Completed Course: A course or layer that is ready for next layer or next phase of Work.

F. Lift: Loose (uncompacted) layer of material.

G. Geosynthetics: Geotextiles, geogrids, or geomembranes.

H. Well-Graded:

1. A mixture of particle sizes with no specific concentration or lack thereof of one or more sizes.
2. Does not define numerical value that must be placed on coefficient of uniformity, coefficient of curvature, or other specific grain size distribution parameters.
3. Used to define material type that, when compacted, produces a strong and relatively incompressible soil mass free from detrimental voids.

I. Influence Area: Area within planes sloped downward and outward at 60-degree angle from horizontal measured from:

1. 1 foot outside outermost edge at base of foundations or slabs.
2. 1 foot outside outermost edge at surface of roadways or shoulder.
3. 0.5 foot outside exterior at spring line of pipes or culverts.

J. Borrow Material: Material from required excavations or from designated borrow areas on or near Site.

K. Selected Backfill Material: Materials available onsite that ENGINEER determines to be suitable for specific use.

L. Imported Material: Materials obtained from sources offsite, suitable for specified use.

M. Structural Fill: Fill materials as required under structures, pavements, and other facilities.

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N. Embankment Material: Fill materials required to raise existing grade in areas other than under structures.

1.03 SUBMITTALS

A. Action Submittals:

1. Shop Drawings: Manufacturer's specifications with application and installation instructions for proprietary materials and items.
2. Samples: Imported material taken at source.

B. Informational Submittals:

1. Manufacturer's data sheets for compaction equipment.
2. Certified test results from independent testing agency.

1.04 QUALITY ASSURANCE

A. Notify ENGINEER when:

1. Structure or tank is ready for backfilling, and whenever backfilling operations are resumed after a period of inactivity.
2. Soft or loose subgrade materials are encountered wherever embankment or site fill is to be placed.
3. Fill material appears to be deviating from Specifications.

1.05 SEQUENCING AND SCHEDULING

A. Complete applicable Work specified in Section 02 41 00, Demolition; Section 31 10 00, Site Clearing; Section 31 23 16, Excavation; and Section 31 23 13, Subgrade Preparation, prior to placing fill or backfill.

B. Backfill against concrete structures only after concrete has attained compressive strength, specified in Section 03 30 00, Cast-in-Place Concrete.. Obtain ENGINEER's acceptance of concrete work and attained strength prior to placing backfill.

C. Backfill around water-holding structures only after completion of satisfactory leakage tests as specified in Section 03 30 00, Cast-in-Place Concrete.

D. Do not place granular base, subbase, or surfacing until after subgrade has been prepared as specified in Section 31 23 13, Subgrade Preparation.

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PART 2 - PRODUCTS

2.01 SOURCE QUALITY CONTROL

A. Gradation Tests:

1. As necessary to locate acceptable sources of imported material.
2. During production of imported material, test as follows:
   a. Granular Fill: [_____]
   b. Sand: [_____]
   c. Backfill Around Buried Tanks: [_____]
   d. Granular Drain Material: [_____]
   e. Granular Filter Material: [_____]
   f. Base Course Rock: [_____]
   g. Foundation Stabilization Rock: [_____]
   h. Crushed Rock for Substations:
      1) Base Course: [_____]
      2) Finish Grade Rock: [_____]
      3) Access Road Surfacing: [_____]
   i. Soil Cover Over Geotextiles: [_____]
   j. Soil Cover Over Geomembranes: [_____]

B. Samples: Collected in accordance with ASTM D75:

1. During production of imported material, provide Samples as follows:
   a. Granular Fill: [_____]
   b. Sand: [_____]
   c. Backfill Around Buried Tanks: [_____]
   d. Granular Drain Material: [_____]
   e. Granular Filter Material: [_____]
   f. Base Course Rock: [_____]
   g. Foundation Stabilization Rock: [_____]
   h. Crushed Rock for Substations:
      1) Base Course: [_____]
      2) Finish Grade Rock: [_____]
      3) Access Road Surfacing: [_____]
   i. Soil Cover Over Geotextiles: [_____]
   j. Soil Cover Over Geomembranes: [_____]
2. Clearly mark to show source of material and intended use.

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2.02 EARTHFILL

A. Excavated material from required excavations [and designated borrow sites,] free from rocks larger than 3 inches, from roots and other organic matter, ashes, cinders, trash, debris, and other deleterious materials.

B. [Material containing more than 10 percent gravel, stones, or shale particles is unacceptable.]

C. [Provide imported material of equivalent quality, if required to accomplish Work.]

2.03 GRANULAR FILL

A. 1-inch minus crushed gravel or crushed rock.

B. Free from dirt, clay balls, and organic material.

C. Well-graded from coarse to fine and containing sufficient fines to bind material when compacted, but with maximum 8 percent by weight passing No. 200 sieve.

2.04 SAND

A. Free from clay, organic matter, or other deleterious material.

B. Gradation as determined in accordance with ASTM C117 and ASTM C136:

Sieve Size	**Percent Passing by Weight**
1/4-inch	100
No. 4	95 - 100
No. 200	0 - 8

2.05 GRANULAR DRAIN MATERIAL

A. As specified in Section 31 23 23.15, Trench Backfill.

2.06 GRANULAR FILTER MATERIAL

A. Clean, hard, durable gravel, free from foreign materials and washed.

B. Gradation as determined in accordance with ASTM C117 and ASTM C136:

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Sieve Size	Percent Passing by Weight
1/2 inch	
3/8 inch	
No. 4	
No. 8	
No. 16	
No. 30	
No. 50	
No. 200	

2.07 WATER FOR MOISTURE CONDITIONING

A. Free of hazardous or toxic contaminates, or contaminants deleterious to proper compaction.

2.08 BASE COURSE ROCK

A. As specified in Section 32 11 23, Aggregate Base Courses.

2.09 FOUNDATION STABILIZATION ROCK

A. Crushed rock or pit run rock.

B. Uniformly graded from coarse to fine.

C. Free from excessive dirt and other organic material.

D. Maximum 2-1/2-inch particle size.

2.10 CRUSHED ROCK FOR SUBSTATIONS

A. Clean, hard, durable crushed rock, free from foreign materials and washed.

B. Gradation as determined in accordance with ASTM C117 and ASTM C136.

C. Base Course:

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Sieve Size	Percent Passing by Weight
2 inches	-100
1-1/2 inches	95 - 100
3/4 inch	55 - 75
1/4 inch	35 - 50
No. 10	4 - 60

A. Finish Grade Rock:

Sieve Size	Percent Passing by Weight
2 inches	-100
1-1/2 inches	90 - 100
1 inch	30 - 65
3/4 inch	0 - 15

D. Access Road Surfacing: Gradation same as for base course.

2.11 SOIL COVER OVER GEOTEXTILES

A. Particle Size: Maximum [1] [_____] inch.

B. Free of sharp angular pieces that may damage geotextile.

2.12 SOIL COVER OVER GEOMEMBRANES

A. Granular material.

B. Particle Size: Maximum 1/4 inch.

C. Particle Shape: Rounded.

PART 3 – EXECUTION

3.01 GENERAL

A. Keep placement surfaces free of water, debris, and foreign material during placement and compaction of fill and backfill materials.

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B. Place and spread fill and backfill materials in horizontal lifts of uniform thickness, in a manner that avoids segregation, and compact each lift to specified densities prior to placing succeeding lifts. Slope lifts only where necessary to conform to final grades or as necessary to keep placement surfaces drained of water.

C. During filling and backfilling, keep level of fill and backfill around each structure and buried tank even.

D. Do not place fill or backfill, if fill or backfill material is frozen, or if surface upon which fill or backfill is to be placed is frozen.

E. If pipe, conduit, duct bank, or cable is to be laid within fill or backfill:

1. Fill or backfill to an elevation 2 feet above top of item to be laid.
2. Excavate trench for installation of item.
3. Install bedding, if applicable, as specified in Section 31 23 23.15, Trench Backfill.
4. Install item.
5. Backfill envelope zone and remaining trench, as specified in Section 31 23 23.15, Trench Backfill, before resuming filling or backfilling specified in this section.

F. Tolerances:

1. Final Lines and Grades: Within a tolerance of 0.1 foot unless dimensions or grades are shown or specified otherwise.
2. Grade to establish and maintain slopes and drainage as shown. Reverse slopes are not permitted.

G. Settlement: Correct and repair any subsequent damage to structures, pavements, curbs, slabs, piping, and other facilities, caused by settlement of fill or backfill material.

3.02 BACKFILL UNDER AND AROUND STRUCTURES

A. Under Facilities: Within influence area beneath structures, slabs, pavements, curbs, piping, conduits, duct banks, and other facilities, backfill with granular fill, unless otherwise shown. Place granular fill in lifts of [6] [_____]-inch maximum thickness and compact each lift to minimum of [95] [_____] percent relative compaction as determined in accordance with ASTM [D1557,] [D698,] Method [_____]. [90 percent relative density.]

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B. Subsurface Drainage: Backfill with granular drain material, where shown. Place granular drain material in lifts of [6] [_____]-inch maximum thickness and compact each lift to minimum of [90] [_____] percent relative density.

C. Other Areas: Backfill with [earthfill] [granular fill] to lines and grades shown, with proper allowance for topsoil thickness where shown. Place in lifts of [6] [_____]-inch maximum thickness and compact each lift to minimum [_____] percent [relative compaction as determined in accordance with ASTM [D1557,] [D698,] Method [_____]] [relative density].

3.03 BACKFILL AROUND TANKS

A. Backfill to top of tank, unless otherwise shown, with granular fill and thoroughly water settle by saturating backfill and vibrating saturated backfill with a concrete vibrator inserted through full depth of backfill on 1-foot maximum centers.

B. Backfill above top of tank with earthfill placed in [8] [_____]-inch lifts. Compact each lift to minimum [_____] percent [relative compaction as determined in accordance with ASTM [D1557,] [D698,] Method [_____]] [relative density].

3.04 FILL

A. Outside Influence Areas beneath Structures, Tanks, Pavements, Curbs, Slabs, Piping, and Other Facilities: Unless otherwise shown, place earthfill as follows:

1. Allow for [6] [_____]-inch thickness of topsoil where required.
2. Maximum [8] [_____]-inch thick lifts.
3. Place and compact fill across full width of embankment.
4. [Compact to minimum [_____] percent [relative compaction as determined in accordance with ASTM [D1557,] [D698,] Method [_____].] [relative density]. [Compact to [98] [96] [_____] percent relative compaction as determined in accordance with ASTM [D1557,] [D698,] Method [_____,] based on average of most recent four tests on like material. If any two of the four most recent tests falls below [96] [94] percent or any one of the four preceding tests falls below [94] [92] percent, additional compactive effort will be required.]
5. Dress completed embankment with allowance for topsoil, crest surfacing, and slope protection, where applicable.

3.05 SITE TESTING

A. Gradation:

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1. One sample from each [1,500] [_____] tons of finished product or more often as determined by ENGINEER, if variation in gradation is occurring, or if material appears to depart from Specifications.
2. If test results indicate material does not meet Specification requirements, terminate material placement until corrective measures are taken.
3. Remove material placed in Work that does not meet Specification requirements.

B. In-Place Density Tests: In accordance with ASTM [D1556] [D6938]. During placement of materials, test as follows:

1. Granular Fill: [_____]
2. Sand: [_____]
3. Backfill Around Buried Tanks: [_____]
4. Granular Drain Material: [_____]
5. Granular Filter Material: [_____]
6. Base Course Rock: [_____]
7. Foundation Stabilization Rock: [_____]
8. Crushed Rock for Substations:
   a. Base Course: [_____]
   b. Finish Grade Rock: [_____]
   c. Access Road Surfacing: [_____]
9. Soil Cover Over Geotextiles: [_____]
10. Soil Cover Over Geomembranes: [_____]

3.06 SAND BLANKET OVER VAPOR RETARDER

A. Place sand in manner that avoids damage to underlying vapor retarder.

B. Moisten sand and thoroughly compact it with a vibratory plate compactor.

3.07 GRANULAR BASE, SUBBASE, AND SURFACING

A. Place and Compact as specified in Section 32 11 23, Aggregate Base Courses.

3.08 REPLACING OVEREXCAVATED MATERIAL

A. Replace excavation carried below grade lines shown or established by ENGINEER as follows:

1. Beneath Footings: as specified in [Section 03 30 00, Cast-in-Place Concrete.
2. Beneath Fill or Backfill: Same material as specified for overlying fill or backfill.

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3. Beneath Slabs-On-Grade: Granular fill.
4. Trenches:
    a. Unauthorized Overexcavation: Either trench stabilization material or granular pipe base material, as specified in Section 31 23 23.15, Trench Backfill.
    b. Authorized Overexcavation: Trench stabilization material, as specified in Section 31 23 23.15, Trench Backfill.
5. Permanent Cut Slopes (Where Overlying Area is Not to Receive Fill or Backfill):
    a. Flat to Moderate Steep Slopes (3:1, Horizontal Run: Vertical Rise or Flatter): Earthfill.
    b. Steep Slopes (Steeper than 3:1):
        1) Correct overexcavation by transitioning between overcut areas and designed slope adjoining areas, provided such cutting does not extend offsite or outside easements and right-of-ways, or adversely impacts existing facilities, adjacent property, or completed Work.
        2) Backfilling overexcavated areas is prohibited, unless in ENGINEER's opinion, backfill will remain stable, and overexcavated material is replaced as compacted earthfill.

3.09 SUBSTATION SITE SURFACING

A. Base Course:

1. 6-inch layer.
2. Installed after Site grading and substation construction is complete.
3. Compact to at least 95 percent of maximum dry density as determined by ASTM D698.

B. Finish Grade:

1. 3-inch layer.
2. Installed over base course.
3. Finish grade layer shall not be compacted.

3.10 ACCESS ROAD SURFACING

A. Place and compact as specified in Section 32 11 23, Aggregate Base Courses.

END OF SECTION

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SECTION 31 41 00
SHORING

PART 1 - GENERAL

1.01 SUBMITTALS

A. Informational Submittals:

1. Excavation support plan.
2. Movement monitoring plan.
3. Trench excavation plan.
4. Movement measurement and data and reduced results indicating movement trends.

1.02 QUALITY ASSURANCE

A. Provide surveys to monitor movements of critical facilities.

PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.01 GENERAL

A. Design, provide, and maintain shoring, sheeting, and bracing as necessary to support the sides of excavations and to prevent detrimental settlement and lateral movement of existing facilities, adjacent property, and completed the Work.

3.02 EXCAVATION SUPPORT PLAN

A. Prepare excavation support plan addressing following topics:

1. Details of shoring, bracing, sloping, or other provisions for worker protection from hazards of caving ground.
2. Design assumptions and calculations.
3. Methods and sequencing of installing excavation support.
4. Proposed locations of stockpiled excavated material.
5. Minimum lateral distance from the crest of slopes for vehicles and stockpiled excavated materials.
6. Anticipated difficulties and proposed resolutions.

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3.03 MOVEMENT MONITORING PLAN

A. Prepare movement monitoring plan addressing following topics:

1. Survey control.
2. Location of monitoring points.
3. Plots of data trends.
4. Interval between surveys.

3.04 REMOVAL OF EXCAVATION SUPPORT

A. Remove excavation support in a manner that will maintain support as excavation is backfilled.

B. Do not begin to remove excavation support until support can be removed without damage to existing facilities, completed Work, or adjacent property.

C. Remove excavation support in a manner that does not leave voids in the backfill.

3.05 TRENCHES

A. Provide trench excavations exceeding 4 feet in depth with adequate safety systems meeting the requirements of the Washington Industrial Safety and Health Act, Chapter 49.17 RCW.

B. For trench excavation exceeding 5 feet in depth, provide adequate safety system meeting requirements of California Labor Code Section 6707, applicable local construction safety orders, and federal requirements.

C. For trench excavation exceeding 5 feet in depth, provide adequate safety system meeting requirements of applicable state and local construction safety orders, and federal requirements.

END OF SECTION

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SECTION 32 11 23
AGGREGATE BASE COURSES

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Association of State Highway and Transportation Officials (AASHTO):
   a. T11, Standard Method of Test for Materials Finer Than 75μm (No. 200) Sieve in Mineral Aggregates by Washing.
   b. T27, Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates.
   c. T89, Standard Specification for Determining the Liquid Limit of Soils.
   d. T90, Standard Specification for Determining the Plastic Limit and Plasticity Index of Soils.
   e. T96, Standard Specification for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.
   f. T99, Standard Specification for the Moisture-Density Relations of Soils Using a 2.5 kg (5.5 pound) Rammer and a 305 mm (12 in) Drop.
   g. T180, Standard Specification for Moisture-Density Relations of Soils Using a 4.54 kg (10-lb) Rammer and a 457 mm (18-in) Drop.
   h. T190, Standard Specification for Resistance R-Value and Expansion Pressure of Compacted Soils.
   i. T265, Standard Method of Test for Laboratory Determination of Moisture Content of Soils.
   j. T310, Standard Specification for In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth).
2. ASTM International (ASTM):
   a. C88, Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate.
   b. D1883, Test Method for CBR (California Bearing Ratio) of Laboratory Compacted Soils.
   c. D2419, Test Method for Sand Equivalent Value of Soils and Fine Aggregate.
   d. D4791, Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate.

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B. DEFINITIONS

C. Completed Course: Compacted, unyielding, free from irregularities, with smooth, tight, even surface, true to grade, line, and cross-section.

D. Completed Lift: Compacted with uniform cross-section thickness.

1.02 SUBMITTALS

A. Action Submittals:

1. Samples: Submit for specified materials 20 days prior to delivery to Site.

B. Informational Submittals:

1. Certified Test Results on Source Materials: Submit copies from commercial testing laboratory 20 days prior to delivery of materials to Project showing materials meeting the physical qualities specified.

Certified results of in-place density tests from independent testing agency.

PART 2 = PRODUCTS

2.01 BASE COURSE

A. Clean, hard durable, pit run gravel or crushed stone graded from coarse to fine containing enough fines to bind material when compacted.

B. Physical Qualities:

1. Abrasion, AASHTO T96: 35 percent maximum wear.
2. Fractured Face:75 percent minimum particles.
3. Liquid Limit, AASHTO T89: Maximum 30 percent.
4. Plasticity Index, AASHTO T90: Maximum 6 percent. [Nonplastic.]
5. Sand Equivalency, ASTM D2419: 35percent, minimum.
6. Resistance (R) Value, AASHTO T190: 75 minimum.
7. Soundness, ASTM C88: 12 percent, maximum.
8. Flat and Elongated Particles, ASTM D4791: 8 percent, maximum.

C. Gradation, AASHTO T27, Based on U.S. Standard Sieves:

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Table 1
Gradation Percent Passing by Weight

Sieve Designation	Material	
(Square Opening)	Aggregate Base Course	[Leveling Course] [and] [Gravel Surfacing]
50 mm (2")		
38 mm (1-1/2")		
25 mm (1")		
19 mm (3/4")		
4.75 mm (1/4")		
2.00 mm (No. 10)		
1.20 mm (No. 16)		
425 μm (No. 40)		
177 μm (No. 80)		
150 μm (No. 100)		
75 μm (No. 200)		

2.02 LEVELING COURSE AND GRAVEL SURFACING

A. Clean, tough, uniform quality, durable fragments of crushed rock, free from flat, elongated, soft or disintegrated pieces, or other objectionable matter occurring either free or as coating on stone. Gradation as specified in Table 1.

B. Physical Qualities: Same as for base course.

2.03 SOURCE QUALITY CONTROL

A. Perform tests necessary to locate acceptable source of materials meeting specified requirements.

B. Final approval of aggregate material will be based on test results of installed materials.

C. Should separation of coarse from fine materials occur during processing or stockpiling, immediately change methods of handling materials to correct uniformity in grading.

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PART 3 - EXECUTION

3.01 SUBGRADE PREPARATION

A. As specified in Section 31 23 13, Subgrade Preparation.

B. Obtain Engineer's acceptance of subgrade before placing base course or surfacing material.

C. Do not place base course or surfacing materials on soft, muddy, subgrade.

3.02 EQUIPMENT

A. Compaction Equipment: Adequate in design and number to provide compaction and to obtain specified density for each layer.

3.03 HAULING AND SPREADING

A. Hauling Materials:

1. Do not haul over surfacing in process of construction.
2. Loads: Of uniform capacity.
3. Maintain consistent gradation of material delivered; loads of widely varying gradations will be cause for rejection.

B. Spreading Materials:

1. Distribute material to provide required density, depth, grade, and dimensions with allowance for subsequent lifts.
2. Produce even distribution of material upon roadway or prepared surface without segregation.
3. Should segregation of coarse from fine materials occur during placing, immediately change methods of handling materials to correct uniformity in grading.

3.04 CONSTRUCTION OF COURSES

A. Untreated Aggregate Base Course:

1. Maximum Completed Lift Thickness: 6 inches.
2. Completed Course Total Thickness: As shown.
3. Spread lift on preceding course to required cross-section.
4. Lightly blade and roll surface until thoroughly compacted.

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5. Add keystone to achieve compaction and as required when aggregate does not compact readily due to lack of fines or natural cementing properties, as follows:
   a. Use leveling course or surfacing material as keystone.
   b. Spread evenly on top of base course, using spreader boxes or chip spreaders.
   c. Roll surface until keystone is worked into interstices of base course without excessive displacement.
   d. Continue operation until course has become thoroughly keyed, compacted, and will not creep or move under roller.
6. Blade or broom surface to maintain true line, grade, and cross-section.

B. Leveling Course:

1. Maximum Completed Lift Thickness: 4 inches.
2. Completed Course Total Thickness: As shown.
3. Spread on roadway or preceding course to depth, grade, and cross-section shown.
4. Lightly blade surface and roll until thoroughly compacted to line and grade shown.
5. Maintain moisture levels to prevent loss of fines during processing.

C. Gravel Surfacing:

1. Maximum Completed Lift Thickness: 9 inches. Completed Course Total Thickness: As shown.
2. Spread on preceding course in accordance with cross-section shown.
1. Blade lightly and roll surface until material is thoroughly compacted.

3.05 ROLLING AND COMPACTION

A. Commence compaction of each layer of base after spreading operations and continue until density of 95 percent of maximum density has been achieved as determined by AASHTO T99.

B. Roll each layer of material until material does not creep under roller before succeeding layer is applied.

C. Commence rolling at outer edges and continue toward center; do not roll center of road first.

D. Apply water as needed to obtain specified densities.

E. Place and compact each lift to required density before succeeding lift is placed.

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F. Remove floating or loose stone from surface of preceding course before placing leveling course.

G. Surface Defects: Remedy by loosening and rerolling. Reroll entire area, including surrounding surface, until thoroughly compacted.

H. Finished surface shall be true to grade and crown before proceeding with surfacing.

3.06 SURFACE TOLERANCES

A. Blade or otherwise work surfacing as necessary to maintain grade and cross-section at all times, and to keep surface smooth and thoroughly compacted.

B. Finished Surface of Untreated Aggregate Base and Leveling Course: Within plus or minus 0.04 foot of grade shown at any individual point.

C. Gravel Surfacing: Within 0.04 foot from lower edge of 10-foot straightedge placed on finished surface, parallel to centerline.

D. Overall Average: Within plus or minus 0.01 foot from crown and grade specified.

3.07 DRIVEWAY RESURFACING

A. Replace gravel surfacing on driveways that were gravel surfaced prior to construction.

B. Provide compacted gravel surfacing to depth equal to original, but not less than 4 inches.

C. Leave each driveway in as good or better condition as it was before start of construction.

3.08 FIELD QUALITY CONTROL

A. In-Place Density Tests:

1. Provide Engineer at least 2 hours advance notification prior to testing.
2. Show proof that areas meet specified requirements before requesting that Engineer identify density test locations.
3. Refer to Table 2 for minimum sampling and testing requirements for aggregate base course and surfacing.

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Table 2
Minimum Sampling and Testing Requirements

Property	Test Method	Frequency	Sampling Point
Gradation	AASHTO T11 and AASHTO T27	One sample every [500] [_____] tons but at least every 4 hours of production	Roadbed after processing
Moisture Density (Maximum Density)	AASHTO [T180] [T99], Method D	One test for every aggregate grading produced	Production output or stockpile
In-Place Density and Moisture Content	AASHTO [T310] [_____], and AASHTO T265 for moisture content	One for each 500 ton but at least every 10,000 sq ft of area	In-place completed, compacted area

3.09 CLEANING

A. Remove excess material from the Work area. Clean stockpile and staging areas of all excess aggregate.

END OF SECTION

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SECTION 32 12 16
ASPHALT PAVING

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Association of State Highway and Transportation Officials (AASHTO):
   a. M17, Standard Specification for Mineral Filler for Bituminous Paving Mixtures.
   b. M81, Standard Specification for Cut-Back Asphalt (Rapid Curing Type).
   c. M82, Standard Specification for Cut-Back Asphalt (Medium Curing Type).
   d. M140, Standard Specification for Emulsified Asphalt.
   e. M208, Standard Specification for Cationic Emulsified Asphalt.
   f. T166, Standard Method of Test for Bulk Specific Gravity of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens.
   g. T176 Standard Method of Test for Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test.
   h. T230, Standard Method of Test for Determining Degree of Pavement Compaction of Bituminous Aggregate Mixtures.
   i. T245, Standard Method of Test for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus.
   j. T246, Standard Method of Test for Resistance to Deformation and Cohesion of Bituminous Mixtures by Means of Hveem Apparatus.
   k. T247, Standard Method of Test for Preparation of Test Specimens of Bituminous Mixtures by Means of California Kneading Compactor.
   l. T283, Standard Method of Test for Resistance of Compacted Bituminous Mixture to Moisture Induced Damage.
   m. T304, Standard Method of Test for Uncompacted Void Content of Fine Aggregate (Method A).
2. Asphalt Institute (AI):
   a. Manual Series No. 2 (MS-2), Mix Design Methods for Asphalt Concrete.
   b. Superpave Series No. 2 (SP-2), Superpave Mix Design.

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3. ASTM International (ASTM):
   a. D2041, Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures.
   b. D4318, Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.
   c. D4791, Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate.
   d. D5821, Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate.
   e. E329, Specification for Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction.

1.02 DEFINITIONS

A. Combined Aggregate: All mineral constituents of asphalt concrete mix, including mineral filler and separately sized aggregates.

B. RAP: Reclaimed asphalt pavement.

1.03 DESIGN REQUIREMENTS

A. Prepare asphalt concrete mix design, meeting the following design criteria, tolerances, and other requirements of this specification.

B. Design Criteria:

1. [Marshall Method, AASHTO T245:
   a. Number of Blows: [50.] [75.]
   b. Air Voids (AI MS-2): [3] [4] percent
   c. Voids in Mineral Aggregate: See Table 1.
   d. Voids Filled with Asphalt, AI MS-2: [75-80] [65-78] percent.
   e. P200/Effective AC Ratio: 0.6 to 1.2.
   f. Stability, Minimum: [8,000 (1,800).] [9,800 (2,200).] Newtons (Pounds).
   g. Tensile Strength Ratio, AASHTO T283: 80 percent, minimum.
   h. [Flow 0.25 millimeter (0.01 inch): 8-12.]]
2. [Hveem Method, AASHTO T246 and AASHTO T247:
   a. Air Voids, AI MS-2: [3] [4] percent.
   b. Voids in Mineral Aggregate: See Table 1.
   c. Voids Filled with Asphalt, AI MS-2: [75-80] [65-78] percent.
   d. P200/Effective AC Ratio: 0.6 to 1.2.
   e. Stability, Minimum: [35.] [40.]
   f. Tensile Strength Ratio, AASHTO T283: 80 percent, minimum.]]

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3. [Superpave Method, AI SP-2:
   a. Design Gyrations, NDES: [_____]
   b. Coarse Aggregate Angularity, ASTM D5821: One or more fractured faces [_____] percent minimum; two or more fractured faces [_____] percent, minimum.
   c. Fine Aggregate Angularity, AASHTO T304: [40] [45] percent below 4 inches from surface and [40] [45] percent above 4 inches from surface.
   d. Flat and Elongated Particles, ASTM D4791: 10 percent, maximum.
   e. Clay Content, AASHTO T176: Minimum sand equivalent of [40] [45] [50] percent.
   f. Voids in Mineral Aggregate: See Table 1.
   g. Voids Filled with Asphalt: [70-80] [65-78] [65-75] percent.
   h. Mixture Density as a Percentage of Theoretical Maximum Density at Initial Gyration Level: [89] [90.5] [91.5] percent, maximum.
   i. Mix Density at Maximum Number of Gyrations: Less than 98 percent of theoretical maximum density.
   j. Dust Proportion: 0.8 to 1.6.
   k. Air Voids: 4 percent.
   l. Tensile Strength Ratio, AASHTO T283: 80 percent, minimum.

Table 1
Voids in Mineral Aggregate (VMA) Criteria

Nominal Maximum Aggregate Size (mm)	Minimum VMA, Percent
9.5 (3/8")	15
12.5 (1/2")	14
19.0 (3/4")	13
25.0 (1")	12
37.5 (1-1/2")	11]

C. Furnished Mix Tolerances: Conform to asphalt concrete mix formula within the following, plus or minus:

1. Aggregate Passing .187 inch (No. 4) and Larger Sieves: 5 percent.
2. Aggregate Passing the .09 inch (No. 8) to 150 μm (100) Sieves: 4 percent.
3. Aggregate Passing the 75 μm (No. 200) Sieve: 2 percent.
4. Bitumen Content: 0.3 percent of volume or batch weight of aggregate.
5. Temperature Leaving Mixer: 20 degrees F.

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6. Temperature in Paving Machine Hopper: 20 degrees F.

1.04 SUBMITTALS

A. Action Submittals:

1. Samples:
   a. Mix Constituents: Representative Samples of materials to be incorporated into the Work.
   b. Core Samples of Compacted Asphalt Concrete: 6 inches.

B. Informational Submittals:

1. Asphalt Concrete Mix Formula:
2. Submit minimum of 15 days prior to start of production.
3. Submittal to include the following information:
   a. Gradation and portion for each aggregate constituent used in mixture to produce a single gradation of aggregate within specified limits.
   b. Bulk specific gravity for each aggregate constituent.
   c. Measured maximum specific gravity of mix at optimum asphalt content determined in accordance with ASTM D2041.
   d. Properties as stated in this section for at least four different asphalt contents other than optimum, two below optimum, and two above optimum.
   e. Percent of asphalt lost due to absorption by aggregate.
   f. Index of Retained Strength (TSR) at optimum asphalt content as determined by AASHTO T283.
   g. Percentage of asphalt cement, to nearest 0.1 percent, to be added to mixture.
   h. Optimum mixing temperature.
   i. Optimum compaction temperature.
   j. Temperature-viscosity curve of asphalt cement to be used.
   k. Brand name of any additive to be used and percentage added to mixture.
4. Test Report for Asphalt Cement:
   a. Submit minimum 10 days prior to start of production.
   b. Show appropriate test method(s) for each material and the test results.
5. Manufacturer's Certificate of Compliance, in accordance with Section 01 43 33, Manufacturers' Field Services, for the following materials:
   a. Aggregate: Gradation, source test results as defined in [this section.
   b. Asphalt for Binder: Type, grade, and viscosity-temperature curve.
   c. Prime Coat: Type and grade of asphalt.

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d. Tack Coat: Type and grade of asphalt.
e. Additives.
f. Mix: Conforms to job-mix formula.

6. Statement of qualification for independent testing laboratory.
7. Test Results:
   a. Mix design.
   b. Asphalt concrete core.
   c. Gradation and asphalt content of uncompacted mix.

1.05 QUALITY ASSURANCE

A. Qualifications:

1. Independent Testing Laboratory: In accordance with ASTM E329.
2. Asphalt concrete mix formula shall be prepared by approved certified independent laboratory under the supervision of a certified asphalt technician.

B. Compaction Control Strip:

1. General:
   a. Construct to approximately 478.4 square yards in area and at location that will become a portion of completed paved area.
   b. Thickness: Typical of thickness to be paved on Project.
2. Rollers Used for Compaction:
   a. Steel Wheel Rollers: Minimum static weight 10 tons.
   b. Pneumatic Rollers: Capable of exerting pressure of 80 psi on bituminous surface.
   c. Vibratory Rollers: Static weight minimum 6 tons, capable of applying a 10-ton impact force equipped with amplitude and frequency control specifically designed for compaction of bituminous mixtures.
3. Compaction:
   a. Bituminous mat shall be compacted, using a standard rolling pattern that covers the entire control strip. Request that ENGINEER performs final density test.
   b. Continue rolling until no further compaction can be obtained as determined by field density testing.
   c. Temperature and condition of bituminous mat shall be considered workable when further compaction can no longer be obtained.
4. Target Density Determination:
   a. Select test point near center of normal roller pass, but no closer than 2 feet from edge of mat and 50 feet from either end of control strip.

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Mat thickness at this point shall be at least depth of finished pavement.

b. Point at which no further densification can be obtained.

5. Establish new target density if change is made in mix design, nominal depth of mat being placed, aggregate source, or material properties.

1.06 ENVIRONMENTAL REQUIREMENTS

A. Temperature: Do not apply asphalt materials or place asphalt mixes when ground temperature is lower than 50 degrees F or air temperature is lower than 40 degrees F. Measure ground and air temperature in shaded areas away from heat sources or wet surfaces.

B. Moisture: Do not apply asphalt materials or place asphalt mixes when application surface is wet.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Prime Coat: Cut-back asphalt, [Grade MC-70 conforming to AASHTO M82] [Grade RC-250 conforming to AASHTO M81] [conform to Section [_____] of the Standard Specifications].

B. Tack Coat: Emulsified asphalt, [Grade SS-1, SS-1h conforming to AASHTO M140] [Grade CSS-1, CSS-1h conforming to AASHTO M208] [conform to Section [_____] of the Standard Specifications].

C. Sand (Blotter Material): [As specified in Section [_____] of the Standard Specifications.] [Clean, dry, with 100 percent passing 4.75-millimeter (No. 4) sieve, and a maximum of 10 percent passing 75 μm (No. 200) sieve.]

2.02 ASPHALT CONCRETE MIX

A. General:

1. Mix formula shall not be modified except with written approval of ENGINEER.
2. Source Changes:
   a. Should material source(s) change, establish new asphalt concrete mix formula before new material(s) is used.
   b. Perform check tests of properties of plant-mix bituminous materials on first day of production and as requested by ENGINEER to confirm that properties are in compliance with design criteria.

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c. Make adjustments in gradation or asphalt content as necessary to meet design criteria.

B. Composition: Hot-plant mix of aggregate, mineral filler if required and paving grade asphalt cement. The several aggregate fractions shall be sized, uniformly graded, and combined in such proportions that resulting mixture meets grading requirements of mix formula.

C. Aggregate:

1. Coarse:
   a. Material retained on a .093-inch sieve.
   b. Minimum 75 percent by weight of individual pieces having two or more fractured faces, and 90 percent by weight having at least one fractured face.
2. Fine:
   a. Material passing a .093-inch sieve.
   b. Clean, sound, durable, angular shaped particles produced by crushing.
   c. Plasticity Index: Maximum 6.
   d. Liquid Limit: Maximum 25, when tested in accordance with ASTM D4318.
3. Natural Sand: Shall not be used.

D. Mineral Filler: In accordance with AASHTO M17.

E. Asphalt Cement: Paving Grade [_____,] as specified in [Section [_____] of the Standard Specifications] [_____].

PART 3 - EXECUTION

3.01 GENERAL

A. Traffic Control:

1. In accordance with Section 01 50 00, Temporary Facilities and Controls.
2. Minimize inconvenience to traffic, but keep vehicles off freshly treated or paved surfaces to avoid pickup and tracking of asphalt.

B. Driveways: Repave driveways from which pavement was removed. Leave driveways in as good or better condition than before start of construction.

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3.02 LINE AND GRADE

A. Provide and maintain intermediate control of line and grade, independent of underlying base, to meet finish surface grades and minimum thickness.

B. Shoulders: Construct to line, grade, and cross-section shown.

3.03 APPLICATION EQUIPMENT

A. In accordance with Section of the Standard Specifications.

3.04 PREPARATION

A. Prepare subgrade as specified in Section 31 23 13, Subgrade Preparation.

B. Existing Roadway:

1. Modify profile by grinding, milling, or overlay methods as approved, to provide meet lines and surfaces and to produce smooth riding connection to existing facility.
2. Remove existing material to a minimum depth of 1 inch.
3. Paint edges of meet line with tack coat prior to placing new pavement.

C. Thoroughly coat edges of contact surfaces (curbs, manhole frames) with emulsified asphalt or asphalt cement prior to laying new pavement. Prevent staining of adjacent surfaces.

3.05 PAVEMENT APPLICATION

A. General: Place asphalt concrete mixture on approved, prepared base in conformance with this section.

B. Prime Coat:

1. Heat cut-back asphalt prior to application.
2. Apply uniformly to clean, dry surfaces avoiding overlapping of applications.
3. Do not apply when moisture content of upper 3 inches of base exceeds optimum moisture content of base, or if free moisture is present.
4. Application Rate: Minimum 0.15 to 0.50 gallons per square yard of surface area.
5. Remove or redistribute excess material.
6. Allow a minimum of 5 full days for curing of primed surface before placing asphalt concrete.

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C. Tack Coat:

1. Apply uniformly to clean, dry surfaces avoiding overlapping of applications.
2. Do not apply more tack coat than necessary for the day's paving operation.
3. Touch up missed or lightly coated surfaces and remove excess material.
4. Application Rate:
   a. Minimum 0.05 to 0.15 gallon per square yard of asphalt (residual if diluted emulsified asphalt) of surface area.
   b. Apply at rate, within range specified, sufficient to assure good bonding, but not so heavy that surplus asphalt flushes into asphalt concrete being placed.

D. Pavement Mix:

1. Prior to Paving:
   a. Sweep primed surface free of dirt, dust, or other foreign matter.
   b. Patch holes in primed surface with asphalt concrete pavement mix.
   c. Blot excess prime material with sand.
2. Place asphalt concrete pavement mix in one single lift.
3. Compacted Lift Thickness:
   a. Minimum: Twice maximum aggregate size, but in no case less than 1 inch.
   b. Maximum: 4 inches.
4. Total Compacted Thickness: As shown.
5. Apply such that meet lines are straight and edges are vertical.
6. Collect and dispose of segregated aggregate from raking process. Do not scatter material over finished surface.
7. Joints:
   a. Offset edge of each layer a minimum of 6 inches so joints are not directly over those in underlying layer.
   b. Offset longitudinal joints in roadway pavements so longitudinal joints in wearing layer coincide with pavement centerlines and lane divider lines.
   c. Form transverse joints by cutting back on previous day's run to expose full vertical depth of layer.
8. Succeeding Lifts: Apply tack coat to pavement surface between each lift.
9. After placement of pavement, seal meet line by painting a minimum of 6 inches on each side of joint with cut-back or emulsified asphalt. Cover immediately with sand.

E. Compaction: Uniformly compact each course to target density arrived at in compaction control strip.

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F. Tolerances:

1. General: Conduct measurements for conformity with crown and grade immediately after initial compression. Correct variations immediately by removal or addition of materials and by continuous rolling.
2. Completed Surface or Wearing Layer Smoothness:
   a. Uniform texture, smooth, and uniform to crown and grade.
   b. Maximum Deviation: 1/8 inch from lower edge of a 12-foot straightedge, measured continuously parallel and at right angle to centerline.
   c. If surface of completed pavement deviates by more than twice specified tolerances, remove and replace wearing surface.
3. Transverse Slope Maximum Deviation: 1/4 inch in 12 feet from rate of slope shown.
4. Finished Grade:
   a. Perform field differential level survey on maximum 50-foot grid and along grade breaks.
   b. Maximum Deviation: 0.02 foot from grade shown.

G. Seal Coat:

1. General: Apply seal coat of paving grade or emulsified asphalt to finished surface at longitudinal and transverse joints, joints at abutting pavements, areas where asphalt concrete was placed by hand, patched surfaces, and other areas as directed by ENGINEER.
2. Preparation:
   a. Surfaces that are to be sealed shall be maintained free of holes, dry, and clean of dust and loose material.
   b. Seal in dry weather and when temperature is above 35 degrees F.
3. Application:
   a. Fill cracks over 1/16 inch in width with asphalt-sand slurry or approved crack sealer prior to sealing.
   b. When sealing patched surfaces and joints with existing pavements, extend minimum 6 inches beyond edges of patches.

3.06 PATCHING

A. Preparation:

1. Remove damaged, broken, or unsound asphalt concrete adjacent to patches. Trim to straight lines exposing smooth, sound, vertical edges.

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2. Prepare patch subgrade as specified in Section 31 23 13, Subgrade Preparation.

B. Application:

1. Patch Thickness: 3 inches or thickness of adjacent asphalt concrete, whichever is greater.
2. Place asphalt concrete mix across full width of patch in layers of equal thickness.
3. Spread and grade asphalt concrete with hand tools or mechanical spreader, depending on size of area to be patched.

C. Compaction:

1. Roll patches with power rollers capable of providing compression of 350 to 525 Newtons per 200 to 300 pounds per linear inch. Use hand tampers where rolling is impractical.
2. Begin rolling top course at edges of patches, lapping adjacent asphalt surface at least 1/2 the roller width. Progress toward center of patch overlapping each preceding track by at least 1/2 width of roller.
3. Make sufficient passes over entire area to remove roller marks and to produce desired finished surface.

D. Tolerances:

1. Finished surface shall be flush with and match grade, slope, and crown of adjacent surface.
2. Tolerance: Surface smoothness shall not deviate more than plus 1/4 inch or minus 0 inch when straightedge is laid across patched area between edges of new pavement and surface of old surfacing.

3.07 FIELD QUALITY CONTROL

A. General: Provide services of approved certified independent testing laboratory to conduct tests.

B. Field Density Tests:

1. Perform tests from cores or sawed samples in accordance with AASHTO T230 and AASHTO T166.
2. Measure with properly operating and calibrated nuclear density gauge in accordance with ASTM D2950.
3. Maximum Density: In accordance with ASTM D2041, using sample of mix taken prior to compaction from same location as density test sample.

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C. Testing Frequency:

1. Quality Control Tests:
   a. Asphalt Content, Aggregate Gradation: Once per every 500 tons of mix or once every 4 hours, whichever is greater.
   b. Mix Design Properties, Measured Maximum (Rice's) Specific Gravity: Once every 1,000 tons or once every 8 hours, whichever is greater.
2. Density Tests: Once every 500 tons of mix or once every 4 hours, whichever is greater.

END OF SECTION

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SECTION 32 17 23
PAVEMENT MARKINGS

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Association of State Highway and Transportation Officials (AASHTO):
   a. M237, Standard Specification for Epoxy Resin Adhesives for Bonding Traffic Markers to Hardened Portland Cement and Asphalt Concrete.
   b. M247, Standard Specification for Glass Beads Used in Traffic Paint.
   c. M248, Standard Specification for Ready-Mixed White and Yellow Traffic Paints.
   d. M249, Standard Specification for White and Yellow Reflective Thermoplastic Striping Material (Solid Form).
2. ASTM International (ASTM): D4280, Standard Specification Extended Life Type, Nonplowable, Prismatic, Raised, Retroreflective Pavement Markers.
3. Federal Specifications (FS):
   a. A-A-2886A, Paint, Traffic, Solvent Based.
   b. TT-B-1325C, Beads (Glass Spheres); Retroreflective.

1.02 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. Product Data:
      1) Paint.
      2) Thermoplastic material.
      3) Reflective markers.
      4) Epoxies, resins, and primers to be used.
   b. Glass Beads: Proposed gradation.

2. Informational Submittals:
3. Description of proposed methods for removal of drips, overspray, improper markings, paint and thermoplastic material tracked by traffic, and existing markings.

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4. Manufacturer's Certificate of Compliance for products specified in this section.
5. Equipment List: Proposed equipment to be used, including descriptive data.
6. Manufacturer's Instructions:
   a. Application of preformed tape.
   b. Application of portland cement concrete primer.
   c. Application of glass beads.
   d. Application of epoxy resin.
   e. Installation of reflective markers.

PART 2 - PRODUCTS

2.01 PAINT

A. Color: White or yellow.

B. Traffic paint in accordance with [AASHTO M248, Type [F] [N] [S]] [FS TT-P-1952D] [FS A-A-2886A] [Section [_____] of the Standard Specifications] [_____].

C. Homogeneous, easily stirred to smooth consistency, with no hard settlement or other objectionable characteristics during storage period of 6 months.

2.02 THERMOPLASTIC MARKING

A. Color: White or yellow.

B. AASHTO M249.

2.03 RAISED REFLECTIVE MARKERS

A. Metallic or nonmetallic, or prismatic reflector type, of permanent colors retaining color and brightness under action of traffic.

B. Rounded surfaces presenting a smooth contour to traffic.

C. Marker in accordance with ASTM D4280.

D. Epoxy in accordance with AASHTO M237.

2.04 GLASS BEADS

A. In accordance with [AASHTO M247, Type [I] [II]] [FS TT-B-1325C, Type [IA] [IB] [III]] [Section [_____] of the Standard Specifications].

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PART 3 - EXECUTION

3.01 SURFACE PREPARATION

A. Cleaning:

1. Thoroughly clean surfaces to be marked before application of pavement marking material.
2. Remove dust, dirt, and other granular surface deposits by sweeping, blowing with compressed air, rinsing with water or a combination of these methods.
3. Completely remove rubber deposits, surface laitance, existing paint markings, and other coatings adhering to pavement with scrapers, wire brushes, sandblasting, approved chemicals, or mechanical abrasion.
4. Scrub areas of old pavement affected with oil or grease with several applications of trisodium phosphate solution or other approved detergent or degreaser, and rinse thoroughly after each application.
5. Surfaces shall be completely free of dirt and ice, and dry of water at the time of application of materials specified herein.
6. Oil-Soaked Areas: After cleaning, seal with cut shellac to prevent bleeding through the new paint.
7. Reclean surfaces when the Work has been stopped due to rain.
8. Existing Pavement Markings:
    a. Remove existing pavement markings that may interfere or conflict with newly applied marking patterns, or that may result in a misleading or confusing traffic pattern.
    b. Do not apply thermoplastic markings over existing preformed or thermoplastic markings.
    c. Perform grinding, scraping, sandblasting or other operations so finished pavement surface is not damaged.

B. Pretreatment for Early Painting: Where painting is required prior to 30 days after paving rigid pavements, pretreat with an aqueous solution containing 3 percent phosphoric acid and 2 percent zinc chloride.

C. New Concrete Pavement:

1. Allow a minimum cure time of 30 days before cleaning and marking.
2. Clean by either sandblasting or water blasting to the following results:
    a. No visible evidence of curing compound on peaks of textured concrete surface.
    b. No heavy puddled deposits of curing compound in valleys of textured concrete surface.

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c. Remaining curing compound is intact, with loose and flaking material completely removed.
d. Peaks of textured pavement surface are rounded in profile and free of sharp edges and irregularities.

3. Allow a minimum drying time of 24 hours after water blasting before applying thermoplastic markings.

D. New Asphalt Pavement: Allow a minimum pavement cure time of 30-days before applying paint.

3.02 PAINT APPLICATION

A. General:

1. Thoroughly mix pigment and vehicle together prior to application, and keep thoroughly agitated during application.
2. Do not add thinner.
3. Apply only when air and pavement temperatures are above 40 degrees F and less than 95 degrees F. Maintain paint temperature within these same limits.
4. Apply only when surface is dry.
5. Do not apply when conditions are windy to the point of causing overspray or fuzzy line edges.
6. Provide guidelines and templates to control paint application.
7. Take special precautions in marking numbers, letters, and symbols.
8. Sharply outline edges of markings and apply without running or spattering.

B. Rate of Application:

1. Reflective Markings: Apply evenly, 105 plus or minus 5 square feet per gallon.
2. Glass Bead Application:
   a. Apply immediately following application of paint.
   b. Use evenly distributed drop-on application method.
   c. Rate: 6 pounds per gallon of paint.
3. Nonreflective Markings: Apply paint evenly to pavement surface at a rate of 105 plus or minus 5 square feet per gallon.
4. On new pavement or new asphalt surface treatments, apply two coats of paint at a uniform rate of 210 square feet per gallon.

C. Drying:

1. Provide maximum drying time to prevent undue softening of bitumen and pickup, displacement, or discoloration by traffic.

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2. If drying is abnormally slow, discontinue painting operations until cause is determined and corrected.

D. Protection:

1. Protect markings from traffic until paint is thoroughly dry.
2. Protect surfaces from disfiguration by paint spatters, splashes, spills, or drips.

E. Cleanup: Remove paint spatters, splashes, spills, or drips from the Work and staging areas including areas outside the immediate Work area where spills occur.

3.03 THERMOPLASTIC MARKING APPLICATION

A. Following specified surface preparation, prime and apply marking and glass beads to provide a reflectorized strip as shown on Drawings.

B. Application Temperatures:

1. Pavement Surface: Minimum 40 degrees F and rising.
2. Thermoplastic: Minimum 375 degrees F, maximum 425 degrees F.

C. Primer:

1. On portland cement concrete and existing asphalt pavements, apply epoxy resin primer/sealer according to thermoplastic manufacturer’s recommendations.
2. All primer/sealer to dry prior to applying thermoplastic.

D. Thermoplastic Marking:

1. Extrude or spray in a molten state, free of dirt or tint at a minimum thickness of 0.125 inch; maximum thickness of 0.190 inch.
2. Apply centerline, skipline, edgeline, and other longitudinal type markings with a mobile applicator.
3. Apply special markings, crosswalks, stop bars, legends, arrows, and similar patterns with a portable, extrusion-type applicator.

E. Glass Bead Application:

1. Immediately after marker application, mechanically apply such that the beads are held by and imbedded in the surface of the molten material.
2. Application Rate: 1 pound per 20 square feet of compound.

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F. Cool completed marking to ambient temperature prior to allowing vehicular traffic.

3.04 INSTALLATION OF RAISED REFLECTIVE MARKERS

A. Apply epoxy to cleaned and prepared pavement area per manufacturer's instructions.

B. Apply marker to epoxy before epoxy has a chance to set.

C. Align markers carefully, projecting no more than 3/4 inch above level of pavement.

D. Spacing:

1. Solid Longitudinal Lines: As shown.
2. Broken Centerlines: As shown.

END OF SECTION

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SECTION 32 31 13
CHAIN LINK FENCES AND GATES

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM):
   a. A121, Standard Specification for Metallic-Coated Carbon Steel Barbed Wire.
   b. A313/A313M, Standard Specification for Stainless Steel Spring Wire.
   c. A392, Standard Specification for Zinc-Coated Steel Chain-Link Fence Fabric.
   d. A491, Standard Specification for Aluminum-Coated Steel Chain-Link Fence Fabric.
   e. A497/A497M, Standard Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete.
   f. A615/A615M, Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement.
   g. A780, Standard Specification for Repair of Damaged and Uncoated Areas of Hot-Dipped Galvanized Coatings.
   h. A824, Standard Specification for Metallic-Coated Steel Marcelled Tension Wire for Use with Chain Link Fence.
   i. A1011/A1011M, Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability.
   j. C94/C94M, Standard Specification for Ready-Mixed Concrete.
   k. C150, Standard Specification for Portland Cement.
   l. C387, Standard Specifications for Packaged, Dry, Combined Materials for Mortar and Concrete.
   m. F552, Standard Terminology Relating to Chain Link Fencing.
   n. F567, Standard Practice for Installation of Chain-Link Fence.
   o. F626, Standard Specification for Fence Fittings.
   p. F668, Standard Specification for Polyvinyl Chloride (PVC) and Other Organic Polymer-Coated Steel Chain-Link Fence Fabric.
   q. F900, Standard Specification for Industrial and Commercial Swing Gates.
   r. F934, Standard Specification for Standard Colors for Polymer-Coated Chain Link Fence Materials.

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s. F1043, Standard Specification for Strength and Protective Coatings on Metal Industrial Chain Link Fence Framework.
t. F1083, Standard Specification for Pipe, Steel, Hot-Dipped Zinc-Coated (Galvanized) Welded, for Fence Structures.
u. F1183, Standard Specifications for Aluminum Alloy Chain Link Fence Fabric.
v. F1184, Standard Specifications for Industrial and Commercial Horizontal Slide Gates.
w. F1379, Standard Terminology Relating to Barbed Tape.
x. F1911, Standard Practice for Installation of Barbed Tape.
y. F1916, Standard Specification for Selecting Chain Link Barrier Systems with Coated Chain Link Fence Fabric and Round Posts for Detention Applications.

2. Institute of Electrical and Electronic Engineers (IEEE), Inc.: C2, National Electrical Safety Code.
3. National Electrical Manufacturers Association (NEMA): 250, Enclosures for Electrical Equipment (1,000 volts max.).

1.02 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. Product Data: Include construction details, material descriptions, dimensions of individual components, and finishes for chain link fences and gates.
      1) Fence, gate posts, rails, and fittings.
      2) Chain link fabric.
      3) Gates and hardware.
      4) Gate operators, motors, and mounting arrangements, switches, and controls; include operating instructions.
      5) Gate access system, including access control features, power and control wiring diagrams, and operating instructions.
2. Samples:
   a. Chain Link Fabric: Approximately 6 inches square.
   b. Posts, Rails, Braces, Wire, and Ties: Approximately 6 inches long.
   c. Fittings: 1 each.
   d. PVC or Polymer Coated Fabric Including Manufacturer’s Color Selections: Approximately 6 inches square.
   e.
3. Test Reports: Field test result for compliance of installation of chain link fence, gates, and gate operators.

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B. Informational Submittals:

1. Manufacturer's recommended installation instructions.
2. Evidence of Supplier and installer qualifications.

1.03 QUALITY ASSURANCE

A. Qualifications:

1. Automatic Gate Operator System Supplier: 5 years' experience in gate operator systems.
2. Automatic Gate Operator System Installer: Experienced installer who has completed chain link fences and gates similar in material, design, and extent to those indicated for Project and whose work has resulted with a record of successful in-service performance with a minimum 3 years' experience.

B. Design, supply of equipment and components, installation, and on-call service shall be product of individual company with record of installations meeting requirements specified.

C. Preinstallation Conference: Conduct conference at project Site with gate installer to verify layout and operations of automatic gate operating system.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Deliver materials to Site in undamaged condition. Store materials off the ground to provide protection against oxidation caused by ground contact.

1.05 SCHEDULING AND SEQUENCING

A. Complete necessary Site preparation and grading before installing chain link fence and gates.

B. Interruption of Existing Utility Service: Notify OWNER of utility 72 hours prior to interruption of utility services. Do not proceed with interruption of utility service without written permission from utility OWNER.

1.06 SPECIAL GUARANTEE

A. Provide manufacturer's extended guarantee or warranty, with OWNER named as beneficiary, in writing, as special guarantee. Special guarantee shall provide for correction, or at the option of the OWNER, removal and replacement of the following items found defective during a period of 5 years after the date of

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Substantial Completion. Duties and obligations for correction or removal and replacement of defective Work shall be as specified in the General Conditions.

1. Faulty operations of gate operators and controls.
2. Deterioration of metals, metal finishes, and other materials beyond normal weathering.
3. Deflection of fence fabric beyond limits.

PART 2 - PRODUCTS

2.01 GENERAL

A. Match style, finish, and color of each fence component with that of other fence components.

2.02 CHAIN LINK FENCE FABRIC

A. PVC-coated or Polymer-coated galvanized fabric conforming to ASTM F668, Class 1 or Class 2a over metallic-coated steel wire.

B. Color: Brown, complying with ASTM F934.

C. Height: 72inches, unless otherwise shown.

D. Core Wire Gauge: No. 12.

E. Pattern: 2-inch diamond-mesh.

F. Diamond Count: Manufacturer’s standard and consistent for fabric furnished of same height.

G. Loops of Knuckled Selvages: Closed or nearly closed with space not exceeding diameter of wire.

H. Wires of Twisted Selvages:

1. Twisted in a closed helix three full turns.
2. Cut at an angle to provide sharp barbs that extend minimum 1/4 inch beyond twist.

2.03 POSTS

A. General:

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1. Strength and Stiffness Requirements: ASTM F1043, heavy industrial fence, except as modified in this section.
2. Round Steel Pipe, Schedule 40: ASTM F1083.
3. Roll-Formed Steel Shapes: Roll-formed from ASTM A1011/A1011M, Grade 45, High-Strength Low-Alloy steel.
4. Lengths: Manufacturer's standard with allowance for minimum embedment below finished grade of 34 inches.
5. Protective Coatings:
   a. Zinc Coating: ASTM F1043, Type A external and internal coating.
6. Color Coating: ASTM F1043, minimum 10 mils thickness over zinc coating to match color of chain link fabric.

B. Line Posts:

1. Round Steel Pipe:
   a. Outside Diameter: 2.375 inches.
   b. Weight: 3.65 pounds per foot.

C. End, Corner, Angle, and Pull Posts:

1. Round Steel Pipe:
   a. Outside Diameter: 2.875 inches.
   b. Weight: 5.79pounds per foot.

D. Posts for Removable Fence Panels: As specified for end, corner, angle, and pull posts.

E. Posts for Swing Gates 8 Feet High and Under:

1. ASTM F900.
2. Round Steel Pipe:
   a. Outside Diameter: inches.
   b. Weight: pounds per foot.

F. Posts for Swing Gates Over 8 Feet High: As recommended by fence manufacturer.

G. Posts for Horizontal Sliding Gates:

1. ASTM F1184, Type I II, Class 1.
2. Round Steel Pipe:
   a. Outside Diameter: inches.
   b. Weight: pounds per foot.

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3. Guide posts for Class 1 horizontal-slide gates, equal gate post height, one size smaller, but weight is not less than 3.11 pounds per foot, installed adjacent to gate post to permit gate to slide in space between.

2.04 TOP AND BRACE RAILS

A. Galvanized Round Steel Pipe:

1. ASTM F1083.
2. Outside Diameter: 1.66 inches.
3. Weight: 2.27 pounds per foot.

B. Galvanized Roll-Formed Steel C Shapes:

1. Roll formed from ASTM A1011/A1011M, Grade 45.
2. Outside Dimensions: 1.625 inches by 1.25 inches.
3. Weight: 1.40 pounds per foot.

C. Protective Coatings: As specified for posts.

D. Color Coating: ASTM F1043, minimum 10-mil thickness over zinc coating to match color of chain link fabric.

E. Strength and Stiffness Requirements: ASTM F1043, top rail, heavy industrial fence.

2.05 FENCE FITTINGS

A. General: In conformance with ASTM F626, except as modified by this article.

B. Post and Line Caps: Designed to accommodate passage of top rail through cap, where top rail required.

C. Tension and Brace Bands: No exceptions to ASTM F626.

D. Tension Bars:

1. One-piece .
2. Length not less than 2 inches shorter than full height of chain link fabric.
3. Provide one bar for each gate and end post, and two for each corner and pull post.

E. Truss Rod Assembly: 3/8-inch diameter, steel, hot-dip galvanized after threading rod and turnbuckle or other means of adjustment.

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F. Tie Wires, Clips, and Fasteners: According to ASTM F626.

G. Barbed Wire Supporting Arms: Pressed steel or cast iron with clips, slots, or other means for attaching strands of barbed wire integral with post cap for each post, with V-shape darms for supporting five strands of barbed wire. Arms shall withstand 250 pounds of downward pull at outermost ends of the arms without failure.

2.06 TENSION WIRE

A. Zinc-coated steel marcelled tension wire conforming to ASTM A824 , Type I.

2.07 BARBED WIRE

A. Zinc-Coated Barbed Wire: ASTM A121, Chain Link Fence Grade:

B. Aluminum-Coated Steel Barbed Wire: ASTM A121, Type I.

1. Line Wire: Two strands of No. 12-1/2 gauge.
2. Barbs:
   a. Number of Points: Two.
   b. Length: 3/8 inch minimum.
   c. Shape: Round.
   d. Diameter: No. 14 gauge.
   e. Spacing: 5 inches.

2.08 BARBED TAPE

A. Series 430 stainless steel hardened to Rockwell (30N) 35-40 minimum; 0.025-inch thick by 1-inch wide before fabrication, die stamped to produce clusters of four pointed needle-sharp barbs at 4 inches on center, minimum 1.2 inches long, offset in alternate directions 0.15 to 0.45 inch.

B. Permanently cold clench stainless steel strip to minimum 230 degrees F around core wire.

C. Core wire: 0.098-inch diameter, high-tensile-strength stainless steel complying with ASTM A313/A313M.

D. Stainless steel strip between barb clusters shall be 1/4-inch wide minimum after cold clenching to create a flange extending out from the wire, tapering off adjacent to the barb cluster to allow maximum barb penetration.

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E. Fabrication: Continuous coils of barbed tape as defined in ASTM F1379 for the following characteristics:

1. Configuration: Double coil.
2. Style: Concertina pattern.
3. Coil Diameters: 24-inch inner coil and 30-inch outer coil, plus or minus 2 inches, when coil compressed.
4. Coil Loop Spacing: 12 inches.
5. Clips: Stainless steel, 0.065-inch thick by 0.375-inch wide; capable of withstanding a minimum pull load of 200 pounds for a minimum of 30 seconds without separation, or other damage.

F. Tie Wires: Stainless steel, 0.065-inch diameter.

2.09 GATES

A. General:

1. Gate Operation: Opened and closed easily by one person.
2. Metal Pipe and Tubing: Galvanized steel. Comply with ASTM F1043 and ASTM F1083 for materials and protective coatings.
3. Frames and Bracing: Fabricate members from round galvanized steel tubing with outside dimension and weight according to ASTM F900.
4. Gate leaves more than 8-feet wide shall have intermediate tubular members and diagonal truss rods to provide rigid construction, free from sag or twist.
5. Gate Fabric Height: Same as for adjacent fence height.
6. Welded Steel Joints: Paint with zinc-based paint.
7. Chain Link Fabric: Attached securely to gate frame at intervals not exceeding 15 inches.
8. Gate Posts and Frame Members: Extend gateposts and frame end members above top of chain-link fabric at both ends of gate frame to attach barbed [wire] [tape] assemblies.
9. Latches: Arranged for padlocking so padlock will be accessible from both sides of gate.

B. Swing Gates: Comply with ASTM F900 for double swing gate types.

1. Leaf Width: As shown.
2. Hinges: Offset type, malleable iron.
   a. Furnished with large bearing surfaces for clamping in position.

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b. Designed to swing either 180 degrees outward, 180 degrees inward, or 90 degrees in or out, as shown, and not twist or turn under action of gate.

3. Latches: Plunger bar arranged to engage stop, except single gates of openings less than 10 feet wide may each have forked latch.
4. Gate Stops: Mushroom type or flush plate with anchors, suitable for setting in concrete.
5. Locking Device and Padlock Eyes: Integral part of latch, requiring one padlock for locking both leaves of double gate.
6. Hold-Open Keepers: Designed to automatically engage gate leaf and hold it in open position until manually released.

C. Cantilever Horizontal Sliding Gates:

1. Comply with ASTM F1184 for double slide gate types Iroller assemblies.
2. Cantilever Gate Support Posts: Spaced on maximum 10-foot centers.
3. Overhead Track Assembly: Manufacturer's standard track, with overhead framing supports, bracing, and accessories, designed to support size, weight, width, operation, and design of gate and roller assemblies.
4. Roller Guards: As required per ASTM F1184 for Type II, Class 1 gate.
5. Hangers, roller assemblies, and stops fabricated from galvanized malleable iron.

D. Rolling Gate:

1. Track Rollers: Malleable iron or heavy pressed steel with provision for grease lubrication.
2. Ground Rollers: Malleable iron or heavy pressed steel with provision for grease lubrication.
3. Support Posts: Spaced on maximum 7-foot centers.
4. Gates more than 8 feet in height shall have three tracks.
5. Frames: ASTM F1184, Type I.
6. Gate Accessories: ASTM F1184.

2.10 GATE OPERATOR SYSTEM

A. General: Provide factory-assembled automatic operating system designed for gate size, type, weight, and operation frequency. Provide operation control system with characteristics suitable for Project conditions, safety devices, and weatherproof enclosures; coordinate electrical requirements with Division 26, Electrical.

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1. Provide operator designed so motor may be removed without disturbing limit-switch adjustment and without affecting auxiliary emergency operator.
2. Provide operator with UL approved components.
3. Provide electronic components with built-in troubleshooting diagnostic feature.
4. Provide unit designed and wired for both right-hand/left-hand opening, permitting universal installation.

B. Motor Characteristics: Sufficient to start, accelerate, and operate connected loads at designated speeds, within installed environment, with indicated operating sequence, and without exceeding nameplate rating or considering service factor.

C. Gate Operator:

1. Heavy-duty, high frequency, electrical models designed to open and close gates provided.
2. For each gate, supply manufacturer of gate operator with complete details of gate, hardware, track rollers, adjacent fence posts, and fence construction for development and detailing of gate operator.
3. Furnish with following features:
    a. Metal enclosure, including attachments shall be constructed with finish and design suitable for exterior installation in all-weather environment.
    b. Minimum 1-hp motor, 208V ac, three-phase, 60-Hz electric power, reversible.
    c. Electric motor driven hydraulic power pack with hard rubber wheels in contact with operating type secured to gate. Transmission of opening or closing forces to gate shall be by rotation of wheels against operating type.
    d. Positive limit switch, to sense position of gate and provide control to prevent damage to gate operator.
    e. NEMA 250, Type 12 enclosure for motor control components.
    f. Motor Overload Protection: Industrial quality with manual reset.
    g. 24V ac control circuit to power remote control gate activation devices.
    h. Manual operation feature or disconnect, without use of tools, for easy operation during power failure, malfunction, or emergency.
    i. Aluminum drive rail designed for attachment to sliding gate in manner that reinforces gate assembly.
    j. Gate Travel Speed:
        1) Minimum 1 foot per second.
        2) Speed adjusting feature that provides range of appropriate speeds for slide gate operation is acceptable but not required.

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3) Maximum Gate Weight: 3,000 pounds.
4) Frequency of Use: 10 cycles per hour.
5) Operating Type: Roller chain with manual release.

k. Compatible with gate operator control devices provided.
l. Manufacturers:
1) Hy-Security Gate Operator, Seattle, WA.
2) Automated Equipment Co., Seattle, WA.
3) Stanley.
4) Richards Wilcox, Aurora, IL.

D. Access System:

1. Digital keypad in weatherproof enclosure mounted on steel tube post anchored to concrete foundation outside gate. Face lighted unit fully visible at night.
a. Digital Keypad:
1) Multiple-programmable code capability of not less than 500 possible individual codes, consisting of 5-digit codes.
2) Features:
a) Timed anti-passback.
b) Limited-time usage.
c) Capable of monitoring and auditing gate activity.
2. For safety, provide loop detectors minimum of 4 feet away from each side of gate.
3. Gate Operation:
a. Entry: Gate opens when activated by valid code in reader. Gate closes after adjustable time period up to 90 seconds.
b. Exit: Gate opens when activated by detector loop in pavement or pushbutton inside gate. Gate closes as for entry.
c. Override or 7-day timer to allow gate to remain open for up to 12 hours with equipment at rest.
4. Serial communication interface, including cable, with Supervisory Control System specified in Section 40 90 00, Instrumentation and Control for Process Systems, for remote monitoring of gate activity. Gate usage shall send code after each access to plant.
5. Manufacturers:
a. Power Door Engineering, Seattle, WA.
b. Quentin Control Systems, NW, Inc., Seattle, WA.
c. Continental Instruments Corp., Westbury, NY.
d. Richards Wilcox, Aurora, IL.

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2.11 PRIVACY SLATS

A. Material: Polyethylene tubular slats, not less than 0.023-inch thick, manufactured for chain link fences from virgin polyethylene containing UV inhibitor, sized to fit mesh specified for direction indicated , with vandal-resistant fasteners and lock strips.

B. Color: As shown.

C. Fabric Selvage: Knuckled.

D. Furnish continuous galvanized top rail, manufacturer's standard heavyweight galvanized line, corner, gate, and end posts, and accessories and fasteners.

E. Gates: Manufacturer's standard for use with chain link, wood slat fence. Furnish galvanized hardware for complete gate installation.

F. Hardware: Galvanized.

2.12 REMOVABLE FENCE PANELS

A. Panel Length:

1. Equal division of total length of removable fence section.
2. Maximum 10 feet.

B. Frames: ASTM F1184, Type I.

2.13 CONCRETE

A. Provide as specified in Section 03 30 00, Cast-in-Place Concrete.

2.14 FENCE GROUNDING

A. Conductors: Bare, solid wire for 6 AWG and smaller; stranded wire for 4 AWG and larger.

1. Material above Finished Grade: Copper.
2. Material on or below Finished Grade: Copper.
3. Bonding Jumpers: Braided copper tape, 1-inch wide, woven of 30 AWG bare copper wire, terminated with copper ferrules.

B. Connectors and Grounding Rods: Comply with UL 467.

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1. Connectors for Below-Grade Use: Exothermic welded type.
2. Grounding Rods: Copper-clad steel.

PART 3 - EXECUTION

3.01 GENERAL

A. Install chain link fences and gates in accordance with ASTM F567, except as modified in this section, and in accordance with fence manufacturer's recommendations, as approved by ENGINEER. Erect fencing in straight lines between angle points.

B. Provide necessary hardware for a complete fence and gate installation.

C. Any damage to galvanized surfaces, including welding, shall be repaired with paint containing zinc dust in accordance with ASTM A780.

D. Drainage Crossings: Where the chain-link fence must cross drainage ditches or swales, the main fence shall be carried across a ditch or swale with additional fence added below.

1. Frames and Bracing: The fence added below shall be fabricated with galvanized round steel pipe conforming to the requirements for top and brace rails.
2. The construction of the frame shall be welded or assembled with corner fittings. The frame shall be rigid and to the extent necessary to maintain a 2-inch clearance between bottom of the frame and finish grade. If necessary to maintain rigidity, attach to the frame a series of 3/8-inch diameter galvanized steel pipe stakes that are embedded a minimum of 2 feet to the sides and bottom of the ditch.
3. Attach chain link fabric securely to frame at intervals not exceeding 12 inches.

3.02 PREPARATION

A. Clear area on either side of fence to the extent specified in Section 31 10 00, Site Clearing. Eliminate ground surface irregularities along fence line to the extent necessary to maintain a 2-inch clearance between bottom of fabric and finish grade.

B. Stake locations of fence lines, gates, and terminal posts. Do not exceed intervals of 500 feet or line of sight between stakes. Indicate locations of utilities, lawn sprinkler system, underground structures, benchmarks, and property monuments.

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3.03 POST SETTING

A. Drill or hand-excavate holes for posts to diameters and spacing indicated, in firm, undisturbed soil. Driven posts are not acceptable. Postholes shall be clear of loose materials. Waste materials from postholes shall be removed from Site or regraded into slopes on Site.

B. Posthole Depth:

1. Minimum 3 feet below finished grade.
2. 2 inches deeper than post embedment depth below finish grade.

C. Set posts with minimum embedment below finished grade of 34 inches and with top rail at proper height above finished grade. Verify posts are set plumb, aligned, and at correct height and spacing. Brace posts, as necessary, to maintain correct position and plumbness until concrete sets.

D. Backfill postholes with concrete to 2 inches above finished grade. Vibrate or tamp concrete for consolidation. Protect above ground portion of posts from concrete splatter.

E. Before concrete sets, crown and finish top of concrete to readily shed water.

F. Terminal Posts: Locate terminal end, corner, and gate posts per ASTM F567 and terminal pull posts at changes in horizontal or vertical alignment of 15 degrees or more.

G. Line Posts: Space line posts uniformly at 10 feet on centers between terminal end, corner, and gate posts.

3.04 POST BRACING

A. Install according to ASTM F567, maintaining plumb position, and alignment of fencing. Install braces at gate, end, pull, and corner posts diagonally to adjacent line posts to ensure stability. Install braces on both sides of corner and pull posts.

1. Locate horizontal braces at mid-height of fabric or higher, on fences with top rail, and 2/3-fabric height on fences without top rail. Install so posts are plumb when diagonal truss rod assembly is under proper tension.

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3.05 TOP RAILS

A. Install according to ASTM F567, maintaining plumb position and alignment of fencing. Run rail continuously through line post caps and terminating into rail end attached to posts or posts caps fabricated to receive rail at terminal posts. Install top rail sleeves with springs at 105 feet maximum spacing to permit expansion in rail.

3.06 BARBED WIRE SUPPORTING ARMS

A. Barbed wire supporting arms shall be installed as indicated and as recommended by manufacturer. Bolt or rivet supporting arm to top of post in a manner to prevent easy removal with hand tools. Angle single arms to outside of fence.

3.07 TENSION WIRE

A. Install according to ASTM F567 and ASTM F1916, maintaining plumb position and alignment of fencing. Pull wire taut, without sags. Fasten fabric to tension wire with tie wires at a maximum spacing of 24 inches on center.

B. Install tension wire within 6 inches of bottom of fabric and tie to each post with not less than same diameter and type of wire.

3.08 CHAIN LINK FABRIC

A. Do not install fabric until concrete has cured minimum 7 days.

B. Apply fabric to outside of enclosing framework. Pull fabric taut to provide a smooth and uniform appearance free from sag, without permanently distorting fabric diamond or reducing fabric height. Tie fabric to posts, rails, and tension wires. Anchor to framework so fabric remains under tension after pulling force is released.

C. Splicing shall be accomplished according to ASTM F1916 by weaving a single picket into the ends of the rolls to be joined.

D. Leave 2 inches between finish grade or surface and bottom selvage, unless otherwise indicated.

E. Tension or Stretcher Bars: Thread through fabric and secure to end, corner, pull, and gate posts with tension bands spaced not more than 15 inches on center.

F. Tie Wires:

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1. Fasten ties to wrap a full 360 degrees around rail or post and a minimum of one complete diamond of fabric.
2. Twist ends of tie wire three full twists, and cut off protruding ends to preclude untwisting by hand.
3. Maximum Spacing: Tie fabric to line posts at 12 inches on center and to brace and top rails at 24 inches on center.

3.09 PRIVACY SLATS

A. Install slats in chain link fabric to limits shown on Drawings.

B. Slats shall be installed diagonally into locking channel at bottom of chain link fabric as recommended by manufacturer.

3.10 BARBED WIRE

A. Install barbed wire uniformly in configurations of five strands of barbed wire on supporting arms. Pull wire taut and install securely to supporting arms and secure to end terminal post or terminal arms.

3.11 BARBED TAPE

A. Install barbed tape uniformly on top of the barbed wire and V-shaped supporting arms in the configuration shown on Drawings. Secure each loop to arms or single strand of barbed wire to prevent movement or displacement according to ASTM F1911.

3.12 GATES

A. Install gates according to manufacturer’s written instructions, level, plumb and secure for full opening without interference. Attach fabric and hardware to gate using tamper-resistant or concealed means. Adjust hardware for smooth operation and lubricate where necessary so gates operate satisfactorily from open or closed position.

B. Set gate stops in concrete to engage center drop rod or plunger bar.

3.13 GATE OPERATOR SYSTEMS

A. Install gate operator systems in accordance with manufacturer’s recommendations, aligned and true to fence line and grade.

B. Furnish with equipment and accessories necessary for complete installation.

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C. Hand excavate holes for pads in firm undisturbed soil to dimensions, depths, and locations as required by gate operator component manufacturer's written instructions and as shown on the drawings.

D. Vehicle Loop Detector System: Cut grooves in pavement and bury and seal wire loop according to manufacturer's written instructions. Connect to equipment operated by detector.

3.14 ELECTRICAL GROUNDING

A. Ground fences at a maximum interval of 1,000 feet in accordance with applicable requirements of IEEE C2, National Electrical Safety Code.

B. Protection at Crossings of Overhead Electrical Power Lines: Ground fence at location of crossing and at a maximum distance of 150 feet on each side of crossing.

C. Grounding Method: At each grounding location, drive a grounding rod vertically until top is 6 inches below finished grade. Connect rod to fence with 6 AWG conductor. Connect conductor to each fence component at grounding location.

3.15 FIELD QUALITY CONTROL

A. Post and Fabric Testing: Test fabric tension and line post rigidity according to ASTM F1916.

B. Gate Tests:

1. Prior to acceptance of installed gates, demonstrate proper operation of gates under each possible open and close condition specified.
2. Adjust gate to operate smoothly, easily, and quietly, free of binding, warp, excessive deflection, distortion, nonalignment, misplacement, disruption, or malfunction, throughout entire operational range.
3. Confirm that latches and locks engage accurately and securely without forcing and binding.

C. Automatic Gate Operator:

1. Energize circuits to electrical equipment and devices.
2. Adjust operators, controls, safety devises, and limit switches.
3. Start units to confirm proper motor rotation and unit operation free of binding. Test and adjust all gate controls for proper operation.
4. Replace damaged and malfunctioning controls and equipment.

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5. Lubricate hardware, gate operator and other moving parts.

3.16 MANUFACTURER'S SERVICES

A. Provide manufacturer's representative at Site in accordance with Section 01 43 33, Manufacturers' Field Services, to train OWNER's personnel to adjust, operate, and maintain gates.

3.17 CLEANUP

A. Remove excess fencing materials and other debris from Site.

END OF SECTION

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SECTION 33 05 01
CONVEYANCE PIPING—GENERAL

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Concrete Institute (ACI): 301, Specifications for Structural Concrete.
2. American Water Works Association (AWWA):
   a. C110/A21.10, Ductile-Iron and Gray-Iron Fittings.
   b. C115/A21.15, Flanged Ductile-Iron Pipe with Ductile-Iron or Gray-Iron Threaded Flanges.
   c. C207, Steel Pipe Flanges for Waterworks Service - Sizes 4 in. Through 144 in. (100 mm Through 3,600 mm).
   d. C210 Liquid-Epoxy Coating Systems for the Interior and Exterior of Steel Water Pipelines.
   e. C213, Fusion-Bonded Epoxy Coating for the Interior and Exterior of Steel Water Pipelines.
   f. C217, Petrolatum and Petroleum Wax Tape Coatings for the Exterior of Connections and Fittings for Steel Water Pipelines.
   g. C219, Bolted, Sleeve-Type Couplings for Plain-End Pipe.
   h. C221, Fabricated Steel Mechanical Slip-Type Expansion Joints.
   i. C606, Grooved and Shouldered Joints.
3. ASTM International (ASTM):
   a. A497/A497M, Standard Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete.
   b. A615/A615M, Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement.
   c. C94/C94M, Standard Specification for Ready-Mixed Concrete.
   d. C150/C150M, Standard Specification for Portland Cement.
   e. F593, Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs.
4. NSF International (NSF): 61, Drinking Water System Components - Health Effects.

1.02 DESIGN REQUIREMENTS

A. Where pipe class or wall thickness is not indicated, design piping system for maximum stress based on the following [operating pressure and earth loads] [test pressure and earth loads] [earth and traffic loads]:

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1. Operating Pressure: [_____]
2. Field Hydrostatic Test Pressure: [_____]
3. Earth Loads: [_____]
4. Soil Density: [_____]
5. Traffic Loads: [_____]

1.03 SUBMITTALS

A. Action Submittals:

1. Detailed pipe fabrication drawings showing pipe details, special fittings and bends, dimensions, coatings, and other pertinent information.
2. Layout drawing showing location of each pipe section and each special length.
3. Pipe pressure class.
4. Wall thickness, reinforcing, and strength calculations.
5. Product Data: Manufacturer's data for couplings, saddles, gaskets, and other pipe accessories. Indicate maximum rated working pressure and test pressure for each item.

B. Informational Submittals: Provide manufacturer's certificate(s) in accordance with Section 01 43 33, Manufacturers' Field Services.

1.04 DELIVERY, STORAGE, AND HANDLING

A. In accordance with manufacturer's recommendations [and as specified in individual Specification(s) following this section].

B. Marking at Plant: Mark each pipe and fitting at plant. Include date of manufacture, manufacturer's identification, specification standard, diameter of pipe [dimension ratio,] [pipe class,] [pipe number for laying purposes,] and other information required for type of pipe.

C. Pipe, specials, and fittings received at Project Site in damaged condition will not be accepted.

D. Gasket Storage: Store rubber gaskets in cool, well ventilated place, and do not expose to direct rays of sun. Do not allow contact with oils, fuels, petroleum, or solvents.

E. Store and support pipe securely to prevent accidental rolling and to avoid contact with mud, water, or other deleterious materials.

F. Handling:

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1. Pipe shall be handled with proper equipment in a manner to prevent distortion or damage. Use of hooks, chains, wire ropes, or clamps that could damage pipe, damage coating or lining, or kink and bend pipe ends is not permitted.
2. Use heavy canvas, or nylon slings of suitable strength for lifting and supporting materials.
3. Lifting pipe during unloading or lifting into trench shall be done using two slings placed at quarter point of pipe section. Pipe may be lifted using one sling near center of pipe, provided pipe is guided to prevent uncontrolled swinging and no damage will result to pipe or harm to workers. Slings shall bear uniformly against pipe.
4. Pipe and fittings shall not be stored on rocks or gravel, or other hard material that might damage pipe. This includes storage area and along pipe trench.

PART 2 -PRODUCTS

2.01 PIPE

A. As specified in the individual Specification(s) following this section.

2.02 JOINTS

A. As specified in the individual Specification(s) following this section.

2.03 COUPLINGS

A. General:

1. Coupling linings for use in potable water systems shall be in conformance with NSF 61.
2. Couplings shall be rated for appropriate operating pressure and hydrostatic test pressure.
3. Exposed, bolted, sleeve-type couplings shall be [lined and coated with fusion bonded epoxy in accordance with AWWA C213] [lined and coated with liquid epoxy in accordance with AWWA C210] [_____].
4. Buried, bolted, sleeve-type couplings shall be [lined and coated with fusion-bonded epoxy in accordance with AWWA C213] [lined and coated with liquid epoxy in accordance with AWWA C210] [and wrapped with petroleum wax tape in accordance with AWWA C217].

B. For Pipe with Plain-Ends:

1. Bolted, sleeve-type coupling, in accordance with AWWA C219.

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a. Manufacturer of couplings shall observe same quality control requirements as specified in AWWA C221 for fabrication of pipe expansion joints.
b. Unless thrust restraint is provided by other means, bolted, sleeve-type couplings shall be harnessed. Harness details shall be in accordance with requirements of appropriate reference standard or as shown on Drawings.
c. [Certified Welding Inspector at coupling fabrication facility shall verify welders and welding procedures are qualified, procedures are being followed, and quality assurance functions are being implemented.]
d. Pipe Type to be Joined: [_____]
e. Standard to Which Pipe is Manufactured: [_____]
f. Pipe Ends Tolerance: [Conform to Table 4 of AWWA C219.] [_____]
g. Pipe Outside Diameter, Including Coating: [_____]
h. Service Type: [_____]
i. Rated Working Pressure: [_____]
j. Test Pressure: [_____]
k. Operating Temperature Range: [_____]
l. Anticipated Angular Deflection of Pipe: [_____]
m. Inner Sleeve:
    1) Length: [_____]
    2) Thickness: [_____]
n. Hydrostatic Test Requirements and Reporting: [_____]
o. Additional Nondestructive Weld Evaluation: [_____]
p. Marking Requirements: [_____]
q. [Certificate of Compliance in accordance with Section 01 43 33, Manufacturers' Field Services.]

2. Fabricated steel, mechanical slip-type expansion joints, in accordance with AWWA C221.
a. Pipe Type Expansion Joint to Connect: [_____]
b. Standard to Which Pipe is Manufactured: [_____]
c. Pipe Ends Tolerance: [Conform to Table 2 of AWWA C221.] [_____]
d. Pipe Outside Diameter, Including Coating: [_____]
e. Wall Thickness, Schedule, or Pipe Class: [_____]
f. Rated Working Pressure: [_____]
g. Test Pressure: [_____]
h. Operating Temperature Range: [_____]
i. Pipe End Tolerance: [_____]
j. Anticipated Axial Movement: [_____]
k. Body and Slip Pipe: [_____]
l. Slip Pipe Length: [_____]
m. Slip Pipe Thickness: [_____]

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n. Body Length: [_____]
o. Body Thickness: [_____]
p. Slip Pipe Material: [Chrome plated steel.] [Type 304 stainless steel.]
q. Coating Requirements: [_____]
r. Special Packing Requirements: [_____]
s. Special Bolting Requirements: [_____]
t. Hydrostatic Test Requirements and Reporting: [_____]
u. Additional Nondestructive Weld Evaluation: [_____]
v. Marking Requirements: [_____]
w. Limit Rods: [_____]
x. [Certificate of Compliance in accordance with Section 01 43 33, Manufacturers' Field Services.]

C. For Pipe with Grooved Ends:

1. Grooved couplings, in accordance with AWWA C606. System shall provide for [flexible joints] [rigid joints] [flexible or rigid joints as shown on Drawings].
2. Exposed couplings shall be lined and coated with [liquid epoxy in accordance with AWWA C210] [_____].
3. Buried couplings shall be lined and coated with [coal tar epoxy in accordance with AWWA C210] [and wrapped with petroleum wax tape in accordance with AWWA C217] [_____].

D. For Pipe with Flanged Ends:

1. Flanged coupling adapters, in accordance with AWWA C219.
   a. Pipe Type to be Joined: [_____]
   b. Standard to Which Pipe is Manufactured: [_____]
   c. Pipe Ends Tolerance: [Conform to Table 4 of AWWA C219.] [_____]
   d. Pipe Outside Diameter, Including Coating: [_____]
   e. Service Type: [_____]
   f. Rated Working Pressure: [_____]
   g. Test Pressure: [_____]
   h. Operating Temperature Range: [_____]
   i. Anticipated Angular Deflection of Pipe: [_____]
   j. Hydrostatic Test Requirements and Reporting: [_____]
   k. Nondestructive Examination Requirements: [_____]
   l. Marking Requirements: [_____]
   m. [Certificate of Compliance in accordance with Section 01 43 33, Manufacturers' Field Services.]

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2. Dismantling joints for connecting flanged pipe shall be AWWA C219 compliant. Provide studs and nuts to seal gasket separate and independent from tie-bar restraint system.
3. Rubber expansion joints shall allow compression, extension, and lateral deflection of the pipes being joined.
    a. Joints shall be suitable for use with [potable water] [_____]
    b. Materials of Construction: [_____]
    c. Flange Drilling Pattern: [_____]
    d. Coating: [_____]
    e. Maximum Movement: [_____]
    f. Control Rods: [_____]
    g. Working Pressure: [_____]
    h. Test Pressure: [_____]
    i. Manufacturers:
        1) Red Valve Company, Carnegie, PA.
        2) Mercer Rubber Company, Hauppauge, NY.

E. Bolting Materials for Couplings: [In accordance with the applicable AWWA standard.] [As recommended by coupling manufacturer for specified conditions.] [Stainless steel in accordance with AWWA C219.] [_____]

2.04 SERVICE SADDLES

A. Double strap design rated for [150 psi minimum working pressure] [_____].

2.05 SLAB, FLOOR, WALL, AND ROOF PENETRATIONS

A. Modular Mechanical Seal:

1. Type: Interconnected synthetic rubber links shaped and sized to continuously fill annular space between pipe and wall sleeve opening.
2. Assemble interconnected rubber links with Type 316 stainless steel bolts, nuts, and pressure plates.
3. Size modular mechanical seals according to manufacturer's instructions for the size of pipes shown to provide a watertight seal between pipe and wall sleeve opening.
4. Manufacturers and Products:
    a. Thunderline/LinkSeal, Div. of PSI, Houston, TX; Link Seal.
    b. Calpico, Inc., South San Francisco, California; Sealing Linx.
    c. Advance Products and Systems, Lafayette, Louisiana; Innerlynx.

B. Wall Sleeves:

1. Diameter, ends, and length shall be as shown on Drawings.

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2. Shall include integral seep ring to minimize seepage between metal sleeve and concrete.

C. Wall Couplings:

1. Diameter, ends, and length shall be as shown on Drawings.
2. Wall couplings shall provide flexible mechanical joint.
3. Body and end rings shall be coated with fusion bonded epoxy.
4. Body shall include integral seep ring.
5. Shall comply with AWWA C219.

D. [If core drilling is required for penetrations of existing concrete walls or slabs, locations of drilling shall be determined by radiograph to avoid damage to reinforcing steel and conduits.]

2.06 FLANGES, FLANGE GASKETS, AND BOLTING MATERIALS

A. As specified in individual specifications following this section.

B. Flanges, bolting materials, and flange gaskets for steel flanges shall conform to AWWA C207.

C. Flanges, bolting materials, and flange gaskets for ductile iron flanges shall conform to AWWA C110 and AWWA C115.

D. [Stainless steel bolting material shall conform to ASTM F593, Type 304 stainless steel, Group 1, Condition SH1, 2, 3 or 4.]

E. [If the flanges are coated, provide two washers for each bolt on each side of the flange to minimize damage to the coating as the nuts are tightened. Provide bolts of the proper length to accommodate the washers.]

2.07 CONCRETE FOR THRUST BLOCKS

A. Thrust Block Concrete: As specified in Section [03 30 00, Cast-in-Place Concrete] [_____].

B. Reinforcing Steel: ASTM A615/A615M, Grade 60 deformed bars.

C. Welded Wire Fabric: ASTM A497/A497M.

D. Formwork: Plywood [; earth cuts may be used as approved by ENGINEER].

E. Mix: ASTM C94/C94M, Option A.

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1. Cement: ASTM C150/C150M, Type [I] [II] [III].
2. Coarse Aggregate Size: [1-1/2] [3/4] inch(es).
3. Design for Minimum Compressive Strength at 28 Days: [2,500] [3,000] [_____] psi.

2.08 PIPE LOCATING TAPE

A. As specified in Section 31 23 23.15, Trench Backfill.

2.09 PIPE BEDDING AND PIPE ZONE MATERIAL

A. [Granular material] [or] [Controlled low strength material] as specified in Section 31 23 23.15, Trench Backfill.

2.10 TRENCH STABILIZATION MATERIAL

A. As specified in Section 31 23 23.15, Trench Backfill.

PART 3 - EXECUTION

3.01 GENERAL

A. Notify ENGINEER at least 2 weeks prior to field fabrication of pipe or fittings.

B. Furnish feeler gauges of proper size, type, and shape for use during installation for each type of pipe furnished.

C. Distributing Materials: Place materials along trench only as will be used each day, unless otherwise approved by ENGINEER. Placement of materials shall not be hazardous to traffic or to general public, obstruct access to adjacent property, or obstruct others working in area.

3.02 EXAMINATION

A. Verify size, material, joint types, elevation, and horizontal location of existing pipeline to be connected to new pipeline or new equipment.

B. Inspect size and location of structure penetrations to verify adequacy of wall pipes, sleeves, and other openings.

C. Damaged Coatings and Linings: Repair using coating and lining materials in accordance with manufacturer’s instructions.

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3.03 PREPARATION OF TRENCH

A. Prepare trench as specified in Section 31 23 16, Excavation.

B. Unless otherwise permitted by ENGINEER, maximum length of open trench shall not exceed [50] [500] [_____] feet.

3.04 INSTALLATION

A. General:

1. Join pipe and fittings in accordance with manufacturer's instructions, unless otherwise shown or specified.
2. Install individual pipe lengths in accordance with approved lay diagram. Misplaced pipe shall be removed and replaced.
3. Inspect pipe and fittings before installation, clean ends thoroughly, remove foreign matter and dirt from inside.
4. Flanged Joints:
   a. Install perpendicular to pipe centerline.
   b. Bolt Holes: Straddle vertical centerline, aligned with connecting equipment flanges or as shown on Drawings.
   c. Use torque-limiting wrenches to provide uniform bearing and proper bolt tightness.
   d. Flange Type: Use flat-faced flange when joining with flat-faced ductile or cast iron flange.

B. Couplings:

1. Install in accordance with manufacturer's written instructions.
2. Before coupling, clean pipe holdback area of oil, scale, rust, and dirt.
3. [Remove pipe coating, if necessary, to obtain smooth surface.] [Do not remove pipe coating. If damaged, repair before joint is made.]
4. Clean gaskets before installation.
5. If necessary, lubricate with gasket lubricant for installation on pipe ends.
6. Tighten coupling bolts progressively, drawing up bolts on opposite sides gradually until bolts have uniform tightness.

C. Buried Pressure Pipe:

1. Concrete Encased or Embedded Pipe: Do not encase joints in concrete, unless specifically shown on Drawings.
2. Placement:
   a. Keep trench dry until pipe laying and joining is completed.

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b. Exercise care when lowering pipe into trench to prevent twisting or damage to pipe.
c. Measure for grade at pipe invert, not at top of pipe.
d. Excavate trench bottom and sides of ample dimensions to permit proper joining, welding, visual inspection, and testing of entire joint.
e. Prevent foreign material from entering pipe during placement.
f. Close and block open end of last laid pipe section when placement operations are not in progress and at close of day's work.
g. In general, lay pipe upgrade with bell ends pointing in direction of laying.
h. Deflect pipe at joints for pipelines laid on a curve using unsymmetrical closure of spigot into bell. If joint deflection of standard pipe lengths will not accommodate horizontal or vertical curves in alignment, provide:
1) Shorter pipe lengths.
2) Special mitered joints.
3) Standard or special fabricated bends.

3. Check gasket position with feeler gauge to assure proper seating.
a. After joint has been made, check pipe alignment and grade.
b. Place sufficient pipe zone material to secure pipe from movement before next joint is installed.
c. Prevent uplift and floating of pipe prior to backfilling.

4. Tolerances:
a. Deflection From Horizontal Line: Maximum [2] [_____] inches.
b. Deflection From Vertical Line: Maximum [1] [_____] inch(es).
c. Joint Deflection: Maximum of 75 percent of manufacturer's recommendation.
d. Horizontal position of pipe centerline on alignment around curves maximum variation of [1] [_____] foot from position shown.

5. Cover Over Top of Pipe: Minimum [3] [_____] feet, unless otherwise shown.
6. Disposal of Excess Excavated Material: As specified in Section 31 23 16, Excavation.

3.05 THRUST RESTRAINT

A. Location: At pipeline tees, plugs, caps, bends, and locations where unbalanced forces exist.

B. Thrust Blocking:

1. Place only where shown on Drawings.
2. Quantity of Concrete: Sufficient to cover bearing area of pipe and provide required soil bearing area as shown on Drawings.

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3. Place blocking so pipe and fitting joints are accessible for repairs.
4. Place concrete in accordance with [Section 03 30 00, Cast-in-Place Concrete] [ACI 301].

3.06 CORROSION PROTECTION

A. Buried Pipe: As specified in the individual specifications following this section.

B. Notify ENGINEER at least 3 days prior to start of surface preparation, coating application, and corrosion protection work.

3.07 PLACEMENT OF PIPE LOCATING TAPE

A. Place pipe locating tape in accordance with Section 31 23 23.15, Trench Backfill.

3.08 PIPE BEDDING AND ZONE MATERIAL

A. Place pipe bedding and pipe zone material in accordance with Section 31 23 23.15, Trench Backfill.

3.09 FIELD QUALITY CONTROL

A. Pressure Leakage Testing: As specified in the individual Specification(s) following this section.

3.10 CLEANING [AND DISINFECTION]

A. Following assembly and testing, and prior to [disinfection and] final acceptance, flush pipelines with water at 2.5 fps minimum flushing velocity until foreign matter is removed. Dispose of water and flushed foreign matter.

B. If impractical to flush large diameter pipe at 2.5 fps, [clean pipe in-place from inside by brushing and sweeping, then flush or blow line at lower velocity] [clean pipe by use of pipe pig as approved by ENGINEER. Multiple passes of pipe pig may be required to adequately clean line].

C. Remove accumulated debris through blowoffs 2 inches and larger or by removing spools and valves from piping.

D. Disinfection: [As specified in Section 33 13 00, Disinfection of Water Utility Distribution Facilities.] [_____]

END OF SECTION

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SECTION 33 05 01.10
HIGH-DENSITY POLYETHYLENE (HDPE) PRESSURE PIPE AND FITTINGS

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards that may be referenced in this section:

1. American Society of Mechanical Engineer's (ASME):
   a. B16.1, Gray Iron Pipe Flanges and Flanged Fittings (Classes 25, 125, and 250).
   b. B18.2.2, Square and Hex Nuts (Inch Series).
2. American Water Works Association (AWWA):
   a. C906, Polyethylene (PE) Pressure Piping and Fittings, 4 in. through 63 in., for Water Distribution and Transmission.
   b. Manual M55, PE Pipe - Design and Installation.
3. ASTM International (ASTM):
   a. A193/A193M, Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications.
   b. A194/A194M, Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both.
   c. A240/A240M, Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications.
   d. A307, Standard Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength.
   e. A536, Standard Specification for Ductile Iron Castings.
   f. A563, Standard Specification for Carbon and Alloy Steel Nuts.
   g. D638, Standard Test Method for Tensile Properties of Plastics.
   h. D3350, Standard Specification for Polyethylene Plastics Pipe and Fittings Materials.
   i. F714, Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter.
   j. F2164, Standard Practice for Field Leak Testing of Polyethylene (PE) Pressure Piping Systems Using Hydrostatic Pressure.
   k. F2620, Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings.

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4. Code of Federal Regulations (CFR): Title 49 Part 192.285, Plastic Pipe: Qualifying Persons to Make Joints.
5. NSF International (NSF): 61, Drinking Water System Components - Health Effects.
6. Plastics Pipe Institute (PPI):
   a. Handbook of Polyethylene Pipe.
   b. Technical Note 38, Bolt Torque for Polyethylene Flanged Joints.
   c. TR-33, Generic Butt Fusion Joining Procedure for Field Joining of Polyethylene Pipe.

1.02 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. Catalog information confirming pipe, fittings, and other materials conform to requirements of this section.
   b. Drawings of specific connection details.
   c. [_____]

B. Informational Submittals:

1. Manufacturer's Certificate of Compliance, in accordance with Section 01 43 33, Manufacturers' Field Services.
2. Infrared temperature gun product data.
3. [Certificates of qualification for persons to be fusing HDPE pipe.] [Experience and training record of persons to be fusing HDPE pipe.]
4. Testing Plan: Submit at least 15 days prior to testing and include the following as a minimum:
   a. Testing dates.
   b. Piping systems and section(s) to be tested.
   c. Method of isolation.
   d. Method of conveying water from source to system being tested.
5. Certifications of Calibration: Approved testing laboratory certificate if pressure gauge for hydrostatic test has been previously used. If pressure gauge is new, no certificate is required.
6. Test report documentation.
7. [Fusion parameters including recommended limits of criteria recorded by data logger.]
8. [Fusion report for each joint, including information listed under Article Field Quality Control.]
9. [_____]

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1.03 QUALITY ASSURANCE

A. Qualifications:

1. Pipe Manufacturer: Listed with Plastic Pipe Institute.
2. Persons fusing HDPE pipe shall [be certified under 49 CFR § 192.285] [have minimum of [1] [_____] year(s) of experience with fusing HDPE pipe and shall have received a minimum of 20 hours of training for fusing HDPE pipe from pipe supplier or fusing equipment supplier].

1.04 DELIVERY, STORAGE, AND HANDLING

A. Shipping: Do not cut, kink, or otherwise damage pipe during transportation.

B. Storage:

1. Limit stacking of pipe to a height that will not cause excessive deformation of bottom layers of pipes under anticipated temperature conditions.
2. Where necessary, because of ground conditions, store pipe on wooden sleepers, spaced suitably and of such widths as not to allow deformation of pipe at point of contact with sleeper or between supports.
3. Keep pipe shaded from direct sunlight prior to installation in trench.

1.05 CONNECTIONS TO EXISTING PIPE

A. Fusing to Existing Pipe: [Comply with manufacturer's or distributor's recommendations based on Site conditions and PPI TR-33.] [_____]

PART 2 - PRODUCTS

2.01 MATERIALS

A. Pipe and Fittings:

1. Conform to requirements of [AWWA C906] [ASTM F714].
2. In compliance with NSF 61.
3. Resin:
   a. Polyethylene resin shall meet or exceed requirements of ASTM D3350 for PE 3408 material. Pressure rating shall be based on hydrostatic design stress of 800 psi at 73.4 degrees F.
   b. [Polyethylene resin shall meet or exceed requirements of ASTM D3350 for PE 4710 material with cell classification of

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445474C, or better. Pressure rating shall be based on hydrostatic design stress of 1,000 psi at 73.4 degrees F.]

4. Pressure Rating: [_____] [and nominal SDR of _____].
5. Outside Diameter Basis: [IPS] [DIPS].
6. Pipe lengths, fittings, and flanged connections to be joined by thermal butt-fusion shall be of a compatible resin mix for the fusion process.
7. Fittings:
   a. Sizes 6 Inches and Smaller: Molded and fabricated from polyethylene pipe.
   b. Sizes 8 Inches and Larger: Use thermal butt-fusion.
   c. Polyethylene fittings shall have same or higher pressure rating as pipe.

B. Backup Rings:

1. Convoluted for Flanged Connections:
   a. [ASTM A240/A240M, Type 316 stainless steel] [ASTM A536, ductile iron].
   b. Complete with one-piece, molded polyethylene flange adapters.
   c. Flanged Connections: Same or greater pressure rating as pipe.
2. Ductile Iron: [Shop primed with red oxide] [and] [shop coated in accordance with requirements in Section 09 90 00, Painting] [shop coated with two-part epoxy material in accordance with AWWA C550. Dry film thickness shall be 10 mils minimum].]

C. Gaskets: Material, size, and thickness shall be as recommended by pipe or flange manufacturer, and in accordance with PPI Technical Note 38.

D. Joints: Thermal butt-fusion or electrofusion, except [where connecting to unions, valves, and equipment with flanged or threaded connections that may require future disassembly] [in specific locations as shown on Drawings].

E. Bolts, Nuts, Washers:

1. [Type 316 stainless steel, ASTM A193/A193M, Grade B8 hex head bolts; and ASTM A194/A194M, Grade 8 hex head nuts.] [Carbon steel, ASTM A307, Grade A hex head bolt, and ASTM A563, Grade A hex head nuts.]
2. Bolts: Fabricated in accordance with ASME B18.2.2 and provided with washers of same material as bolts.

F. Wall Anchor:

1. Material: Same as HDPE pipe.

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2. Internal Diameter: Equal to adjacent pipe.
3. Shear Strength: Equal to or greater than tensile strength of adjacent pipe.
4. Fabrication: Butt fusion. Extrusion bead welding is not allowed.

G. Electrofusion Flex Restraint:

1. Material: HDPE.
2. Method of Attachment: Electrofusion.
3. Designed for restraining movement of HDPE pipe.
4. Manufacturers:
   a. Central Plastics Company.
   b. ISCO Industries.

H. Special Markings: [_____]

I. Concrete Thrust Blocks: See Section 33 05 01, Conveyance Piping—General.

J. Products that restrain HDPE pipe with wedges, machined serrations, or clamps are not acceptable.

2.02 SERVICE CONDITIONS

A. [_____]

PART 3 - EXECUTION

3.01 INSTALLATION

A. General:

1. Install polyethylene pipe in conformance with AWWA M55, PPI TR-33, ASTM F2620, and pipe manufacturer's recommendations.
2. Joining: Butt-fuse pipes and fittings in accordance with pipe manufacturer's recommendations. Depending on Site conditions, perform butt-fusion joining in or outside of excavation.
3. [Remove and extract internal fusion bead from pipe.
   a. Verify complete internal fusion bead removal was performed. Accomplish by examination of extracted internal fusion bead or by means of closed circuit television (CCTV) examination.
   b. Extracted Internal Fusion Bead:
      1) Appearance shall have same double roll back semblance as does the external fusion bead.

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2) Possess smooth root cut, or pipe smoothness and shall be verified by means of closed circuit television (CCTV) examination.

c. Removal of internal bead may include pipe wall mass. However, wall mass that is removed shall not exceed 1/10th of pipe wall thickness.]

4. If HDPE pipe surface temperature is above [_____] degrees F as measured with infrared temperature gun, allow pipe to cool prior to making any connections to flanges, existing pipeline systems, or structures.
5. Connect HDPE pipe to auxiliary equipment such as valves, pumps, tanks, and other piping systems with flanged connections as follows:
   a. Polyethylene flange adapter, thermally butt-fused to end of pipe. Flange "stub ends" are not allowed.
   b. [Convoluted backing flange, as specified.]
   c. Bolt and nut of sufficient length to show a minimum of three complete threads when joint is made and tightened to manufacturer's standard.
   d. Follow requirements of PPI Technical Note 38 including mandatory 4-hour bolt re-torquing.
6. Special Precautions at Flanges: Support polyethylene pipe connected to heavy fittings, manholes, and rigid structures in such a manner that no subsequent relative movement between polyethylene pipe at flanged joint and rigid structures is possible.
7. Minimum Long-Term Field Bending Radius: Restricted to limits recommended by AWWA M55, Table 8-2.

B. Placement in Trench:

1. Handle joined pipeline in such a manner that pipe is not damaged by dragging it over sharp and cutting objects.
2. Position slings for handling pipeline away from butt-fused joints.
3. Remove sections of damaged pipe and replace it with undamaged pipe. Damaged pipe is defined as pipe with kinks or gouges exceeding 10 percent of pipe wall thickness.
4. Exercise care when lowering pipe into trench to prevent damage or twisting of pipe.
5. [Snake pipe from one side of trench to other to allow for thermal and settling movements, and as recommended by pipe manufacturer.]
6. At flanges, valves, and connections, excavate out trench bottom sufficiently to ensure clearance between undisturbed trench bottom and flange, valve, or connection.

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3.02 FIELD QUALITY CONTROL

A. Joint Fusion:

1. Measure and log each joint fusion by an electronic monitoring device (data logger) affixed to fusion machine, and shall be capable of being retrieved electronically. Data to be logged shall include the following:
   a. Pipe size and dimensions.
   b. Machine model and size.
   c. Operator identification.
   d. Job identification number.
   e. Weld number.
   f. Fusion, heating, and drag pressure settings.
   g. Heater plate temperature.
   h. Time stamp showing when weld was performed.
   i. Heating and curing time of weld.
   j. Curing temperature readings and time stamps of readings.
   k. Error messages and warnings for out of range temperature or pressure settings.
2. In addition to logged items above, the following shall be logged or annotated on report:
   a. Location of joint being fused by pipeline station or by reference to pipe Shop Drawing.
   b. Ambient temperature and humidity.
   c. If internal bead was removed.

B. Joint Weld Testing:

1. Test Procedure: ASTM D638.
2. Specimens: Cut pipe 12 inches on each side of field made joint. Rejoin ends and proceed with Work.
3. Test Frequency:
   a. First [1,000] [_____] Linear Feet: [Two] [_____] joints selected at random by ENGINEER.
   b. Each Additional [5,000] [_____] Linear Feet: [One] [_____] joint selected at random by ENGINEER.
   c. Each Test Failure: [Two] [_____] additional joints selected at random by ENGINEER.

C. Pipeline Hydrostatic Test:

1. General:

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a. Notify ENGINEER in writing [5] [_____] days in advance of testing. Perform testing in presence of ENGINEER.
b. Furnish testing equipment and perform tests in manner satisfactory to ENGINEER. Testing equipment shall provide observable and accurate measurements of initial service leak and allowable make-up water volume under specified conditions.
c. Test newly installed pipelines.
d. Isolate new pipelines that are connected to existing pipelines.
e. Using water as test medium, pipes shall successfully pass a hydrostatic test prior to acceptance.
f. Conduct field hydrostatic test on buried piping after trench has been completely backfilled. Testing may, as approved by ENGINEER, be done prior to placement of asphaltic concrete or roadway structural section.
g. CONTRACTOR may, if field conditions permit and as determined by ENGINEER, partially backfill trench and leave joints open for inspection and conduct initial service leak test. Final field hydrostatic test shall not be conducted until backfilling has been completed as specified above.
h. Supply of temporary water shall be as stated in Section 01 50 00, Temporary Facilities and Controls.
i. Dispose of water used in testing in accordance with federal, state, and local requirements.

2. Preparation:
   a. Install temporary thrust blocking or other restraint as necessary to prevent movement of pipe and protect adjacent piping or equipment. Make necessary taps in piping prior to testing.
   b. Wait [5] [_____] days minimum after concrete thrust blocking or designed thrust collars are installed to perform pressure tests. If high-early strength cement is used for thrust blocking, wait may be reduced to [2] [_____] days.
   c. Prior to test, remove or suitably isolate appurtenant instruments or devices that could be damaged by pressure testing.
   d. New Piping Connected to Existing Piping: Isolate new piping with grooved-end pipe caps, blind flanges, or other means as acceptable to ENGINEER.
3. Procedure:
   a. Test pressure shall be [150 percent] [_____] of system operating pressure based on pressure as measured at [lowest point in pipeline] [_____].

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b. Test pressure shall be [100] [_____] psi above system operating pressure, [but in no case less than] [_____] psi as measured at [_____].
c. Test pressure shall be [_____] [psi] [feet of head] as measured at [low point of pipeline] [_____].
d. Maximum filling velocity shall not exceed [0.25 feet per second] [_____], calculated based on full area of the pipe.
e. Expel air from pipe system during filling.
f. Test procedure shall be in accordance with ASTM F2164.
    1) Initial Expansion Phase: Add water as required to maintain test pressure for 4 hours.
    2) Test Phase: Reduce pressure by 10 psi and start pressure test.
    3) Test is successful if pressure says within 5 percent of initial value for 1 hour.
g. If test is not completed because of leakage, equipment failure, or other reasons, depressurize test section and allow it to relax for at least 8 hours before retesting.
h. If there is leakage, repair defective pipe section and repeat hydrostatic test.

3.03 MANUFACTURER'S SERVICES

A. Provide pipe manufacturer's representative at Site [in accordance with Section 01 43 33, Manufacturers' Field Services,] for assistance during pipe joining operations and pipe installation.

END OF SECTION

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SECTION 33 05 13
MANHOLES

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards that may be referenced in this section:

1. American Association of State Highway and Transportation Officials (AASHTO): M198, Standard Specification for Joints for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed Flexible Joint Sealants.
2. ASTM International (ASTM):
   a. A36/A36M, Standard Specification for Carbon Structural Steel.
   b. A48/A48M, Standard Specification for Gray Iron Castings.
   c. A123/A123M, Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
   d. A536, Standard Specification for Ductile Iron Castings.
   e. A615/A615M, Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement.
   f. B139/B139M, Standard Specification for Phosphor Bronze Rod, Bar, and Shapes.
   g. C14, Standard Specification for Nonreinforced Concrete Sewer, Storm Drain, and Culvert Pipe.
   h. C31/C31M, Standard Practice for Making and Curing Concrete Test Specimens in the Field.
   i. C39/C39M, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.
   j. C150/C150M, Standard Specification for Portland Cement.
   k. C192/C192M, Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory.
   l. C387/C387M, Standard Specification for Packaged, Dry, Combined Materials for Mortar and Concrete.
   m. C443, Standard Specification for Joints for Concrete Pipe and Manholes Using Rubber Gaskets.
   n. C478, Standard Specification for Precast Reinforced Concrete Manhole Sections.
   o. C923, Standard Specification for Resilient Connectors Between Reinforced Concrete Manhole Structures, Pipes, and Laterals.

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p. C990, Standard Specification for Joints in Concrete Pipe, Manholes, and Precast Box Sections using Preformed Flexible Joint Sealants.
q. C1311, Standard Specification for Solvent Release Sealants.
r. C1244, Standard Test Method for Concrete Sewer Manholes by the Negative Air Pressure (Vacuum) Test Prior to Backfill.
s. D698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft3 (600 kN-m/m3)).
t. D4101, Standard Specification for Propylene Injection and Extrusion Materials.
u. F593, Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs.
v. F594, Standard Specification for Stainless Steel Nuts.

1.02 SUBMITTALS

A. Action Submittals:

1. Shop Drawings including details of construction, reinforcing and joints, anchors, lifting, [external straps], erection inserts, and other items cast into members.
2. Product Data:
   a. Concrete mix design.
   b. Manhole frame to structure seals.
   c. Manhole frame to structure anchor bolt.
   d. Rubber gaskets and sealants.
   e. External joint wrap.

B. Informational Submittals:

1. Experience Record:
   a. Precast concrete production capabilities.
   b. Evidence of current PCI plant certification.
2. [Calculations: Proposed details and design calculations for stresses in precast concrete members for loading conditions including earth pressures and transportation, handling, and erection. Calculations shall be stamped by engineer registered in the same state as the Project.]
3. Certificate of Compliance: Certify admixtures and concrete do not contain calcium chloride.
4. Test Reports:
   a. Precast manufacturer’s concrete test cylinders.
   b. [Core compression test.]

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c. [Absorption test.]
5. [Certified load test data for precast manhole steps.]
6. Manufacturer's recommended installation instructions.
7. Field quality control report.

1.03 QUALITY ASSURANCE

A. Manufacturer Qualifications:

1. Precast Concrete and Precast Prestressed Concrete: Product of manufacturer with 3 years' experience producing precast concrete products of quality specified.
2. Precast Plant: PCI certified plant with current certification.

PART 2 - PRODUCTS

2.01 GENERAL

A. Materials of Construction and Service Conditions:

1. Screws, Bolts, or Nuts: Type 304 stainless steel conforming to ASTM F593 and ASTM F594.
2. Gaskets: Internal and external seals shall be made of materials that have been proven to be resistant to the following exposures and conditions:
   a. Sanitary sewage.
   b. Corrosion or rotting under wet or dry conditions.
   c. Gaseous environment in sanitary sewers and at road surfaces including common levels of ozone, carbon monoxide, and other trace gases at installation site.
   d. Biological environment in soils and sanitary sewers.
   e. Chemical attack by road salts, road oil, and common street spillages or solvents used in street construction or maintenance.
   f. Temperature ranges, variations, and gradients in construction area.
   g. Variations in moisture conditions and humidity.
   h. Fatigue failure caused by a minimum of 30 freeze-thaw cycles per year.
   i. Vibrations because of traffic loading.
   j. Fatigue failure because of repeated variations of tensile, compressive and shear stresses, and repeated elongation and compression. Material shall remain flexible allowing repeated movement.
3. Materials shall be compatible with each other and manhole materials.
4. Designed to provide a 20-year service life.

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B. Structures shall meet requirements of ASTM C478, this specification and the following:

1. Concrete:
   a. Cement: Meet requirements of ASTM C150/C150M.
   b. Compressive Strength:
      1) Minimum 4,000 psi.
      2) Minimum strength shall be confirmed at 7 days by making two standard cylinders per manhole for testing.
   c. [Concrete mix design shall include Xypex C-500 or C-1000 based upon mix design at dosage recommended by manufacturer for installation.]
2. Reinforcement: Grade 60, unless otherwise specified.
3. Ring: Custom made with openings to meet indicated pipe alignment conditions and invert elevations.
4. Floor: Minimum [_____] inches below pipe to provide clearance for grouting channels.
5. Joint:
   a. Form joint contact services with machined castings.
   b. Surfaces shall be parallel with nominal 1/16-inch clearing and tongue equipped with recess for installation of O-ring rubber gasket.
6. Gasket: Meet requirements of ASTM C443.

2.02 PRECAST MANHOLES

A. Riser Sections:

1. Fabricate in accordance with ASTM C478.
2. Diameter: Minimum [48] [_____] inches.
3. Wall Thickness: Minimum 4 inches or 1/12 times inside diameter, whichever is greater.
4. Top and bottom surfaces shall be parallel.
5. Joints: [Tongue-and-groove] [and] [confined O-ring with rubber gaskets meeting ASTM C443].

B. Cone Sections:

1. [Concentric.] [Eccentric.]
2. Same wall thickness and reinforcement as riser section.
3. Top and bottom surfaces shall be parallel.

C. Base Sections and Base Slab:

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1. Base slab integral with sidewalls.
2. Fabricate in accordance with ASTM C478.

D. Manhole Extensions:

1. Concrete grade rings; maximum 6 inches high.
2. Fabricate in accordance with ASTM C478.

E. Joint Seal Manufacturers and Products:

1. Butyl Gaskets:
   a. Hamilton Kent, Sparks, NV; Kent-Seal No. 2.
   b. Henry Company, Houston, TX; Ram-Nek.
   c. Trelleborg Engineered Solutions, Park Hills, MO; NPC Bidco C-56.
2. Confined Plastic or Rubber O-Ring:
   a. As recommended by precasting manufacturer.
   b. Meet requirements of ASTM C443.
3. External Wrap:
   a. Sealing Systems, Inc., Loretto, MN; Gator Wrap.
   b. Henry Company, Houston, TX; RU116 Rubr-Nek External Joint Wrap.
   c. Trelleborg Engineered Solutions, Park Hills, MO; NPC External Joint Wrap.
   d. Cretex Specialty Products, Waukesha, WI; Cretex Wrap.

F. [Galvanized Steel Steps:

1. Fabricate from minimum 3/4-inch steel bar meeting ASTM A36/A36M.
2. Minimum Width: 12 inches, center-to-center of legs, drop pattern with 2-inch drop and 2-inch hook on embedment end.
3. Bends: 1-inch radius minimum, 2-inch radius maximum.
4. Embedment: 3-inch minimum and 4-1/2-inch minimum projection from face of concrete at point of embedment to center of step.
5. Galvanize after bending to meet ASTM A123/A123M.
6. Cast in manhole sections by manufacturer.
7. Load Test: Capable of withstanding ASTM C478 vertical and horizontal load tests.]

G. [Polypropylene Steps:

1. Fabricate from minimum 1/2 inch, Grade 60, steel bar meeting ASTM A615/A615M.
2. Polypropylene encasement shall conform to ASTM D4101.

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3. Minimum Width: 13 inches, center-to-center of legs.
4. Embedment: 3-1/2-inch minimum and 4-1/2-inch minimum projection from face of concrete at point of embedment to center of step.
5. Cast in manhole sections by manufacturer.
6. Load Test: Capable of withstanding ASTM C478 vertical and horizontal load tests.]

2.03 CAST-IN-PLACE MANHOLES

A. Concrete: As specified in Section 03 30 00, Cast-in-Place Concrete.

B. Reinforcing Steel: As specified in Section 03 21 00, Reinforcing Steel.

2.04 MANHOLE FRAMES AND COVER

A. Castings:

1. Tough, close-grained gray iron, sound, smooth, clean, free from blisters, blowholes, shrinkage, cold shuts, and defects.
2. Cast Iron: ASTM A48/A48M Class [30B] [35B].
3. Ductile Iron: ASTM A536, Grade 60-40-12.
4. Plane or grind bearing surfaces to ensure flat, true surfaces.

B. Cover: [OWNER's Standard.] [See Detail _____.] [True and seat within ring at all points.] [With the word [SEWER] [DRAIN] in 2-inch raised letters.]

C. [Capscrews for [Watertight] [Tamper-Proof] Covers: High temper phosphor bronze with 60,000 psi minimum tensile strength meeting ASTM B139/B139M.]

D. [Watertight Cover Gasket: Molded from high-quality rubber such as nitrile or EPDM.]

2.05 MANHOLE FRAME CONNECTION TO STRUCTURE

A. Butyl Sealant:

1. Conform to ASTM C1311, or AASHTO M198 and ASTM C990.
2. Trowelable or cartridge applied.
3. Manufacturers and Products:
   a. Tremco Commercial Sealants and Waterproofing, Beachwood, OH; Tremco Butyl Sealant.
   b. Bostik, Middleton, MA; Chem-Calk 300.
   c. Press-Seal Gasket Company, Fort Wayne, IN; EZ-Stik #3.

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B. External Wrap:

1. Meet requirements of ASTM C923.
2. Construct of high quality rubber that will provide flexible watertight seal around joint.
3. Thickness: Minimum 60 mils.
4. Consist of a top and bottom section and be sealed to structure, frame top, and bottom with mastic as applicable.
5. Length: Extend from manhole frame and extension ring to cone section.
6. Bands: If required, constructed of minimum 16-gauge sheet if channeled, or 5/16-inch diameter if round.
7. Manufacturers and Products:
   a. Sealing Systems, Inc., Loretto, MN; Infi-Shield.
   b. Trelleborg Engineered Systems, Milford, NH; NPC Flexrib Frame-Chimney Seals.
   c. Cretex Specialty Products, Waukesha, WI; X-85 Seal.

C. Internal Wrap or Sealing Membrane:

1. Meet requirements of ASTM C923.
2. Minimum internal thickness of 3/16 inch or as recommended by manufacturer for installation climate.
3. Designed for application and have a demonstrated history of accommodating differential expansion between frame and concrete.
4. Width: Minimum 8 inches.
5. Expansive type wraps shall be fabricated of high quality rubber or urethane.
6. Bands: If required, constructed of minimum 16-gauge sheet if channeled, or 5/16-inch diameter if round.
7. Wrap shall not restrict access to manhole.
8. Manufacturers and Products:
   a. Sealing Systems, Inc., Loretto, MN; Flex-Seal Utility Sealant.
   b. Trelleborg Engineered Systems, Milford, NH; NPC Flexrib Frame-Chimney Seals.
   c. Cretex Specialty Products, Waukesha, WI; Internal Manhole Chimney Seal.

D. Frame to Structure Anchor Bolts:

1. 3/4-inch-diameter HAS stainless steel bolts; minimum 6-5/8-inch embedment.
2. Manufacturer and Product: Hilti; HVA Capsules Adhesive Anchoring System.

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2.06 [MONOLITHIC LINER

A. As specified in Section _____.]

2.07 MORTAR

A. Standard premixed in accordance with ASTM C387/C387M, or proportion one part Portland cement to two parts clean, well-graded sand that will pass a 1/8-inch screen.

B. Admixtures: May be included; do not exceed the following percentages of weight of cement:

1. Hydrated Lime: 10 percent.
2. Diatomaceous Earth or Other Inert Material: 5 percent.

C. Mix Consistency:

1. Tongue-and-Groove Type Joint: Such that mortar will readily adhere to pipe.
2. Confined Groove (Keylock) Joint: Such that excess mortar will be forced out of groove and support is not provided for section being placed.

2.08 BACKFILL AROUND AND UNDER MANHOLE

A. [Structural fill as specified in Section 31 23 23, Fill and Backfill.]

B. [One-inch-minus rock or sand free from dirt, clay balls, and organic material.]

2.09 MANHOLE MARKER POSTS

A. Size and Type: 4 inches by 4 inches by 8 feet, pressure-treated construction Grade or better rated for direct burial.

B. Prime top (exposed) 3 feet 8 inches, followed by two coats of safety orange enamel.

1. Primer: Tnemec; Series 36 Undercoater.
2. Enamel: Tnemec; Series 2H Tnemec Gloss.

C. Lettering:

1. Stencil letters [_____] on all sides of each post.
2. Letters: Black enamel, 2 inches high.

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2.10 FLEXIBLE JOINTS FOR SEALING PIPES IN MANHOLE

A. Manufacturers and Products:

1. NPC, Inc., Milford, New Hampshire; Kor-N-Seal flexible rubber boot with stainless steel accessories.
2. A-LOK Products, Inc., Tullytown, PA; Z-LOK XP or A-LOK flexible connectors.

B. [Doghouse Manhole/Manhole Over Existing Pipe (where use of a boot is not possible):

1. Green Streak; hydrophilic waterstop CJ-0725-3k.]

2.11 SOURCE QUALITY CONTROL

A. Prior to delivery of precast manhole sections to Site, yard permeability tests may be required at point of manufacture. ENGINEER or OWNER will select precast sections [not to exceed [5] [_____] percent of the total project quantity] to test from material which is to be supplied to Project. Test specimens shall be mat tested and meet permeability test requirements of ASTM C14.

B. Concrete Testing: Test two concrete test cylinders for each manhole. Compressive strength shall be tested in accordance with ASTM C31/C31M, ASTM C39/C39M, and ASTM C192/C192M.

C. Inspection:

1. Material Quality:
   a. Manufacturing process and finished sections shall be subject to inspection and approval by OWNER and ENGINEER.
      1) Inspections may take place at manufacturer's plant, at Site after delivery, or at both.
      2) Sections not meeting requirements of this Specification or that are determined to have defects which may affect durability of structure are subject to rejection.
      3) Sections rejected after delivery shall be removed and replaced.
      4) Sections damaged after delivery will be rejected and if already installed shall be repaired to satisfaction of OWNER and ENGINEER.
      5) If structure cannot be repaired it shall be removed and replaced entirely at CONTRACTOR's expense.

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2. At the time of inspection the sections will be carefully examined for compliance with ASTM C478 and with manufacturer's drawings. Sections will be inspected for general appearance, dimensions, scratch strength, blisters, cracks, roughness, and soundness. Surface shall be dense and close textured.
3. Imperfections may be repaired, subject to approval of ENGINEER, after demonstration by manufacturer that strong and permanent repairs result.

PART 3- EXECUTION

3.01 GENERAL

A. Prior to installation inspect materials:

1. Sections not meeting requirements of this specification or that are determined to have defects which may affect durability of structure are subject to rejection.
2. Sections damaged after delivery will be rejected and if already installed shall be repaired to satisfaction of OWNER and ENGINEER.
3. Remove and replace structure that cannot be repaired.

B. If needed, dewater excavation during construction and testing operations.

3.02 EXCAVATION AND BACKFILL

A. Excavation: As specified in Section 31 23 16, Excavation.

B. Backfill:

1. [As specified in Section 31 23 23, Fill and Backfill.]
2. [Place structural fill under manhole in 6-inch maximum lifts; minimum of 12 inches unless otherwise specified on Drawings. Compact each lift to 98 percent relative compaction as determined in accordance with ASTM D698.]
3. [Backfill around structure with earth fill to lines and grades shown; allow for topsoil thickness where shown. Place in 8-inch thick maximum lifts. Compact each lift to 92 percent relative compaction as determined in accordance with ASTM D698.]

3.03 INSTALLATION OF PRECAST MANHOLES

A. Concrete Base:

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1. Precast:
   a. Place on compacted structural fill.
   b. Properly locate, ensure firm bearing throughout, and plumb first section.
2. Cast-in-Place:
   a. Invert: Minimum 8 inches below lowest connecting pipe.
   b. First section of manhole shall be cast in concrete base.

B. Sections:

1. Inspect precast manhole sections to be joined.
2. Clean ends of sections to be joined.
3. Do not use sections with chips or cracks in tongue.
4. [Locate precast steps in line with each other to provide continuous vertical ladder.]

C. Preformed Plastic Gaskets or Rubber O-Ring:

1. Use only pipe primer furnished by gasket manufacturer.
2. Install gasket material in accordance with manufacturer's instructions.
3. Completed Manhole: Rigid and watertight.

D. [Mortar Joints:

1. Thoroughly wet joint with water prior to placing mortar.
2. Place mortar on groove of lower section prior to section installation.
3. Fill joint completely with mortar of proper consistency.
4. Trowel interior and exterior surfaces smooth on standard tongue-and-groove joint.
5. Prevent mortar from drying out and cure by applying approved curing compound or comparable approved method.
6. Do not use mortar mixed for longer than 30 minutes.
7. Chip out and replace cracked or defective mortar.
8. Completed Manhole: Rigid and watertight.]

E. External Joint Wraps: Install in accordance with manufacturer's instructions.

F. Extensions:

1. Provide on manholes in streets or other locations where change in existing grade may be likely.
2. Install to height not exceeding 12 inches.
3. Lay grade rings in mortar with sides plumb and tops level.

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4. Seal joints with mortar as specified for sections and make watertight.

3.04 MANHOLE INVERT

A. Construct with smooth transitions to ensure unobstructed flow through manhole. Remove sharp edges or rough sections that tend to obstruct flow.

B. Where full section of pipe is laid through manhole, break out top section and cover exposed edge of pipe completely with mortar. Trowel mortar surfaces smooth.

3.05 MANHOLE FRAMES AND COVERS

A. Install concrete grade rings as required to set covers flush with surface of adjoining pavement or ground surface, unless otherwise shown or directed.

B. Set frames in three equally spaced beads of butyl sealant that run full circumference of frame.

C. Anchor frame to manhole with specified bolts.

D. Install [exterior] [interior] manhole frame to structure seals in accordance with manufacturer's instructions. Seal shall cover grade rings.

3.06 WATERTIGHT MANHOLES

A. [Unless otherwise noted, manholes covers shall be bolted down with sealing gasket.]

B. [Install frame fasteners at [following locations:]

1. [_____]
2. [_____]

3.07 CAST-IN-PLACE MANHOLE

A. Concrete: As specified in Section 03 30 00, Cast-in-Place Concrete.

B. Reinforcing Steel: As specified in Section 03 21 00, Reinforcing Steel.

C. [Steps:

1. Install manhole steps at 16 inches on center, plus or minus 1/4-inch tolerance, and locate to provide a continuous vertical ladder.

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2. Do not vary spacing between any two adjacent steps by more than 1/2 inch.
3. Distance between wall of manhole and center of rung, measured at point of embedment, shall be not less than 4 inches or more than 6-1/4 inches.]
4. [Testing:
    a. Test each step for a horizontal pullout load of 400 pounds with load applied over a width of 3-1/2 inches and centered on rung.
    b. Apply load at a uniform rate until required test load is reached.
    c. Provide suitable hydraulic jacks and gauges to perform test.
    d. Steps will be considered acceptable if they remain solidly embedded after application of test load and if no cracking or fracture of step nor spalling of concrete, masonry, or mortar is evident.
    e. Replace, or reset and retest, steps failing to withstand required load.]

3.08 MANHOLE PIPING

A. Drop Assembly: See Drawings for detail of installation requirements.

B. Flexible Joints:

1. Provide in pipe not more than 1-1/2 feet from manhole walls.
2. Where last joint of pipe is between 1-1/2 feet and 6 feet from manhole wall, provide flexible joint in manhole wall.

C. Stubouts for Future Connections:

1. Provide same type and class of pipe as specified for use in service connection, lateral, main, or trunk sewer construction. Where there are two different classes of pipe at manhole use higher strength pipe.
2. Grout pipe in precast walls or manhole base to provide watertight seal or use flexible joints as specified herein.
3. Maximum Length: 1-1/2 feet outside manhole wall.
4. Construct invert channels as shown. [Unless otherwise approved by ENGINEER, match inside top elevation of service connection pipe to inside top elevation of outlet pipe.]
5. Test Plugs:
    a. Install rubber-gasketed plugs in end of stubouts with gasket joints similar to sewer pipe being used.
    b. Plugs shall withstand internal or external pressures without leakage.
    c. Adequately brace plugs against hydrostatic or air test pressures.

D. Permanent Plugs: Clean interior contact surfaces of pipes to be cut off or abandoned as shown, and construct plug as follows:

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1. Pipe 18 Inches or Less in Diameter: Concrete plug in end, minimum 2 feet long.
2. Pipe 20 Inches and Larger: Concrete plug in end, minimum 4 feet long.
3. Plugs shall be watertight and capable of withstanding internal and external pressures without leakage.

3.09 MANHOLES OVER EXISTING PIPING

A. Maintain flow through existing pipelines at all times.

B. Concrete Pipe: Apply bonding agent on surfaces in contact with concrete.

C. Construct base under existing piping.

D. Construct manhole as detailed in Drawings.

E. Apply minimum of two complete wraps of hydrophilic waterstop centered on pipe in wall.

F. Place a minimum of 24 inches of concrete around each pipe penetration outside manhole against undisturbed soil or compacted aggregate unless otherwise detailed.

G. Grout channel through manhole.

H. Saw cut out or demolish existing pipe within new manhole using method approved by ENGINEER.

I. Protect new concrete or grout for 7 days after placing concrete.

3.10 CONNECTIONS TO EXISTING MANHOLES

A. Core manhole bases and grouting, as necessary.

B. Seal pipe in manhole using flexible connector.

C. Regrout to provide smooth flow into and through manholes.

D. Provide diversion facilities and perform work necessary to maintain flow during connection.

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3.11 FIELD QUALITY CONTROL

A. Conduct negative air pressure (vacuum) test on [all] [specified] [_____ percent of] manholes in accordance with ASTM C1244. [Conduct tests in presence of ENGINEER.]

B. Hydrostatic Testing:

1. When, in ENGINEER's opinion, groundwater table is too low to permit visual detection of infiltration leaks, hydrostatically test [up to 20 percent but in no case less than 10 percent of the total] [all] manholes.
2. Procedure: Plug inlets and outlets and fill manhole with water to height determined by ENGINEER.
3. Manhole may be filled 24 hours prior to time of testing, if desired, to permit normal absorption into pipe walls to take place.
4. Leakage in each manhole shall not exceed 0.1 gallon per hour per foot of head above invert.
5. Repair manholes that do not meet leakage test, or do not meet specified requirements from visual inspection.
6. If more than 25 percent of manholes tested fail the hydrostatic test, test all or as many manholes as ENGINEER deems necessary.

END OF SECTION

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SECTION 33 05 23.16
UTILITY PIPE JACKING

PART 1 GENERAL

1.01 WORK INCLUDED

A. This section covers installation of trenchless crossings under existing structures installed by conventional bore and jack method.

1.02 DEFINITIONS

A. Bore and Jack: Technique using an auger to bore a hole and jacks to advance casing pipe while removing spoil in casing via auger flighting, hand excavation with muck carts or conveyor belts, or other methods.

1.03 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Petroleum Institute (API): 5L, Specification for Line Pipe.
2. American Water Works Association (AWWA):
   a. C200, Steel Water Pipe - 6 in. (150 mm) and Larger.
   b. C210, Liquid-Epoxy Coating Systems for the Interior and Exterior of Steel Water Pipelines.
3. ASTM International (ASTM):
   a. A36/A36M, Standard Specification for Carbon Structural Steel.
   b. A139/A139M, Standard Specification for Electric-Fusion (Arc), Welded Steel Pipe (NPS 4 and Over).
   c. C76, Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe.
   d. C361, Standard Specification for Reinforced Concrete Low-Head Pressure Pipe.
   e. C497, Standard Test Methods for Concrete Pipe, Manhole Sections, or Tile.
   f. D3262, Standard Specification for “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer Pipe.
   g. Burlington Northern Santa Fe (BNSF) Railroad – Utility Accommodation Manual.
   h. American Railway Engineering and Maintenance of Way Association (AREMA)

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1.04 DESIGN CRITERIA

A. Design shaft excavation support systems to withstand lateral earth pressures, ground loads, unrelieved hydrostatic pressures, bottom heave, equipment loads, applicable traffic and construction loads, and other surcharge loads to allow safe construction of shafts without appreciable movement or settlement of ground, and to prevent damage to or movement of adjacent structures, streets, utilities and trees.

B. Design excavation support systems and casing installation equipment to be compatible with geologic conditions.

C. All crossings of railroad trackage shall be designed to carry Cooper's E-80 Railroad live loading with diesel impact AREMA Cooper's loading Section 8-2-8.

D. Vertical deflection clearance of the casing pipe shall be 3 percent of its diameter plus 1/2 inch so that no loads from the roadbed, track, railroad traffic or casing pipe are transmitted to the carrier pipe.

1.05 SUBMITTALS

A. Action Submittals:

1. Casing pipe material including the standard to which it is manufactured, outside diameter, wall thickness, and joint configuration.
2. Details of casing spacers, including recommended spacing.
3. Details of end seals.
4. Boring and jacking plan.

B. Informational Submittals:

1. Documentation that contractor performing the Work in this section has experience required below.

1.06 QUALITY ASSURANCE

A. Design Professional: Submittals for facilities requiring structural design shall be signed and stamped by a registered professional civil or structural engineer.

B. Qualifications: Bore and jack operations shall be performed by a qualified Contractor with at least 5 years of experience involving work of a similar nature.

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PART 2 - PRODUCTS

2.01 STEEL CASING PIPE

A. Fabricated in sections in accordance with AWWA C200 with a minimum yield strength of 35,000 lbs psi.

B. Hydrostatic testing of steel pipe used for casings is not required.

C. Exterior coating or interior lining is optional. Casing pipe shall be cathodically protected.

D. Pipe ends shall be beveled for welding.

E. Shall be suitably insulated from underground conduits carrying electric wires on railroad property.

2.02 CARRIER PIPE

A. Carrier pipe shall conform to Section 33 05 01.10, HDPE Pressure Pipe.

B. Emergency shutoff valves shall be installed within effective distances, and outside of railroad right-of-way and/or highway on each side of the crossing.

C. Markers shall be placed at each right-of-way line identifying utilities crossing railroad or highway property. 6-inch-wide warning tape shall be used.

2.03 GROUT FOR FILLING VOIDS OUTSIDE CASING

A. Neat cement grout with a minimum 2 sacks of cement pcy.

2.04 FILL MATERIAL FOR ANNULAR SPACE BETWEEN CASING PIPE AND CARRIER PIPE

A. Clean, washed sand, suitable for blowing into annular space between casing pipe and carrier.

2.05 CASING SPACERS

A. Fabrication:

1. Spacer Band Material: Polyethylene.
2. Spacer Width: 12 inches.
3. Spacer Runners:
   a. Suitable for supporting weight of carrier pipe.

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b. Manufactured of material having a low coefficient of friction and designed to support the carrier pipe without damage or excessive wear.

4. Size: Sufficient to provide a minimum clearance of 1 inch between outside of carrier pipe bells or couplings and inside of casing.

2.06 CASING END SEALS

A. Synthetic rubber, conical shape, pull-on or wrap-around style with Type 304 stainless steel bands.

B. Manufacturers:

1. Pipeline Seal and Insulator, Inc. (PSI), Houston, TX.
2. Advance Products and Systems, Inc., Lafayette, LA.
3. Cascade Waterworks Mfg. Co., Yorkville, IL.

PART 3 - EXECUTION

3.01 EXISTING UTILITIES

A. Confirm location of all known existing utilities prior to start of shaft/pit excavation and pipe installation.

3.02 SHAFT/PIT INSTALLATION

A. Notify ENGINEER not less than 5 working days before beginning shaft excavation.

B. Methods of construction for shafts/pits shall be such as to ensure the safety of the Work, Contractor's employees, the public, existing utilities, and adjacent property and improvements, whether public or private.

C. Before beginning construction of shaft/pit, adequately protect existing structures, utilities, trees, shrubs, and other existing facilities.

D. Provide complete groundwater control for excavations at all times in accordance with Section 31 23 19.01, Dewatering.

E. Perform shaft/pit excavations using appropriate excavation or large hole drilling methods, as required.

F. Place fencing, gates, lights, and signs, as necessary around shafts and staging areas to provide for public safety.

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G. Inspect shaft/pit excavations daily to check safety of excavation and structural integrity of support system.

H. Jacking or boring pits must be placed a minimum of 30 feet from the traveled roadway. Jacking or boring pits may be allowed less than 30 feet from the traveled roadway under the following restrictions:

1. Protected by guardrail, temporary concrete barrier or other ADOT approved barrier.
2. Fenced to preclude public access.
3. Work vehicles and equipment are restricted to the fenced area.
4. Pit is located outside the pavement structure.
5. Access to the pits cannot be made from the traveled roadway.

I. Jacking or boring pits must be kept to the minimum size necessary and placed at a minimum of 30 feet from the centerline of railroad tracks or no closer than the toe of slope for fill sections.

3.03 EQUIPMENT SELECTION

A. Select necessary equipment and methods to install casing and carrier pipe as shown on Drawings. Selected equipment shall be capable of accurate alignment and grade control, and shall protect against subsidence or other disturbance of ground, existing utilities, and existing structures.

3.04 LUBRICATION OF CASING EXTERIOR

A. Bentonite slurry, minimum of 0.2 lbs per gallon concentration of bentonite clay, may be used to lubricate exterior of casing during installation. Drilling system shall not deposit more than 1 part drilling fluid per 1 part soil excavated (by volume) to prevent erosion and/or saturation of the soil.

3.05 CASING INSTALLATION—BORE AND JACK METHOD

A. Verify casing pipe minimum wall thickness is adequate for anticipated jacking loads.

B. Diameter of hole shall not exceed outside diameter of casing pipe by more than 1 inch.

C. Where unstable soil conditions are found to exist, boring operations shall be conducted in a manner that will not be detrimental to the facility being crossed.

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D. Tolerance shall be as follows:

1. Line Tolerance: 2 inches, maximum.
2. Grade Tolerance 2 inches, maximum.

E. Provide means of checking line and grade at least once a day to confirm allowable tolerance has been achieved.

F. Rail elevations over the work must be monitored at intervals prescribed by the railroad (Burlington Northern Santa Fe) to detect any track movement. Movement of over 1/4 inch vertically shall be immediately reported to the BNSF Roadmaster as it may be necessary to resurface the track.

G. If necessary to abandon a bored hole, remedial measures shall be taken by CONTRACTOR, subject to review by ENGINEER and approval of Owner of facility being crossed.

3.06 STEEL PIPE CASING WELDED JOINTS

A. Welds shall be continuous, complete joint penetration (CJP) butt joint welds as required for rigid and watertight connections.

3.07 CORRECTION OF GRADE

A. If required grade tolerance has not been achieved, use one of the following methods to correct grade:

1. Place concrete or grout in invert of casing as required to achieve proper grade.
2. Use casing spacers of varying height.
3. Install rails inside casing that allows complete grout or sand encasement.

3.08 CARRIER PIPE INSTALLATION

A. Entire length of casing shall be installed complete before any carrier pipe is placed therein. Repair defects in casing pipe or leakage at joints.

B. Install casing spacers to each length of carrier pipe in such a manner that electrical continuity will not occur between casing pipe and carrier pipe. Spans between spacers shall be per casing spacer manufacturer’s recommendations.

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C. Check each joint makeup and pipe segment prior to pushing carrier pipe segments into casing.

3.09 CASING PIPE AND CARRIER PIPE ANNULAR SPACE

A. Fill annular space with sand using a Gunite or similar machine for blowing sand.

B. Provide a positive means of preventing collapse or flotation of carrier pipe.

3.10 REMOVAL OF SHAFT/PIT SUPPORT SYSTEM

A. Removal of support system shall be performed in a manner that will not disturb or harm adjacent construction or facilities.

B. Fill voids created by removal of support system with clean sand as approved by ENGINEER.

3.11 BACKFILLING OF SHAFTS/PITS

A. Seal shaft/pit opening and backfill at shafts when no longer required.

B. Backfill shall be as specified in Section 31 23 23.15, Trench Backfill.

END OF SECTION

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SECTION 33 12 16.29
AIR AND VACUUM RELEASE VALVE ASSEMBLIES

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Society of Mechanical Engineers (ASME):
   a. B16.1, Gray Iron Pipe Flanges and Flanged Fittings (Classes 25, 125, and 250).
   b. B36.10M, Welded and Seamless Wrought Steel Pipe.
   c. B36.19M, Stainless Steel Pipe.
   d. Boiler and Pressure Vessel Code.
2. American Water Works Association (AWWA):
   a. C209, Cold-Applied Tape Coatings for the Exterior of Special Sections, Connections, and Fittings for Steel Water Pipelines.
   b. C214, Tape Coating Systems for the Exterior of Steel Water Pipelines.
   c. C220, Stainless Steel Pipe, 4 In. (100 mm) and Larger.
   d. C500, Metal-Seated Gate Valves for Water Supply Service.
   e. C504, Rubber-Seated Butterfly Valves.
   f. C507, Ball Valves, 6 In. Through 48 In. (150 mm Through 1200 mm).
   g. C509, Resilient-Seated Gate Valves for Water Supply Service.
   h. C512, Air-Release, Air/Vacuum, and Combination Air Valves for Waterworks Service.
   i. C550, Protective Interior Coatings for Valves and Hydrants.
   j. C800, Underground Service Line Valves and Fittings.
3. ASTM International (ASTM):
   a. A53/A53M, Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless.
   b. B43, Standard Specification for Seamless Red Brass Pipe, Standard Sizes.
   c. C478, Standard Specification for Precast Reinforced Concrete Manhole Sections.
   d. D1785, Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120.
4. Environmental Protection Agency (EPA): Safe Drinking Water Act.

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1.02 SUBMITTALS

A. Action Submittals:

1. Product data sheets for make and model.
2. Complete catalog information, descriptive literature, specifications, and identification of materials of construction.
3. Maximum recommended test pressure; maximum and minimum recommended working pressures of air valves, isolation valves, flanges, connecting piping, and fittings.
4. Recommended seating materials for specified operating pressures.

B. Informational Submittals:

1. Manufacturers' Instructions:
   a. Installation and testing of products specified.
   b. Pipeline tapping and service saddle installation.
   c. [Instructions for maintaining and recharging carbon filter units including recommendations to reduce restrictions of airflow caused by the filter unit.]
2. Operation and maintenance data.
3. [Affidavit of Compliance in accordance with AWWA C512 stating valve and all materials used conform to applicable requirements of AWWA C512 and these Specifications, and tests specified have been performed and all requirements have been met.]
4. [Affidavit of Compliance that materials comply with the requirements of the EPA Safe Drinking Water Act and other federal, state, and local requirements.]

PART 2 - PRODUCTS

2.01 AIR VALVES

A. General:

1. Air release, air/vacuum, and combination air valves shall conform to AWWA C512.
2. Exterior of air valves shall be coated in accordance with Section 09 90 00, Painting and Coating.
3. Interior of air valves shall be coated in accordance with AWWA C550.
4. Air valves shall be factory tested [in accordance with AWWA C512] [, except test pressure shall be increased from 150 percent of working pressure to _____ percent of working pressure].

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5. Suitable for operating pressures between [_____] and [_____] psi.

B. Air and Vacuum Valve, Water Service, 1/2 Inch to 16 Inches:

1. Suitable for water service.
2. Automatically exhausts air during system filling and allows air to re-enter during draining or when vacuum occurs.
3. Air/water Inlet: [NPT.] [ASME B16.1 Class [125] [250] flange.] [_____]
4. Air Outlet: [NPT.] [Plain outlet with protective hood.] [Mushroom cap with bug screen.] [ASME B16.1 Class 125 flanged.]
5. Rated [150] [300] [_____] psi working pressure, cast iron, ductile iron, or steel body, cover with stainless steel float and trim.
6. [Equip 4 inch and larger with antislam device to throttle flow of water into air valve and prevent damage caused by rapid closure.]
7. Manufacturers and Products:
   a. APCO Valve and Primer Corp.; Series 140 or 150.
   b. Val-Matic Valve; Series 100.
   c. GA Industries; Figure [_____].

C. Air Release Valve, Water Service, 1/2 Inch to 6 Inches:

1. Suitable for water service, automatically exhausts small amounts of entrained air under pressure that accumulates in a system.
2. Air/water Inlet: [NPT.] [ASME B16.1 Class [125] [250] flange.] [_____]
3. Air Outlet: [NPT.] [_____]
4. Rated [150] [300] [_____] psi working pressure; cast iron, ductile iron, or steel body, cover with stainless steel float and trim.
5. Orifice diameter [_____] inches.
6. Manufacturers and Products:
   a. APCO Valve and Primer Corp.; Model [_____].
   b. Val-Matic Valve; Model [_____].
   c. GA Industries; Figure [_____].

D. Combination Air Valve, Water Service, 1 Inch to 16 Inches:

1. Suitable for water service.
2. Combines operating features of air and vacuum valve, and air release valve.
   a. Air and vacuum portion to automatically exhaust air during filling of system and allow air to re-enter during draining or when vacuum occurs.

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b. Air release portion to automatically exhaust entrained air that accumulates in system.

3. Single body or dual body
4. Air/water Inlet: [NPT.] [ASME B16.1 Class [125] [250] flange.] [_____]
5. Air Outlet: [NPT.] [Plain outlet with protective hood.] [Mushroom cap with bug screen.] [ASME B16.1 Class 125 flanged.]
6. Rated [150] [300] [_____] psi working pressure; cast iron, ductile iron, or steel body, cover with stainless steel float and trim.
7. [Equip 4 inch and larger with antislam device to throttle flow of water into air valve.]
8. Manufacturers and Products:
   a. APCO Valve and Primer Corp.; Series [_____].
   b. Val-Matic Valve; Series [_____].
   c. GA Industries; Figure [_____].
   d. Vent-O-Mat; Series RBX.

E. Sewage Air and Vacuum Valve 2 Inches to 14 Inches:

1. Suitable for sewage service.
2. Automatically exhausts air during system filling, and allows air to re-enter during draining or when vacuum occurs.
3. Air/water Inlet: [NPT.] [ASME B16.1 Class [125] [250] flange.] [_____]
4. Air Outlet: [NPT.] [Plain outlet with protective hood.]
5. Rated [150] [300] [_____] psi working pressure; cast iron, ductile iron, or steel body, cover with stainless steel float and trim.
6. [Equip 4 inch and larger with antislam device to throttle flow of water into air valve.]
7. [Fitted with blowoff valve, flushing valve with quick disconnect couplings, and a minimum [5] [_____] feet of hose with quick disconnect couplings to permit backflushing after installation without dismantling valve.]
8. Manufacturers and Products:
   a. APCO Valve and Primer Corp.; Series 401 SAVV.
   b. Val-Matic Valve; Model [_____].
   c. GA Industries; Figure [_____].

F. Sewage Air Release Valve 2 Inches to 4 Inches:

1. Suitable for sewage service.
2. Automatically exhausts entrained air that accumulates in system.

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3. Air/water inlet: [NPT.] [_____]
4. Air outlet: [NPT.] [_____]
5. Rated [150] [300] [_____] psi working pressure; cast iron, ductile iron, or steel body, cover with stainless steel float and trim.
6. [Fitted with blowoff valve, flushing valve with quick disconnect couplings, and a minimum [5] [_____] feet of hose with quick disconnect couplings to permit backflushing after installation without dismantling valve.]
7. Manufacturers and Products:
   a. APCO Valve and Primer Corp.; Series 400 SARV.
   b. Val-Matic Valve; Model [_____].
   c. GA Industries; Figure [_____].

G. Sewage Combination Air Valve 2 Inches to 14 Inches:

1. Suitable for sewage service.
2. Combines operating functions of air and vacuum valve, and an air release valve.
   a. Air and vacuum portion shall automatically exhaust air during filling of system and allow air to re-enter during draining or when vacuum occurs.
   b. Air release portion to automatically exhaust entrained air that accumulates in system.
3. Air/water Inlet: [NPT.] [ASME B16.1 Class [125] [250] flange.] [_____]
4. Air Outlet: [NPT.] [Plain outlet with protective hood.]
5. Rated [150] [300] [_____] psi working pressure; cast iron, ductile iron, or steel body, cover with stainless steel float and trim.
6. [Equip 4 inch and larger with antislam device to throttle flow of water into air valve.]
7. [Fitted with blowoff valve, flushing valve with quick disconnect couplings, and a minimum [5] [_____] feet of hose with quick disconnect couplings to permit backflushing after installation without dismantling valve.]
8. Manufacturers and Products:
   a. APCO Valve and Primer Corp.; Series 440 SCAV.
   b. Val-Matic Valve; Model [_____].
   c. GA Industries; Figure [_____].
   d. Vent-O-Mat; Series RGX.

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2.02 CONNECTION TO MAINLINE

A. Flanged Outlet or Fitting: Flange shall be [Class _____ in accordance with _____] [as required to match drilling pattern of adjoining valve and suitable for test pressure and working pressure].

B. Service Saddle:

1. Stainless steel double straps.
2. Body: Ductile iron, nylon, or epoxy coated.
3. Bolts and Nuts: Type 304 stainless steel.
4. Comply with applicable portions of AWWA C800.
5. Manufacturers and Products:
   a. Mueller; Series DR2S.
   b. Romac; Style 202S or 202N.

C. [For steel pipe, connection to mainline may be flanged or threaded. Make threaded connections with welded, forged fittings in accordance with ASME Boiler and Pressure Code.]

2.03 ISOLATION VALVES

A. Gate Valve 3 Inches and Larger:

1. Iron body, flanged joint ends, nonrising stem, O-ring sealed stuffing box, rated for minimum pressure of [250] [_____] psi.
2. Provide [2-inch operating nut] [handwheel operator].
3. [AWWA C500.] [AWWA C509.]

B. Globe Valve 2 Inches and Smaller:

1. All-bronze, screwed ends, union bonnet, inside screw, rising stem.
2. Rated for minimum pressure of [150] [_____] psi.

C. Corporation Stop:

1. AWWA C800 type, with ends suitable for adjoining pipe.
2. Rated for minimum pressure of [150] [_____] psi.

D. Butterfly Valve:

1. AWWA C504, flanged ends.
2. Rated for minimum pressure of [150] [250] psi.

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3. Provide [2-inch operating nut] [handwheel operator].

E. Ball Valve:

1. AWWA C507, flanged ends.
2. Rated for minimum pressure of [150] [250] [300] psi.
3. Provide [2-inch operating nut] [handwheel operator].

F. Ball Valve:

1. Threaded ends.
2. Rated for minimum pressure of [_____] psi.
3. Provide [insulated handle] [2-inch operating nut] [handwheel operator].

2.04 PIPING BETWEEN MAINLINE AND AIR VALVE [AND PIPING FOR AIR VENT]

A. [Steel pipe conforming to [Section 33 05 01.01, Welded Steel Pipe and Fittings] [ASME B36.10M] [ASTM A53/A53M], minimum wall thickness of [_____].] Coating shall [be tape coating in conformance with AWWA C209 and AWWA C214] [conform to Section 09 90 00, Painting and Coating]. Lining shall conform to Section 09 90 00, Painting and Coating.

B. [PVC pipe conforming to [ASTM D1785,] Schedule [40] [80].]

C. [Ductile iron pipe conforming to [Section 33 05 01.02, Ductile Iron Pipe and Fittings.] [_____]]

D. [Stainless steel pipe conforming to [AWWA C220] [ASTM B36.19].]

E. [Brass pipe conforming to ASTM B43.]

2.05 VALVE VAULT

A. [Precast concrete manhole with inside diameter of [_____] inches, conforming to ASTM C478 with cast or ductile iron frame and cover. Frame and cover shall be designed for [H-20] [_____] loading.]

B. [Precast concrete vault with minimum dimensions of [_____]. Lid shall be designed for [H-20] [_____] loading. Cover plates and frames shall be [spring assisted, galvanized diamond plate with locking latch.] [_____]]

2.06 ACCESSORIES

A. Insulation:

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1. Cellular polystyrene, [1] [2] inch(es) thick.
2. Manufacturer and Product: Dow Chemical Co.; Styrofoam.

B. Carbon Filter:

1. Granulated activated impregnated carbon, PVC housing.
2. Manufacturer and Product: Orenco Systems Inc.; Model CF.

C. Abovegrade Enclosures: [As shown on Drawings.] [Model [_____] as manufactured by Hot Box, Jacksonville, FL.]

PART 3 - EXECUTION

3.01 INSTALLATION

A. Valves:

1. In accordance with manufacturer's printed instructions.
2. Orient valve in vault with easy access to operator.
3. Replace valves that drip or do not function properly.

B. Service Saddle:

1. Tap and install in accordance with manufacturer's printed instructions.
2. Use adapters for size of line being tapped.

C. Valve Vault:

1. [Place off center [as shown on Drawings] for access to operators.]
2. Install so finished grade of top of vault [conforms to slope and elevation of adjacent ground] [is above adjacent ground] [_____].

D. Insulation:

1. Install within vault, above and around designated valve assemblies as required to protect valve from freezing.
2. Provide space for air passage to allow proper functioning of air valves.
3. Support insulation with clips anchored to manhole or vault wall.

E. Carbon Filter: Install in accordance with manufacturer's recommendations.

F. Pipe Support: Install in accordance with [details as shown on Drawings] [Section 40 05 15, Piping Support Systems].

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3.02 TESTING AND INSPECTION

A. Air Valve:

1. May be either tested while testing pipelines, or as a separate step.
2. Isolation valves shall be in open position during pipeline test.

B. Isolation Valves: Test that valves open and close smoothly with operating pressure on one side and atmospheric pressure on the other.

C. Air and Vacuum Valves: Inspect valves as pipe is being filled to verify venting and seating is fully functional.

D. Verify leak-free performance during testing.

END OF SECTION

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SECTION 33 16 13.14
FRAC TANKS

PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes: Design, manufacture, testing, and delivery, and installation of steel frac tanks complete with:

1. Supports.
2. Ground lugs.
3. Lifting lugs.
4. Piping and instrumentation connection.
5. Insulation support: clips; rings.
6. Storage.

B. Equipment and Services Not Provided by This Section:

1. Insulation.
2. Grounding connection.
3. Unloading and storage.
4. Installation.

C. Substitutions/Exceptions/Options

1. Note exceptions and advise of deviations, additions, deletions, or other changes recommended to meet specified requirements.
2. Deviations are permitted only if outlined in full detail. Written approval of those deviations, and reasons for them, will constitute acceptance.
3. State options in proposal.

D. Compliance: Mechanical design in compliance with this Section is responsibility of manufacturer.

1.02 SUBMITTALS

A. Comply with attached Submittal Data Sheet.

B. Submit detailed list of special tools and devices required to install, adjust, repair, test, or operate equipment. Identify and price separately items which are not provided with equipment.

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C. Submit design calculations which demonstrate conformance with requirements of code indicated on Equipment Data Sheet.

D. Submit details and cut sheet of manways with quote.

1.03 QUALITY ASSURANCE

A. Local Codes: Design and fabricate in accordance with state and local codes, ordinances.

B. Conflicting Requirements: If Section requires compliance with 2 or more industry standards which establish different or conflicting requirements, obtain approval before proceeding with affected operations.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Deliver, store, and handle equipment as follows:

1. Use methods which prevent damage, deterioration, and other loss during shipping and temporary on-site storage.
2. Plug, cap, or cover exposed openings with plywood or other suitable material.
3. Provide instructions for proper unpacking.

B. Deliver loose parts in boxed plywood containers and ship as a unit with equipment.

C. Identify shipping boxes by order number, Project name, Project location, equipment number, and description of contents. Use ink, paint, or other indelible material markings. Securely affix copy of completed packing list to each separate shipping package.

D. Inspect equipment when delivered to ensure equipment is undamaged and complies with specified requirements.

E. Store equipment in manner which facilitates inspection and measurement of quantity. Protect stored products from loss by exposure to rain, wind-driven dust, and other similar phenomena.

1.05 WARRANTY

A. Refer to Terms and Conditions attached to Inquiry. Warrant supplied equipment for **[**_____**]** months after shipment against defects in design and manufacturing.

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PART 2 – PRODUCTS

2.01 SOURCE QUALITY CONTROL

A. Comply with requirements, tests, inspections, reports, documentation, and approvals specified herein and standards implemented by this Section. Make available on request copy of any part of quality assurance records. Tests, inspections, reports, and documentation are subject to inspection.

B. Provide notification not less than 10 working days prior to start of fabrication.

C. Maintain records of inspections and tests. Indicate nature and number of deficiencies found, quantities approved and rejected, and nature of corrective actions taken. On request, supply copies of inspection and test data prior to or at time of shipment.

D. Provide notification not less than 5 working days prior to conducting inspection or testing required by this Section.

2.02 MATERIALS

A. Fabricate equipment using materials indicated on attached Equipment Data Sheet**s**.

2.03 EQUIPMENT

A. Fabricate vessels in accordance with code indicated on Equipment Data Sheet**s** and requirements of this Section.

B. Comply with specified code requirements, including certification.

C. Furnish vessels complete as shown on approved vessel Shop Drawings and include necessary bolts, nuts, gaskets, and internals and internal piping.

D. Furnish gaskets and external bolting for manholes and other openings which call for blind flange or cover. Use gasket material as specified on attached Equipment Data Sheet**s.**

E. Nozzle flanges to comply with ANSI B16.5 unless specified otherwise on attached Equipment Data Sheet**s.**

F. Trim vessel connections (not connected to internal piping) flush with inside surface of vessel unless specified otherwise on attached Equipment Data Sheet**[**s**].** Round exposed edges of manhole and nozzle necks at inside surface of vessel.

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G. Vessel tolerances as required by specified code.

2.04 DESIGN

A. Vessel, General:

1. Choose suitable thickness for vessel shells and heads per code.
2. Equip vessels with lifting lugs per attached Equipment Data Sheet**s.**

B. Corrosion Allowance:

1. Unless otherwise specified, corrosion allowance for carbon steel and low alloy steel is 1/16 inch.
2. Do not use corrosion resistant linings unless otherwise specified.
3. Add corrosion allowance to pressure containing parts, including shell, heads, nozzles, and manways.

C. Nozzles and Manholes:

1. Fabricated plate flanges may be used provided material specification, design calculations, and fabrication details are submitted and approved prior to fabrication.
2. Straddle flange bolt holes over natural vessel centerline.
3. Do not warp or otherwise damage forged flanges on tank nozzles during welding. Flange faces must remain true and flat in accordance with applicable ANSI codes.
4. Provide 6-inch minimum projection for connections, except for instrumentation nozzles.
5. Use lightweight vessel manhole covers. Equip manhole covers with open position stops.
6. Fabricate plate type flanges and manways true and flat so non-resilient gaskets may be used for sealing. Heat straighten or machine in shop warped flanges.
7. Employ stud and nuts, not machine bolts, for bolting supplied for nozzles and manway covers. Screw each stud into outer nut until 3 full threads are protruding.

D. Gaskets:

1. Size flat gaskets to fit inside flange bolt holes in accordance with ANSI B16.21.
2. Ship gaskets for blanked connections used in shop testing, where blind flanges are furnished in place.

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3. Make test gaskets for shop fabricated flanges and flanges larger than 18 inches same size, material, and type as those specified for operating conditions.

E. Bolting:

1. For special bolting requirements, refer to attached Equipment Data Sheet**[**s**]**.
2. Make stud extension for pad mounted flanges 1-1/2 times nut thickness with mating flange installed.
3. Supply attached studs, including bolts and nuts, for major flanged joints, manway covers, and other openings, except piping nozzles.

F. Loadings:

1. Design vessels to withstand effects of wind and earthquake loadings in accordance with requirements of specified code.
2. Comply with seismic and wind design listed in Equipment Data Sheets.
3. Include operating weight as weight due to maximum liquid height plug tank weight.
4. Unless specified otherwise, equate specific gravity of liquids with values specified on Equipment Data Sheet**s**.

2.05 FABRICATION/SHOP ASSEMBLY

A. Painting: Paint exposed carbon steel surfaces per manufacturer's standards.

B. Equipment Tagging: Comply with Tag Data Sheet.

C. Welding:

1. Round interior sharp edges and corners (on pipes and baffles).
2. Comply with specified code for welding.
3. Once vessel has been hydrotested, do not perform further welding without prior notification.
4. Major repairs resulting from material defects or manufacturing efforts must be approved before taking corrective action.

D. External Clips:

1. Furnish platform and ladder clips in accordance with attached Equipment Data Sheet**[**s**]**.
2. Drill at least 1/8-inch diameter vent hole in clip reinforcing pad welded to vessel.
3. Continuously weld internal and external clips.

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E. Insulation: Insulation not provided by this Section

2.06 CLEANING

A. Prior to shipping, perform final cleaning of internal and external surfaces after manufacturing and testing operations have been completed.

B. Cleaning procedures are manufacturer's responsibility.

PART 3 – EXECUTION

3.01 INSTALLATION

A. Not applicable. Equipment in this Section will not be received, unloaded, and installed by this Section.

3.02 ATTACHMENTS

A. The following attachments are part of this Section:

1. Equipment Data Sheet**s**.

END OF SECTION

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Project No.: 435062		By: Rolana Harris
Owner: PG&E		Date: 07-18-2012
		Equipment No.: TNK-401, TNK-402, TNK-403, TNK-404
	EQUIPMENT DATA SHEET	Equipment Name: Influent Storage Tank # 1, 2, 3, 4

DESCRIPTION

Service:	Groundwater	Working Volume:	*
Capacity:	21,000 gal	Size:	* (Note 1)

DESIGN CRITERIA

	Shell	Jacket	Coil
Type of Tank	Frac/Portable Tank		
Operating Pressure:	ATM psig	N/A psig	N/A psig
Operating Temp.:	86°F	N/A °F	N/A °F
Design Pressure:	<15 psig	N/A psig	N/A psig
Design Temperature:	130°F	N/A °F	N/A °F
Contents:	Groundwater	N/A	N/A
S.G. Contents:	1	N/A	N/A
Seismic Criteria:	See Note 2	N/A	N/A
Corrosion Allowance:	1/16"	N/A	N/A
Cathodic Protection:	No	N/A	N/A
Code:		N/A	N/A
Stamp:	☐ Yes ☒ No	☐ Yes ☐ No	☐ Yes ☐ No

COMPONENT	**MATERIAL**	**GENERAL**	
Shell:	CS	Weight:	*
Top Head:	CS - Flat/Closed		
Bottom Head:	CS - Sloped Bottom		
Jacket:	N/A		
Coil:			*
Baffles:	N/A	Painting, External:	*
Flanges:		Painting, Internal:	*
Internals:	See EDT-40X Datasheet		
Lining/Coating:	Yes		
Supports:		Tests:	Yes / No
Skirt:	N/A	Hydro	
Bolting:		Stress Relief	
Gaskets:		Rad'Graph	
Insulation:	N/A	Other:	
Insulation Cover:	N/A		
Lifting Lugs:			
Grounding Lugs:			
Handrail/Top Plate:	Yes, Handrail		
Ladders/Platforms:	Yes, for top access		
Rear Wheels:	Fixed Axle		

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Project No.: 435062		By: Rolana Harris
Owner: PG&E		Date: 07-18-2012
		Equipment No.: TNK-401, TNK-402, TNK-403, TNK-404
	EQUIPMENT DATA SHEET	Equipment Name: Influent Storage Tank # 1, 2, 3, 4

REMARKS

* - Manufacturer to provide information

1. Tank width to be 8feet wide.

2.Use CBC 2010, Site Class D - Seismic Design category: D - Ss = 0.434 - S1=0.135

3.Vendor to provide option for rental and purchase.

NOZZLES

Mark	Req'd	Size	Rating	Type	Face	Service	Note[s]
A1	1	2″	150#	RF	WN	Remedy Water – Main Process Inlet	Top
A2	1	2″	150#	RF	WN	25% Caustic	Top
A3	1	2″	150#	RF	WN	19% Hydrochloric Acid	Top
A4	1	2″	150#	RF	WN	Coagulant	Top
A5	1	2″	150#	RF	WN	Remedy Water/Slurry (Off-spec Return)	Top
A6	1	10″/3″	150#	RF	WN	Remedy Water	Bottom (1)
A7	1	10″/3″	150#	RF	WN	Remedy Water	Bottom (1)
A8	1	2″	150#	RF	WN	Remedy Water – pH Control	Top
B1	1	6″	150#	RF	WN	Remedy Water – Recirc. Out	Top
B2	1	2″	150#	RF	WN	Remedy Water - Top Tap	Side (2)
B3	1	2″	150#	RF	WN	Remedy Water- Bottom Tap	Side (2)
B4	1	2″	150#	RF	WN	Slurry	Bottom (3)
B5	1	3″	150#	RF	WN	Remedy Water - Overfill line	Top
DR	1	2″	150#	RF	WN	Drain	Bottom
L	1	3″	150#	RF	WN	Level Element	Top
M	1	22″	150#	RF	WN	Manway	Side
S	1	2″	150#	RF	WN	Spare	Top
V	1	3″	150#	RF	WN	Vent	Top

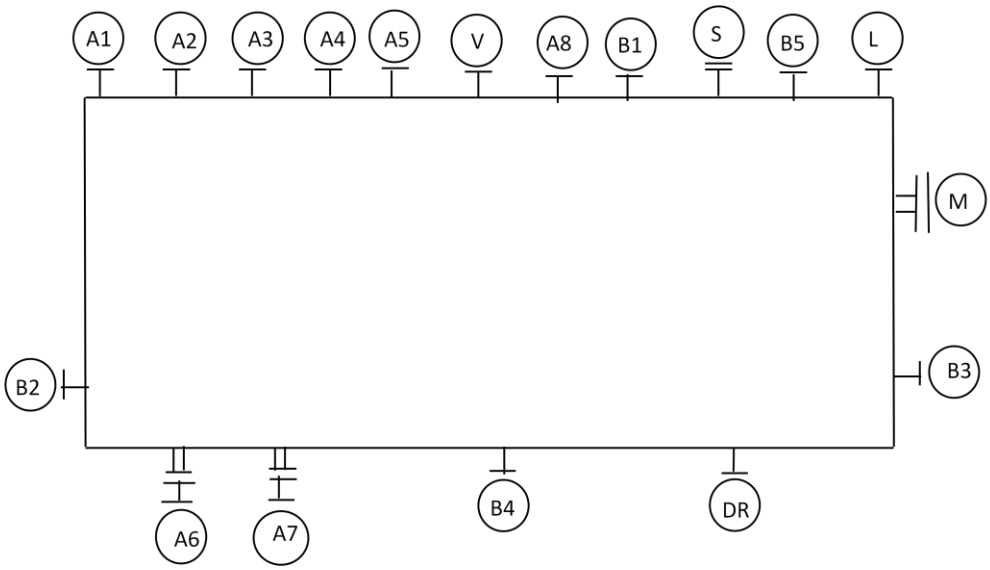
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Project No.: 435062		By: Rolana Harris
Owner: PG&E		Date: 07-18-2012
		Equipment No.: TNK-401, TNK-402, TNK-403, TNK-404
	EQUIPMENT DATA SHEET	Equipment Name: Influent Storage Tank # 1, 2, 3, 4

NOTE[S]
1. Recirculation inlet with eductor. Double nozzle 3″ and outer 10″for outboard eductor access. Eductors approximately 1′ from tank bottom on length of tank.
See Datasheet for EDT 401 through 404A/B for more detail and Drawing CH-M-XXX-01XXAD.dwg
2. Top tap, B2 located approximately 6′ from bottom and bottom tap, B3, located approximately 2′ from tank bottom.
3. Approximately 0.5′ from tank bottom.

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Project No.: 435062	CH2MHILL®	By: Rolana Harris
Owner: PG&E		Date: 07-18-2012
		Equipment No.: TNK-401, TNK-402, TNK-403, TNK-404
	EQUIPMENT DATA SHEET	Equipment Name: Influent Storage Tank # 1, 2, 3, 4



Issue:	Date:	Released for:	Approved:	Owner Approved:
IFR	07-18-2012			

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Project No.: 435062	CH2MHILL	By: Rolana Harris
Owner: PG&E		Date: 07-18-2012
		Equipment No.: TNK-701, TNK-702, TNK-703, TNK-704
	EQUIPMENT DATA SHEET	Equipment Name: Conditioned Water Storage Tank # 1, 2, 3, 4

DESCRIPTION

Service:	Groundwater	Working Volume:	*
Capacity:	21,000 gal	Size:	* (Note 1)

DESIGN CRITERIA

	Shell	Jacket	Coil
Type of Tank	Frac/Portable Tank		
Operating Pressure:	ATM psig	N/A psig	N/A psig
Operating Temp.:	86°F	N/A °F	N/A °F
Design Pressure:	<15 psig	N/A psig	N/A psig
Design Temperature:	130°F	N/A °F	N/A °F
Contents:	Treated Groundwater	N/A	N/A
S.G. Contents:	1	N/A	N/A
Seismic Criteria:	See Note 2	N/A	N/A
Corrosion Allowance:	1/16"	N/A	N/A
Cathodic Protection:	No	N/A	N/A
Code:		N/A	N/A
Stamp:	☐ Yes ☒ No	☐ Yes ☐ No	☐ Yes ☐ No

COMPONENT	**MATERIAL**	**GENERAL**	
Shell:	CS	Weight:	*
Top Head:	CS - Flat/Closed		
Bottom Head:	CS - Sloped Bottom		
Jacket:	N/A		
Coil:			*
Baffles:	N/A	Painting, External:	*
Flanges:		Painting, Internal:	*
Internals:	See EDT-40X Datasheet		
Lining/Coating:	Yes		
Supports:		Tests:	Yes / No
Skirt:	N/A	Hydro	
Bolting:		Stress Relief	
Gaskets:		Rad'Graph	
Insulation:	N/A	Other:	
Insulation Cover:	N/A		
Lifting Lugs:			
Grounding Lugs:			
Handrail/Top Plate:	Yes, Handrail		
Ladders/Platforms:	Yes, for top access		
Rear Wheels:	Fixed Axle		

REMARKS

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Project No.: 435062		By: Rolana Harris
Owner: PG&E		Date: 07-18-2012
		Equipment No.: TNK-401, TNK-402, TNK-403, TNK-404
	EQUIPMENT DATA SHEET	Equipment Name: Influent Storage Tank # 1, 2, 3, 4

* - Manufacturer to provide information
1. Tank width to be 8feet wide.
2.Use CBC 2010, Site Class D - Seismic Design category: D - Ss = 0.434 - S1=0.135
3.Vendor to provide option for rental and purpose.

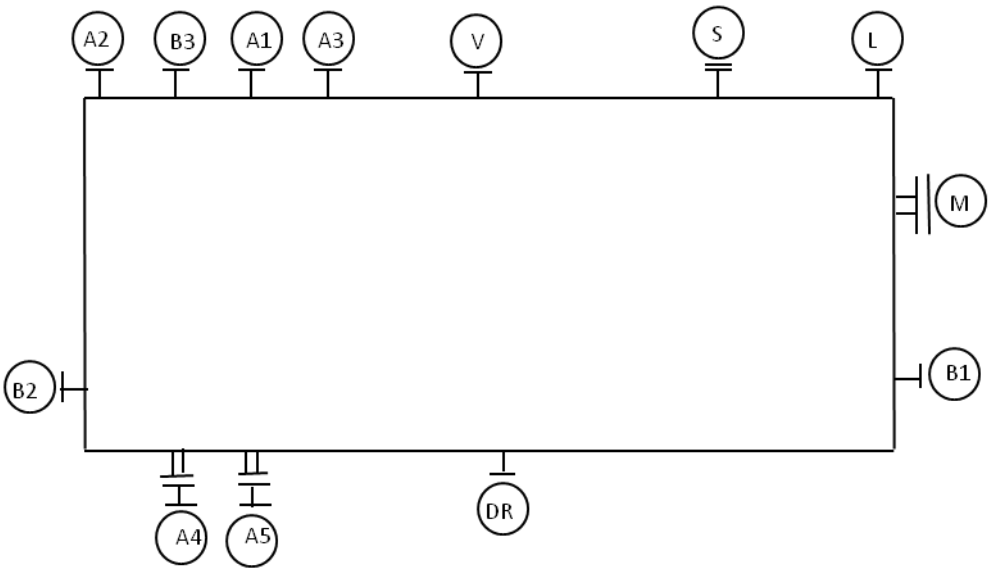
NOZZLES

Mark	Req'd	Size	Rating	Type	Face	Service	Note[s]
A1	1	2″	150#	RF	WN	Treated Water – Main Process Inlet	Top
A2	1	2″	150#	RF	WN	25% Caustic	Top
A3	1	2″	150#	RF	WN	19% Hydrochloric Acid	Top
A4	1	3″/10″	150#	RF	WN	Future	Bottom
A5	1	3″/10″	150#	RF	WN	Future	Bottom
B1	1	2″	150#	RF	WN	Outlet	Side
B2	1	6″	150#	RF	WN	Future	Side
B3	1	3″	150#	RF	WN	Remedy Water - Overfill line	Top
DR	1	2″	150#	RF	WN	Drain	Bottom
L	1	3″	150#	RF	WN	Level Element	Top
M	1	22″	150#	RF	WN	Manway	Side
S	1	2″	150#	RF	WN	Spare	Top
V	1	3″	150#	RF	WN	Vent	Top

NOTE[S]

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Project No.: 435062		By: Rolana Harris
Owner: PG&E		Date: 07-18-2012
		Equipment No.: TNK-401, TNK-402, TNK-403, TNK-404
	EQUIPMENT DATA SHEET	Equipment Name: Influent Storage Tank # 1, 2, 3, 4



Issue:	Date:	Released for:	Approved:	Owner Approved:
IFR	07-18-2012			

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SECTION 33 21 13.01
WATER WELL MOBILIZATION/DEMOBILIZATION

PART 1 - GENERAL

1.01 SCOPE

A. This section includes the Work necessary to mobilize, demobilize, set up, move equipment, and clean drill sites related to the drilling, construction, development, and testing of [list number/description of wells].

1.02 SUBMITTALS

A. Informational Submittals:

1. [Applicable permits.] [Well construction permit(s).]
2. Structural calculations for sound walls or curtains, in accordance with requirements of locally adopted building code.

PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.01 GENERAL

A. Temporary Facilities and Controls: Provide the following temporary facilities and controls:

1. Temporary construction facilities, including [storage area] [field office] [temporary electricity] [temporary telephone service] [temporary water and sanitary services].
2. Temporary controls, including: [security] [fire protection] [safety; includes OSHA required notices and establishment of safety programs].
3. Security Fence:
4. Construct for the protection of materials, tools, and equipment.
   a. At completion of the Work, remove from Site and restore area.
   b. Provide access at all times and any necessary keys to ENGINEER and OWNER.
5. Parking Facilities: Provide within the Work area for personnel working on the Project.
6. [Temporary Sound Barrier: Consisting of acoustic barrier walls [10] [20] feet high, fully encircling drill rig and other sources of high decibel engine or mechanical noise.]

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B. Equipment:

1. The minimum equipment required consists of:
   a. Drilling rig, drilling equipment, and associated self-contained fluid circulation equipment.
   b. Temporary test pump, pump service rig, and equipment capable of setting and operating pumps as specified in these Specifications.
   c. Tanks and storage bins to contain drilling fluid, drill cuttings, and high solids displacement water from each well for a minimum of 40 days.
   d. A water treatment and disposal system including tanks, temporary pipelines, pumps, and associated equipment to treat and dispose of development water and aquifer test discharge water.
   e. High pressure washer and miscellaneous associated equipment for removing mud and trackable debris from drilling equipment.

C. Superintendent shall be at the Site full time.

D. Equipment needed for the first 30 days of Work shall be onsite at start of the Work.

3.02 WORK LAYOUT

A. Set up well drilling rigs, drilling waste solid and liquid containment, storage and treatment systems, pump service rigs, and other related equipment in area designated by ENGINEER.

B. Set up work facilities in a neat and orderly manner within designated area at location of choice.

3.03 NOISE CONTROL

A. Monitor noise levels at least once daily during a time when onsite equipment is in use and noise levels are expected to be the highest. Measure noise levels [50] [_____] feet from drill site.

B. [Night time drilling operations shall not be permitted.] [To the extent possible, conduct night time drilling operations while limiting the following activities: hammering on pipe, racking or making-up of pipe, rapid acceleration and deceleration of diesel engines, and picking up or laying down drill pipe.]

C. If, at any time, the noise limits are exceeded, take immediate corrective action through drilling equipment modifications, addition of supplemental noise

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abatement equipment, or changes in operating procedures. Noise levels will be monitored by ENGINEER to assess compliance.

D. [Provide noise barrier equipment to limit noise and to allow drilling to proceed on next well while pumping and aquifer testing proceeds simultaneously on previous well.]

3.04 EQUIPMENT CLEANING

A. Downhole tools and equipment that may come in contact with tools or equipment that may be positioned directly above borehole or completed well shall arrive onsite free of surface deposits of friable solids; for example, mud, sand, grout, caked on cuttings and cleaned of grease, oils, and other petroleum products. Except that normal amounts of thread joint compound on drill pipe and tool joints, and normal amounts of lubricating grease on mechanical equipment is allowed.

B. Clean downhole equipment, tools, and equipment that may come in contact with downhole equipment that becomes soiled with petroleum products to satisfaction of ENGINEER before resuming work on well.

C. Remove trackable mud, cuttings, sand, grout and other materials from undercarriage, tires and other surfaces of equipment prior to moving equipment on or across public roads and pathways.

D. Do not empty, spill, splash, or slosh containerized drilling mud and fluids onto ground surface while moving containers, pipes and equipment.

E. Cleanup drilling mud, settled solids, and other semi-liquids and solids that spill from, or are emptied from, equipment as it is being moved.

3.05 DEMOBILIZATION

A. Remove temporary above grade or buried utilities, equipment, facilities, materials.

B. Clean and repair damage caused by installation or removal of temporary facilities and equipment.

END OF SECTION

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SECTION 33 21 13.03
WATER WELL DRILLING

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM): D422, Standard Test Method for Particle-Size Analysis of Soils.
2. American Petroleum Institute (API):
   a. 13A, Specification for Drilling-Fluid Materials.
   b. 13B-1, Recommended Practice Standard Procedure for Field Testing Water-Based Drilling Fluids.
3. International Association of Drilling Contractors (IADC): API-Approved Official Daily Drilling Report Form.
4. National Pollutant Discharge Elimination System (NPDES).
5. NSF International (NSF): 61, Drinking Water System Components—Health Effects.

1.02 SUBMITTALS

A. Action Submittals:

1. Detailed product data for drilling fluids and additives.
2. Drilling mud properties.
3. Drill cutting samples.

B. Informational Submittals:

1. Drilling fluid specialist qualifications.
2. Detailed description of drilling fluid program including details on mud tanks, pits, circulation system. [Drilling fluid program shall be prepared by a certified drilling fluid specialist.]
3. Description of drilling equipment and proposed methods.
4. Daily Drilling Log. [Include alignment and plumbness results.] [_____]
5. [Geolograph (or equal) logs for each 8-hour drilling period.]
6. Sieve analyses test results.
7. [Calibration test of mechanical drift indicator tool.]
8. Water quality analysis test results.
9. If applicable, approved chain-of-custody form(s) related to disposing of materials generated during well drilling.

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C. Submittals shall be made in accordance with [Section 01 33 00, Submittal Procedures] [Part 10 of the Special Conditions] [_____].

1.03 QUALITY ASSURANCE

A. Qualifications:

1. Drilling Fluid Specialist: Mud specialist shall be approved by ENGINEER prior to drilling.

B. Regulatory Requirements:

1. Comply with applicable permits, laws, and regulations in disposing of drilling fluids, drill cuttings, and water generated during drilling and well construction. Permits, laws and regulations shall include, but not be limited to, the following:
   a. The water quality effluent limitations specified in NPDES Permit No. [_____] as provided in NPDES Appendix.
   b. Federal, state, and local laws, regulations, and ordinances related to disposing of materials generated in constructing wells.
2. Demonstrate compliance with the applicable permits, laws, and regulations with the following:
   a. Copies of water quality analysis test results demonstrating compliance with NPDES Permit [_____]. Provide water quality analysis results prior to discharge.
   b. If applicable, approved chain-of-custody form(s) demonstrating compliance with disposal of materials generated during well drilling.

PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.01 GENERAL

A. Notify ENGINEER at least 5 working days before drilling begins.

B. Notify ENGINEER of anticipated delays whenever they become apparent.

C. Excavation of mud pits will not be allowed unless approved by ENGINEER.

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3.02 DRILLING EQUIPMENT

A. Provide [direct circulation rotary] [reverse circulation rotary] [down-hole hammer] [auger] [_____] drilling equipment and accessories required to complete well as specified.

B. [Equip drilling rig with a geolograph capable of recording rate of penetration and depth of hole as drilling progresses. Geolograph shall be approved by ENGINEER prior to mobilizing equipment to field.]

3.03 DRILLING FLUIDS

A. Use new materials in the formulation of drilling fluid at each well site. Used drilling fluid materials shall not be reused at subsequent well sites.

B. Properties:

1. Comprised of a polymer-based "mud" or a bentonite "gel"-based mud.
   a. "Gel"-based mud shall be a high-yield, 200-mesh sodium bentonite.
   b. [A bentonite viscosifier only meeting requirements of API 13A will be considered insufficient for applications required in this Project.]
2. NSF 61 Certified.
3. Possess characteristics that are required to:
   a. Adequately clean drill cuttings off drill bit and bottom of hole.
   b. Transport ("float") cuttings to the surface and remove them from the fluid.
   c. Provide borehole stability to prevent caving of the walls as drilling progresses.
   d. Control subsurface pressures.
   e. Cool drill bit and lubricate drill string.
   f. Prevent excessive fluid loss into permeable zones.
   g. Permit recovery of representative samples of drill cuttings.
4. Maintain to deposit only a thin, maximum of 1/16 of an inch, easily removable filter cake on face of borehole. Maintain as follows:
   a. Weight: Not to exceed [9.2] [_____] pounds per gallon.
   b. Viscosity: Not to exceed [32] [_____] seconds per quart.
   c. Sand Content: Not to exceed [1] [5] [_____] percent.
   d. Total Solids Content: Not to exceed [5] [7] [10] [_____] percent.
   e. 30-Minute Water Loss: Not to exceed [15] [_____] milliliters.
5. Manufacturers:
   a. Baroid Industrial Drilling Products; Quik-Gel.
   b. CETCO; Super Gel-X.

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C. Water:

1. Use potable water, with a minimum chlorine residual of 0.5 mg/L, in formulating drilling fluids whether employed alone or in combination with drilling additives.
2. [Contains specific conductance of less than 2,000 micromhos/cm and gross alpha of less than 15 picocuries/liter.]
3. Soda ash is permitted for use to increase pH of the water used to mix drilling fluids.

D. Additives, if required, shall be approved by ENGINEER. Organic drilling additives shall not be used.

E. [Use of salt or brine as a method of increasing mud weight during drilling will not be permitted during construction of well. Materials proposed for controlling the artesian flow shall be reviewed and approved by ENGINEER, prior to use].

3.04 CIRCULATION SYSTEM

A. General:

1. System shall minimize recirculation of drill cuttings.
2. Design to facilitate retrieval of representative samples from the discharge with a minimum of recirculation of material.

B. Include settling tanks of adequate size, a sampling trough, a shaker table, and a desanding/desilting system.

1. Equip with shaker table and desander/desilter system with a minimum of four cones, capable of handling capacity of system.
2. Desander/desilter system shall have pump capable of supplying a minimum of 40 psi at 80 gallons per minute per cone minimum.

C. Settling Tanks:

1. Vessels used for mixing drilling fluids shall be clean and free of contaminants and extraneous materials prior to their use in drilling operations.
2. Use above ground tanks for mixing, circulation and inclusion of approved additives.
3. Use proper controls to prevent spillage of mud or additives onto ground.

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3.05 TEST EQUIPMENT

A. Drilling fluid test equipment and test procedures shall conform to API 13B-1.

B. Equipment for measuring fluid properties shall be made immediately available at drill site.

1. [Mechanical Drift Indicator: Furnish and employ self-checking type to measure borehole deflection.
1. Manufacturer: Eastman Oil Well Survey Company.]

3.06 BOREHOLE DRILLING

A. Before drilling, install temporary or permanent surface or pit casing needed to stabilize surface material.

B. Drill wells by [direct circulation rotary] [reverse circulation rotary] [down-hole hammer] [auger] [_____] method.

C. Drill boreholes to dimensions and depth [as shown] [as determined by ENGINEER] [as specified].

1. Drill boreholes sufficiently straight and plumb to permit installation of casing and screen.

D. Borehole Deflection:

1. Use mechanical drift indicator to measure borehole deflection.
   a. Provide ENGINEER results of calibration test of mechanical drift indicator tool showing tool is operating properly and accurately.
   b. Calibration test shall be performed by tool manufacturer prior to use of tool on Project.
2. Conduct mechanical drift indicators at [100] [200] [50] [_____]-foot intervals.
3. Deflection:
   a. If less than [1] [_____] degree(s), well shall be deemed in proper plumbness and alignment.
   b. If section of borehole exceeds [_____] degrees, correct deviation or plug and abandon borehole at CONTRACTOR's own expense.
4. Periodically conduct analysis of drift indicator record and make part of drilling log record.

E. If geophysical logging is to be done, condition borehole to allow free passage of logging tools to bottom.

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F. Drilling Fluids and Additives:

1. Check drilling fluid properties, including fluid weight, marsh funnel viscosity, water loss, additions of water, sand content, and total solids content, at a minimum of:
   a. Every 100 feet of depth drilled.
   b. Every 12 hours of circulation when not drilling.
   c. As directed by ENGINEER.
2. Maintenance:
   a. Maintain complete control over drilling fluid characteristics during operation of well construction.
   b. If proper control of drilling fluid is not maintained, retain or employ an experienced, qualified mud engineer onsite to supervise and maintain drilling fluid characteristics, at CONTRACTOR's expense.
3. Determine and maintain the quantities and type of commercial drilling mud necessary for the Work, to secure and store those materials at Site, and use them in accordance with accepted practice compliance with water well drilling operations.

G. Use of additional bentonite, clay, mud, or other foreign matter that has a tendency to build a mud cake on the walls of the hole and clog or seal up water-bearing stratum will not be permitted without prior approval of ENGINEER.

3.07 TEST HOLE DRILLING AND SAMPLING

A. Drill [_____]-inch diameter test holes to depths [as specified] [as determined by ENGINEER] [as shown]. Test hole diameters outside of this range are not authorized and no payment will be made for test hole drilling if this drill bit size range is exceeded.

B. ENGINEER will have representative onsite during drilling to determine exact depth of test hole based on cuttings.

C. Rate of penetration of test hole shall be limited to [20] [40] feet per hour so CONTRACTOR can obtain, and ENGINEER can log, geological samples.

D. As test holes are advanced, collect representative formation samples at [5-foot intervals] [10-foot intervals] [as shown] [_____].

E. Collect samples [from circulation fluid] [by split-spoon] [by coring] [by push-tube method] [by auger method] [by bailing].

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3.08 BOREHOLE REAMING

A. Ream borehole for production well to [_____] inches in diameter from bottom of conductor casing, if applicable, to the total depth of about [_____] feet, or as specified by ENGINEER.

B. In order to maintain full borehole diameter, maintain well borehole full of drilling fluid until screen, casing, and gravel pack, if applicable, are installed.

C. Maintain circulation of drilling fluid until casing is set, unless CONTRACTOR judges circulation to be unnecessary.

D. Maintain a free, uncollapsed, open borehole. If borehole collapses, ream borehole at CONTRACTOR's sole expense.

3.09 DAILY LOG

A. General:

1. Keep driller's log of borehole which carefully and accurately describes the materials penetrated.
2. Drilling log shall be available for inspection at Site at all times.

B. Utilize the IADC, API-approved official Daily Drilling Report Form, or equivalent, as approved by ENGINEER.

1. Submit legible forms covering the previous day suitable for photocopying to the ENGINEER on a daily basis.
2. Daily log shall be signed daily by CONTRACTOR and ENGINEER to represent their agreement of the included data.

C. Data:

1. Include the following:
   a. Formations encountered from surface to total depth, indicating the depth of each change in formation and including difficulties and unusual conditions met during drilling.
   b. Drilling rate.
   c. Depth at which water is first encountered.
   d. Other pertinent phenomena observed.
   e. Record of variations in the addition and amount of approved clays or chemical products or water required.
   f. Properties of drilling fluids as described in Article Drilling Fluids and depth at which changes were required.

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3.10 SAMPLE COLLECTION

A. Every [5] [10] feet and at each change in the strata, collect a large, representative sample of the interval or new strata in accordance with procedures approved by ENGINEER.

B. Storage:

1. Store each sample in a suitable gallon-sized, waterproof container and label each “SAMPLE”.
2. Label shall include well number, date, time, and depth interval.
3. Sample containers shall be stored in a manner to prevent breakage or loss.
4. Furnish containers approved by ENGINEER.

3.11 SIEVE ANALYSIS

A. The grain size distribution of at least [5] [10] [_____] cutting samples shall be determined by sieve analysis. Samples selected shall be approved by ENGINEER.

B. Perform sieve analysis in accordance with ASTM D422 and include a table and plot of the cumulative percent of particles retained by each sieve versus particle size.

C. Provide a recommendation for well screen slot size, interval screened, and gravel pack gradation. Obtain ENGINEER’s approval prior to ordering materials.

D. Provide sieve analysis results within [24] [48] hours of completion of borehole.

3.12 DRILL CUTTINGS AND DRILL FLUIDS DISPOSAL

A. Separate drill cuttings and drill fluids generated during borehole drilling using appropriate equipment.

B. Contain drill cuttings while onsite in [roll-off bins, and ultimately disposed of at a Class C landfill] [approved containers or pits with prior approval from ENGINEER].

C. Separate suspended solids from drill fluids using appropriate equipment, including temporary tankage to allow sufficient settling time to meet discharge requirements for suspended solids and turbidity, if applicable.

1. Solids separated from drill fluids shall be contained while onsite in [roll-off bins, and ultimately disposed of at a Class C landfill] [approved containers or pits with prior approval from the ENGINEER].

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2. Discharge water remaining from drill fluids after solids separation:
   a. In accordance with NPDES Permit No. [_____], as provided in NPDES Appendix and as approved by ENGINEER.
   b. At appropriate rates and employing appropriate engineering controls (for example, energy dissipation) to avoid excess erosion.

D. Upon completion of drilling, remove and dispose of drilling mud and cuttings from well from Site in accordance with State and Local regulations.

E. Restore ground surface to its original condition.

END OF SECTION

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SECTION 33 41 01
STORM DRAIN, SANITARY SEWER, AND DRAINAGE PIPING

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section and any supplemental Data Sheets:

1. American Association of State Highway and Transportation Officials (AASHTO):
   a. M36M, Standard Specification for Corrugated Steel Pipe, Metallic-Coated, for Sewers and Drains.
   b. M190M, Standard Specification for Bituminous Coated Corrugated Metal Culvert Pipe and Pipe Arches.
   c. M196M, Standard Specification for Corrugated Aluminum Pipe for Sewers and Drains.
2. American Water Works Association (AWWA):
   a. C104/A21.4, Cement-Mortar Lining for Ductile-Iron Pipe and Fittings for Water.
   b. C105/A21.5, Polyethylene Encasement for Ductile-Iron Pipe Systems.
   c. C110/A21.10, Ductile-Iron and Gray-Iron Fittings, 3 in. Through 48 in. (75 mm Through 1200 mm) for Water and Other Liquids.
   d. C111/A21.11, Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings.
   e. C151/A21.51, Ductile-Iron Pipe, Centrifugally Cast, for Water.
3. ASTM International (ASTM):
   a. A746, Standard Specification for Ductile Iron Gravity Sewer Pipe.
   b. C14, Standard Specification for Concrete Sewer, Storm Drain, and Culvert Pipe.
   c. C76, Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe.
   d. C150, Standard Specification for Portland Cement.
   e. C311, Standard Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use as a Mineral Admixture in Portland-Cement Concrete.
   f. C361, Standard Specification for Reinforced Concrete Low-Head Pressure Pipe.
   g. C425, Standard Specification for Compression Joints for Vitrified Clay Pipe and Fittings.

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h. C443, Standard Specification for Joints for Circular Concrete Sewer and Culvert Pipe, Using Rubber Gaskets.
i. C497, Standard Test Methods for Concrete Pipe, Manhole Sections, or Tile.
j. C507, Standard Specification for Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe.
k. C595, Standard Specification for Blended Hydraulic Cements.
l. C618, Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete.
m. C655, Standard Specification for Reinforced Concrete D-Load Culvert, Storm Drain, and Sewer Pipe.
n. C700, Standard Specification for Vitrified Clay Pipe, Extra Strength, Standard Strength, and Perforated.
o. C1012, Standard Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution.
p. D1248, Standard Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable.
q. D1784, Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds.
r. D2412, Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading.
s. D3034, Standard Specification for Type PSM Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings.
t. D3212, Standard Specification for Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals.
u. F477, Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe.
v. F679, Standard Specification for Poly(Vinyl Chloride) (PVC) Large-Diameter Plastic Gravity Sewer Pipe and Fittings.
w. F794, Standard Specification for Poly(Vinyl Chloride) (PVC) Profile Gravity Sewer Pipe and Fittings Based on Controlled Inside Diameter.
x. F894, Standard Specification for Polyethylene (PE) Large Diameter Profile Wall Sewer and Drain Pipe.

1.02 SUBMITTALS

A. [Informational Submittals: Manufacturer’s Certification of Compliance.]

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PART 2 - PRODUCTS

2.01 PIPE AND FITTINGS

A. As specified in the Data Sheets following “End of Section.”

2.02 SERVICE AND DRAIN CONNECTIONS

A. Pipe and fittings for individual service connection shall be of one type of material throughout.

B. [Vitrified clay] [Nonreinforced concrete] [Ductile iron] [Polyvinyl chloride] [Cast iron soil] pipe.

C. Residential Service: [4] [6] inches.

D. Commercial Service, Including Motel and Apartments: 6 inches, unless shown otherwise.

2.03 SERVICE CONNECTION MARKERS

A. New 2 by 4 lumber [construction] [utility] grade or better.

PART 3 - EXECUTION

3.01 INSTALLATION OF PIPE, FITTINGS, AND APPURTENANCES

A. General:

1. Pipe laying shall proceed upgrade with spigot ends pointing in direction of flow.
2. Excavate bell holes at each joint to permit correct assembly and inspection of entire joint.
3. Pipe invert may deviate from line or grade up to [1/2] [_____] inch for line and [1/4] [_____] inch for grade, provided that finished pipe line will present a uniform bore, and such variation does not result in a level or reverse sloping invert, or less than minimum slope shown.
4. Pipe bedding shall form continuous and uniform bearing and support for pipe barrel between joints. Pipe shall not rest directly on bell or pipe joint.
5. Prevent entry of foreign material into gasketed joints.
6. Plug or close off pipes that are stubbed off for manhole, concrete structure, or for connection by others, with temporary watertight plugs.

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B. Ductile Iron Pipe Corrosion Protection:

1. Remove foreign material from the exterior of the pipe.
2. Wrap pipe with polyethylene encasement tube 2 feet longer than the pipe section prior to laying pipe section.
3. After assembling the pipe joint, overlap encasement tube with adjacent tube and seal joints with securing tape.
4. Provide additional securing tape at 3-foot intervals along the pipe.
5. Repair rips, punctures, or other damage to the polyethylene with securing tape.
6. Fittings may be wrapped with a flat sheet or split tube provided all seams are securely taped.

C. Concrete Closure Collars: Only use concrete closure collars where shown or authorized by ENGINEER.

D. Service Connections:

1. Minimum Slope: [1/4 inch] [_____] per foot.
2. Markers:
   a. Paint the top portion of the marker immediately after its installation with first-quality white, quick-drying enamel. [After the paint has dried, use black, quick-drying enamel and neatly indicate the distance from the natural ground surface to the top of the service connection pipe in feet and inches.]
   b. If marker is broken or knocked out of vertical alignment during backfilling operation, reopen trench and place marker in accordance with Sewer Service Connection Details shown on Drawings.
3. Disconnecting and Reconnecting Existing Service Connections:
   a. Locate the existing service connections prior to constructing the tee in the new sewerline.
   b. Disconnect existing service connections from existing sewers to be abandoned and reconnect them to the new sewers.

E. Square-End Underdrains: Cover top and sides of the joints with a strip of asphalt-saturated 30-pound roofing felt.

F. Perforated Underdrain: Lay with open joints and with perforations down.

3.02 PRESSURE TESTING

A. As specified in Section 40 80 01, Process Piping Leakage Testing.

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3.03 REPAIR AND RETESTING

A. Sections of pipe not meeting the pressure test requirements shall [be replaced] [or] [have individual joints tested and sealed].

B. Following repairs, sections shall be retested as specified.

3.04 SEWER CLEANING

A. Prior to final acceptance and final manhole-to-manhole inspection of the sewer system by ENGINEER, flush and clean all parts of the system. Remove all accumulated construction debris, rocks, gravel, sand, silt, and other foreign material from the sewer system at or near the closest downstream manhole. If necessary, use mechanical rodding or bucketing equipment.

B. Upon ENGINEER's final manhole-to-manhole inspection of the sewer system, if any foreign matter is still present in the system, reflush and clean the sections and portions of the lines as required.

3.05 SUPPLEMENTS

A. Data Sheets.

Number	Title
-.01	Corrugated Metal

END OF SECTION

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SECTION 33 41 01.01 CORRUGATED METAL	
Item	**Description**
Pipe	[AASHTO M36M, Type [I,] [_____,] [galvanized] [or] [AASHTO M196M, Type [I] [_____].]
[Bituminous Coating]	[AASHTO M190M, Type [A] [B] [C] [D].]
Coupling Bands	Manufacturer's standard, with same protective coating as pipe.
[Gaskets]	[Manufacturer's standard.]
Fittings	[_____.]
Source Quality Control	In accordance with specified reference standard.

END OF SECTION

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SECTION 33 46 00
SUBSURFACE DRAINAGE

PART 1 - GENERAL

1.01 GENERAL

A. This section covers requirements for subsurface drainage piping, cleanouts, [silt traps,] [pump station sumps,] [level checks] used to control shallow groundwater elevations within the Project area.

1.02 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Association of State Highway and Transportation Officials (AASHTO):
   a. M252, Standard Specification for Corrugated Polyethylene Drainage Pipe.
   b. M294, Standard Specification for Corrugated Polyethylene Pipe, 300- to 1500-mm Diameter.
2. ASTM International (ASTM):
   a. A48/A48M, Standard Specification for Gray Iron Castings.
   b. C387/C387M, Standard Specification for Packaged, Dry, Combined Materials for Mortar and Concrete.
   c. C478, Standard Specification for Precast Reinforced Concrete Manhole Sections.
   d. D75, Standard Practice for Sampling Aggregates.
   e. D422, Standard Test Method for Particle-Size Analysis of Soils.
   f. D1140, Standard Test Methods for Amount of Material in Soils Finer than No. 200 (75-µm) Sieve.
   g. F405, Standard Specification for Corrugated Polyethylene (PE) Pipe and Fittings.
   h. F449, Standard Practice for Subsurface Installation of Corrugated Polyethylene Pipe for Agricultural Drainage or Water Table Control.
   i. F667, Standard Specification for Large Diameter Corrugated Polyethylene Pipe and Fittings.
3. Natural Resources Conservation Service (NRCS): Conservation Practice Standard 606, Subsurface Drain.

1.03 DEFINITIONS

A. Cleanouts: Surface access ports used to access drain lines and constructed of solid corrugated piping.

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B. Drain Lines: Buried perforated pipe providing collection and conveyance of drain water from saturated soils to Drainage Management Unit (DMU).

C. Drainage Management Unit (DMU): An area drained by continuous connected network of drain lines discharging to a single [outfall] [pump station].

D. Granular Drain Material: Granular (sand or gravel) material used as an envelope around drain lines to provide pipe bedding, a permeable drainage zone, and stabilization of base soils to prevent migration of fines into drain lines.

E. Level Check: Inline water control structure used to control hydraulic grade line within subsurface drainage system by inserting or removing adjustable stoplogs.

F. Silt Trap: Manhole installed within drainage system to provide access for removing sediment collected within drain lines.

1.04 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. Product Data:
      1) Drain line pipe and fittings.
      2) Drain line installation equipment.
      3) High-pressure water jet cleaning equipment.
      4) Drain line sock; include manufacturer's recommendation for length of time UV-resistant sock may be left exposed.
   b. Precast Base, Cone, and Top Slab Manhole Sections: Details of construction.
   c. Level Check Box, Stop Logs, Cover, and Pipe Boots: Details of construction.

B. Informational Submittals:

1. Granular Drain Material:
   a. Manufacturer's Certificate of Compliance, in accordance with Section 01 43 33, Manufacturers' Field Services.
   b. Test results from approved commercial testing laboratory before delivering material to Site and at least 10 days before material is required for use.
2. Surveys:
   a. Survey plan to collect drain line grade QA/QC information, including methods and schedule.
   b. Field Survey:

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1) Information consisting of stationing and ground surface elevation for each drain line prior to installation.
2) Information consisting of stationing and installed invert elevation of drain pipe for drain line grade QA/QC.

3. Final drain line inspection and cleaning certification of compliance.

1.05 QUALITY ASSURANCE

A. Granular Drain Material Source:

1. Sampling:
   a. Conduct sampling of granular drain material source under supervision of Engineer in accordance with ASTM D75.
   b. Samples shall be representative and be clearly marked to show source of the material.
   c. Testing:
      1) In accordance with ASTM D1140 to determine percentage of fines.
      2) In accordance with ASTM D422 to determine gradation of particles larger than No. 200 sieve.
   d. Acceptance:
      1) Based on inspection of source by Engineer.
      2) Certified test results.
   e. Provide additional sampling, testing, and certification for every 500 cubic yards of material and when there is a change in granular drain material.
   f. Upon Engineer's request, supply supplemental samples of granular drain material to a testing laboratory designated by Owner during installation of drain lines. Owner will bear costs of testing.

1.06 DOCUMENTATION

A. Survey Plan:

1. Submit prior to beginning Work.
2. Update on a weekly basis through final drain line inspection and cleaning.

B. Surveying:

1. At least 10 days prior to installation, provide Engineer with the following information for each drain line:
   a. Field survey ground surface elevations at 250-foot increments.
   b. Calculated cut depth from ground surface to drain line invert elevation.

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2. Provide surveyed drain line grades to Engineer no more than 5 days following installation of drain line section.

1.07 DELIVERY, STORAGE, AND HANDLING

A. Drain Sock:

1. Free of tears or other damage. Replace damaged sock.
2. Protect polyethylene drain lines with geotextile sock from UV light while stored onsite, unless geotextile sock is certified UV resistant.
3. UV-resistant Sock Stored Onsite Uncovered:
   a. Mark date of first sunlight exposure for each roll at factory.
   b. Do not allow UV-resistant sock to remain uncovered for more time than recommended by manufacturer.

PART 2 - PRODUCTS

2.01 DRAIN LINES

A. Drain lines shall be perforated, unless otherwise noted on Drawings.

B. Perforated Drain Lines:

1. Heavy-duty corrugated polyethylene pipe meeting NRCS Conservation Practice Specification 606.
2. Conforming to ASTM F405 for 3-inch to 6-inch diameter pipe.
3. Conforming to ASTM F667 for 8-inch to 15-inch diameter pipe.
4. Water Inlet:
   a. Area of at least 1 square inch per foot of length.
   b. Dimensions of water inlet area shall be measured on a straight specimen with no external forces applied. Make measurements with instruments accurate to 0.01 inch.
   c. Perforations:
      1) Locate at least one perforation in the middle of corrugation so there is a shoulder on each side of perforation.
      2) Pipe 4 Inches to 12 Inches in Diameter:
         a) Slotted perforations shall be no wider than 1/8 inch or no longer than 1-1/4 inches.
         b) Slotted perforations equally spaced along length and circumference of tubing in not less than three rows.
      3) Pipe 15 inches in Diameter: Circular perforations will be accepted.

C. Nonperforated Drain Lines:

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1. Heavy-duty corrugated polyethylene pipe with smooth interior walls.
2. Conforming to AASHTO M252 for 3-inch to 10-inch pipe.
3. Conforming to AASHTO M294 for 12-inch to 15-inch pipe, Type S.

D. Drain Sock:

1. Provide geotextile fabric material (sock) surrounding perforated drain lines.
2. [Specify fabric type, weight, and apparent opening size (AOS).]
3. [Manufacturer and Product: _____.]

E. Drain Line Fittings:

1. Includes cleanouts, elbows, tees, branch connections, snap end caps, and reducing couplers.
2. Conforming to ASTM F405 and ASTM F667 as appropriate.
4. Cleanout snap end cap shall have a metal locating plate attached as shown in Drawings.
3. Diameter of cleanout fittings shall be as shown on Drawings.
4. Fittings installed as part of a continuous operation shall be clamp type rather than snap type. Fittings installed after pipe is in place may be either type.

2.02 GRANULAR DRAIN MATERIAL

A. In accordance with Section 31 23 23.15, Trench Backfill.

B. Composed of hard, durable, natural mineral particles free from organic matter, clay balls, soft particles, or other impurities or foreign matter.

C. Material shall conform to the following grading requirements:

Size or U.S. Standard Sieve	**Percent Passing by Dry Weight**
[_____]	[_____]
[_____]	[_____]
[_____]	[_____]
[_____]	[_____]
[_____]	[_____]
[_____]	[_____]

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2.03 TRENCH BACKFILL

A. Above pipe zone shall be in accordance with Section 31 23 23.15, Trench Backfill.

B. Within pipe zone shall be in accordance with Section 31 23 23.15, Trench Backfill.

C. Native backfill free from organic matter and other impurities or foreign matter and free from rocks larger than 3 inches in diameter.

2.04 BASE ROCK

A. In accordance with Section 31 23 23.15, Trench Backfill.

B. Base rock shall be clean 3/4-inch minus crushed granular or crushed rock uniformly graded from coarse to fine and with sufficient fines for proper compaction.

2.05 SILT TRAPS [AND PUMP STATION SUMPS]

A. Provide manholes to serve as silt traps [and pump station sumps] in conformance with Section 33 05 13, Manholes.

B. Manhole dimensions shall be as shown in Drawings.

C. Precast Manhole Sections:

1. Conform to ASTM C478 with minimum [42] [_____]-inch inside diameter.
2. Cone: [Concentric] [Eccentric] type with a wall thickness and reinforcement similar to manhole section, unless otherwise shown.
3. Tops and bottoms of sections shall be parallel.

D. Mortar:

1. Conform to ASTM C387/C387M or be proportioned one part Portland cement to two parts clean, well-graded sand which will pass a 1/8-inch screen.
2. Admixtures shall not exceed the following percentages by weight of cement:
   a. Hydrated Lime: 10 percent.
   b. Diatomaceous Earth or Other Inert Materials: 5 percent.
5. Consistency of mortar shall be such that it will adhere readily to pipe.

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3. Mortar mixed for longer than 30 minutes shall not be used.

E. Manhole Frames and Covers:

1. Cast iron of size and style indicated and shown on Drawings.
2. Castings shall be tough, close-grained gray iron, sound, smooth, and clean, free from blisters, blowholes, shrinkage, cold shuts, and defects.
3. Castings shall conform to ASTM A48/A48M, Class [20] [_____].
4. Where ring and cover are in contact, casting shall be ground to a flat, true bearing surface.

2.06 LEVEL CHECK

A. Dimensions shall be as shown on Drawings.

B. Manufacturer and Product: Agri Drain Corporation, Adair, IA; Inline Water Level Control Structures with internal cross braces for sidewall support perpendicular to direction of flow.

C. Metal components, including corner braces, cross braces, screws, stoplog lifting hooks, covers, and anode bond straps shall be constructed with Type 316 stainless steel.

D. Metal components shall be cathodically protected in accordance with Section 26 42 00, Cathodic Protection, and as detailed in Drawings.

PARAT 3 - EXECUTION

3.01 TRENCH EXCAVATION

A. Trenching Equipment:

1. Automatic laser-guided grade control.
2. Shoe (or boot) that allows granular fill to be placed uniformly around perforated drain lines in a continuous operation during installation.
3. Equipped with specially lengthened shield.
4. Capable of operating at sufficient speed to ensure drain lines can be laid and blinded with granular drain material before groundwater or soil-water slurry moves into trench and into direct contact with [drain line] [geotextile sock].

B. In accordance with Section 31 23 16, Excavation.

C. Excavate to lines and grades shown on Drawings allowing required thickness of granular fill to be placed around drain lines as shown on Drawings.

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D. Installation of Drain Lines below Water Table: Install with trenching machine specifically designed for fluid soil conditions.

3.02 DRAIN LINE INSTALLATION

A. General:

1. No portion of subsurface drainage system in each drainage management unit (DMU) shall be installed until the permanent or temporary [outfall] [pump station] in that DMU is installed and operational.
2. Installation of drain lines shall proceed starting from the DMU [outfall] [pump station].
3. [Size temporary pumping and conveyance facilities to match rated DMU pump flows as specified in Section _____ and to convey water to approved discharge locations as specified in Section _____.]

B. Pipe Installation:

1. Handle and install in conformance with ASTM F449.
2. Lay drain lines and appurtenances to lines and grades shown on Drawings.
3. Take special precautions on hot days to ensure stretch limit is not exceeded and excessive deflection is not caused by premature backfilling.

C. Fitting Installation:

1. Standard connections shall be in conformance with ASTM F449.
2. For nonstandard connections, join drain lines using manufacturer's printed recommended methods to complete connection.
3. Drain lines that are exposed to make a connection after trench backfilling shall have 4 inches of granular drain material replaced around drain line and connection.
4. Wrap connections and fittings with geotextile sock.

3.03 GRANULAR DRAIN MATERIAL INSTALLATION

A. Place granular drain material around perforated drain lines as shown on Drawings.

B. Place granular drain material around perforated drain lines in a continuous operation during placement of drain lines.

C. Place granular drain material with spreader boxes or other equipment in a manner to minimize segregation.

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3.04 TRENCH BACKFILL

A. Trench shall not be left open overnight; plug end of drain lines and backfill trench to prevent animals, sediment, or debris from entering pipe.

B. Perform in a manner that shall minimize settlement.

C. Backfill may be placed automatically by trencher.

D. Where backfill material is placed in drain line trenches mechanically, backfill material shall be pushed onto slope of backfill previously placed and allowed to slide down into trench. Backfill shall not be pushed into trench in such a way as to permit free fall of material until at least 2 feet of cover has been provided over the top of drain line.

E. Place in such a manner to prevent displacement of drain line and granular fill after backfilling.

F. Trench Compaction:

1. After initial backfilling to final grade, a rubber-tired tractor shall be driven a minimum of two passes with tires running parallel on top of trench to facilitate compaction.
2. Additional mechanical backfilling shall be done to leave trench with 4-inch to 6-inch elevated mound on trench.

G. Unless otherwise directed by Engineer, procedures for compaction of trench backfill material shall be accomplished by close of each day's work.

3.05 CLEANING ACCESS INSTALLATION

A. Install inline cleanouts, end-of-line caps, and silt traps [and pump station sumps] as shown on Drawings.

B. Install inline cleanout in drain lines longer than 1,000 feet and place cleanouts no further than 1,000 feet apart in drain lines longer than 2,000 feet. Silt traps may be substituted for inline cleanouts.

C. Install end-of-line caps at upstream end of drain lines.

3.06 SILT TRAP [AND PUMP STATION SUMP] INSTALLATION

A. Silt trap [and pump station] shall be installed in accordance with Section 33 05 13, Manholes.

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B. Base Preparation:

1. Remove loose material from excavation.
2. Place base rock to a compacted depth of not less than 6 inches with top surface at proper elevation.
3. Place precast base section on compacted imported base material.
4. Properly locate, ensure firm bearing throughout, and plumb first section.

C. Placing Precast Manhole Sections:

1. Make joints between precast manhole sections of cement mortar.
2. Place mortar in groove of the lower section of pipe prior to placing next section.
3. Set sections plumb.
4. Fill joints between sections completely with mortar and trowel to a smooth finish.
5. Joints between precast sections shall be watertight.
6. Cut openings in precast manhole sections as required to accommodate inlet and discharge pipes.
7. Cut holes with care and patch with nonshrinking mortar. Bend reinforcement out from the hole insofar as possible so as to reinforce patching.

D. Manhole Inverts: Construct of concrete in accordance with Drawings. Finished inverts shall be free from sharp edges or rough sections and shall provide a smooth flow.

E. Manhole Frame and Cover: Install in bed of mortar so as to provide a tight, secure joint. Elevation of finished cover shall be as shown on Drawings.

3.07 LEVEL CHECK INSTALLATION

A. Preparation of Base: Remove loose material. Place base rock to a compacted depth of not less than 6 inches with top surface at proper elevation.

B. Install level check true and plumb before making watertight connections to drain line.

C. Backfill excavation around level check with trench backfill placed in 12-inch loose lifts to no greater than 85 percent relative compaction.

D. Internal stoplogs shall be easily removed and replaced as needed following installation and backfilling.

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3.08 FIELD QUALITY CONTROL

A. Drain Line Grade:

1. Measure by excavating down to drain every 250 feet and at the beginning and end of each line.
2. Measure drain invert elevation with a survey method accurate to 0.01 foot vertical.
3. Measure for grade at the top of pipe.
4. Drain lines with grades less than 1 percent shall be placed to the design grade within a tolerance of plus or minus 0.1 foot of design invert elevation.
5. Grades of 1 percent or steeper shall be placed to the design grade within a tolerance of plus or minus 0.2 foot of design invert elevation.
6. No reversal in grade of the drain lines shall be permitted.

B. Drain Line Stretching:

1. Drain lines shall not be stretched more than 5 percent during installation.
2. Measure stretch by measuring the distance across a minimum of 10 corrugations and comparing to manufacturer's standard corrugation dimensions.

3.09 FINAL INSPECTION AND CLEANING

A. Preparation:

1. Do not begin jet washing until subsurface drainage work within a DMU is complete.
2. Stage the Work to provide adequate supply of water for jet washing to allow inspection and cleaning of each section of drain line in one continuous operation.
3. Access to drain lines shall be through drain line cleanouts, silt traps, or the [outfall] [pump station sump].

B. High Pressure Jet Washing Equipment:

1. Suitable type and size to perform cleaning specified herein.
2. Cleaning nozzle capable of jet washing 6-inch diameter to 15-inch diameter drain lines in sections up to 1,000 feet long.
3. Capable of negotiating 4-inch diameter cleaning access point.
4. Jet mechanism shall have a forward-piercing jet with trailing side jets that propel mechanism forward.
5. Operating pressures at pump shall not exceed a maximum of 2,300 psi.

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6. Operate in accordance with manufacturer's printed instructions, recommendations, and best practice of the trade.

C. Pass high-pressure water jet cleaner through entire length of each drain line no sooner than 10 calendar days after installation of drain line.

D. When drain lines must be jet washed in sections, upstream sections shall be jet washed before connecting section downstream.

E. If tailwater produced is not clear, run jet cleaner through drain line section up to two more passes.

F. Obstructions within drain lines, collapsed drain line sections, or sections outside allowable tolerances for grade that are identified during final inspection and cleaning shall be repaired and corrected to meet Specification.

G. Complete final drain line inspection and cleaning certification of compliance addressing the following items:

1. Dates of work, equipment, and personnel performing work.
2. Locations and descriptions of obstructions, collapsed sections, out-of-grade sections, and actions taken to repair problems.
3. Locations of sections where tailwater did not run clear after three passes.

H. After completing jet washing for a drain line, restore area to a neat and finished appearance.

END OF SECTION

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SECTION 40 27 02
PROCESS VALVES AND OPERATORS

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Gas Association (AGA): 3, Orifice Metering of Natural Gas and Other Related Hydrocarbon Fluids.
2. American National Standards Institute (ANSI): Z21.15, Manually Operated Gas Valves for Appliances, Appliance Connector Valves and Hose End Valves.
3. American Society of Mechanical Engineers (ASME):
   a. B16.1, Gray Iron Pipe Flanges and Flanged Fittings: Classes 25, 125, and 250.
   b. B16.44, Manually Operated Metallic Gas Valves for Use in Above Ground Piping Systems up to 5 psi.
4. American Society of Sanitary Engineers (ASSE): 1011, Performance Requirements for Hose Connection Vacuum Breakers.
5. American Water Works Association (AWWA):
   a. C111/A21.11, Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings.
   b. C500, Metal-Seated Gate Valves for Water Supply Service.
   c. C504, Rubber-Seated Butterfly Valves, 3 In. (75 mm) Through 72 In. (1,800 mm).
   d. C508, Swing-Check Valves for Waterworks Service, 2-In. Through 24-In. (50-mm Through 600-mm) NPS.
   e. C509, Resilient-Seated Gate Valves for Water Supply Service.
   f. C510, Double Check Valve Backflow Prevention Assembly.
   g. C511, Reduced-Pressure Principle Backflow Prevention Assembly.
   h. C512, Air-Release, Air/Vacuum, and Combination Air Valves for Waterworks Service.
   i. C515, Reduced-Wall, Resilient-Seated Gate Valves for Water Supply Service.
   j. C541, Hydraulic and Pneumatic Cylinder and Vane-Type Actuators for Valves and Slide Gates.
   k. C542, Electric Motor Actuators for Valves and Slide Gates.
   l. C550, Protective Interior Coatings for Valves and Hydrants.
   m. C606, Grooved and Shouldered Joints.
   n. C800, Underground Service Line Valves and Fittings.

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6. ASTM International (ASTM):
   a. A276, Standard Specification for Stainless Steel Bars and Shapes.
   b. A351/A351M, Standard Specification for Castings, Austenitic, for Pressure-Containing Parts.
   c. A380, Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems.
   d. A564/A564M, Standard Specification for Hot-Rolled and Cold-Finished Age-Hardening Stainless Steel Bars and Shapes.
   e. B61, Standard Specification for Steam or Valve Bronze Castings.
   f. B62, Standard Specification for Composition Bronze or Ounce Metal Castings.
   g. B98/B98M, Standard Specification for Copper-Silicon Alloy Rod, Bar, and Shapes.
   h. B127, Standard Specification for Nickel-Copper Alloy (UNS N04400) Plate, Sheet, and Strip.
   i. B139/B139, Standard Specification for Phosphor Bronze Rod, Bar and Shapes.
   j. B164, Standard Specification for Nickel-Copper Alloy Rod, Bar, and Wire.
   k. B194, Standard Specification for Copper-Beryllium Alloy Plate, Sheet, Strip, and Rolled Bar.
   l. B584, Standard Specification for Copper Alloy Sand Castings for General Applications.
   m. D429, Standard Test Methods for Rubber Property—Adhesion to Rigid Substrates.
   n. D1784, Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds.
7. Canadian Standards Association, Inc. (CSA): 9.1, Manually Operated Gas Valves for Appliances, Appliance Connector Valves and Hose End Valves.
8. Chlorine Institute (CI): Pamphlet 6, Piping Systems for Dry Chlorine.
9. FM Global (FM).
10. Food and Drug Administration (FDA).
11. International Association of Plumbing and Mechanical Officials (IAPMO).
12. Manufacturers Standardization Society (MSS):
   a. SP-80, Bronze Gate, Globe, Angle, and Check Valves.
   b. SP-81, Stainless Steel, Bonnetless, Flanged Knife Gate Valves.
   c. SP-85, Gray Iron Globe and Angle Valves, Flanged and Threaded Ends.
   d. SP-88, Diaphragm Valves.
   e. SP-110, Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends.
13. National Electrical Manufacturers Association (NEMA): 250, Enclosures for Electrical Equipment (1000 Volts Maximum).

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14. NSF International (NSF): 61, Drinking Water System Components—Health Effects.
15. Underwriters Laboratories (UL).

1. USC Foundation for Cross-Connection Control and Hydraulic Research.

1.02 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. Product data sheets for each make and model. Indicate valve Type Number, applicable Tag Number, and facility name/number or service where used.
   b. Complete catalog information, descriptive literature, specifications, and identification of materials of construction.
   c. [Certification for compliance to NSF 61 for valves used for drinking water service.]
   d. [Power and control wiring diagrams, including terminals and numbers.]
   e. [For each power actuator provided, manufacturer's standard data sheet, with application specific features and options clearly identified.]
   f. Sizing calculations for open-close/throttle and modulating valves.
   g. Seismic anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Seismic Anchorage and Bracing.

B. Informational Submittals:

1. Seismic anchorage and bracing calculations as required by Section 01 88 15, Seismic Anchorage and Bracing.
2. Manufacturer's Certificate of Compliance, in accordance with Section 01 43 33, Manufacturers' Field Services, for:
   a. Electric actuators; full compliance with AWWA C542.
   b. Butterfly valves; full compliance with AWWA C504.
3. Component and attachment testing seismic certificate of compliance as required by Section 01 45 33, Special Inspection [, Observation,] and Testing.
4. Tests and inspection data.
5. Operation and Maintenance Data as specified in Section 01 78 23, Operation and Maintenance Data.
6. Manufacturer's Certificate of Proper Installation, in accordance with Section 01 43 33, Manufacturers' Field Services.

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PART 2 - PRODUCTS

2.01 GENERAL

A. Valves to include operator, actuator, handwheel, chain wheel, extension stem, floor stand, operating nut, chain, wrench, and accessories to allow a complete operation from the intended operating level.

B. Valve to be suitable for intended service. Renewable parts not to be of a lower quality than specified.

C. Valve same size as adjoining pipe, unless otherwise called out on Drawings or in Supplements.

D. Valve ends to suit adjacent piping.

E. Resilient seated valves shall have no leakage (drip-tight) in either direction at valve rated design pressure. All other valves shall have no leakage (drip-tight) in either direction at valve rated design pressure, unless otherwise allowed for in this section or in stated valve standard.

F. Size operators and actuators to operate valve for full range of pressures and velocities.

G. Valve to open by turning counterclockwise, unless otherwise specified.

H. Factory mount operator, actuator, and accessories.

2.02 SCHEDULE

A. [Additional requirements relative to this section are shown on [Electric Motor Actuator Schedule] [Pneumatic Actuator Schedule] [Self-Regulated Valve Schedule] located at the end of this section.]

2.03 MATERIALS

A. Bronze and brass valve components and accessories that have surfaces in contact with water to be alloys containing less than 16 percent zinc and 2 percent aluminum.

1. Approved alloys are of the following ASTM designations: B61, B62, B98/B98M (Alloy UNS No. C65100, C65500, or C66100), B139/B139M (Alloy UNS No. C51000), B584 (Alloy UNS No. C90300 or C94700), B164, B194, and B127.
2. Stainless steel Alloy 18-8 may be substituted for bronze.

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B. Valve materials in contact with or intended for drinking water service to meet the following requirements:

1. Materials to comply with requirements of the Safe Drinking Water Act and other applicable federal, state, and local requirements.
2. Coatings materials to be formulated from materials deemed acceptable to NSF 61.
3. [Supply certification product is certified as suitable for contact with drinking water by an accredited certification organization in accordance with NSF 61. Provide certification for each valve type used for drinking water service.]

2.04 FACTORY FINISHING

A. General:

1. Interior coatings for valves and hydrants shall be in accordance with AWWA C550, unless otherwise specified.
2. Exterior coating for valves and hydrants shall be in accordance with Section 09 90 00, Painting and Coating.
3. Material in contact with potable water shall conform to NSF 61.
4. Exposed safety isolation valves and lockout valves with handles, handwheels, or chain wheels shall be "safety yellow."

B. Where epoxy lining and coating are specified, factory finishing shall be as follows:

1. In accordance with AWWA C550.
2. Either two-part liquid material or heat-activated (fusion) material except only heat-activated material if specified as "fusion" or "fusion bonded" epoxy.
3. Minimum 7-mil dry film thickness except where limited by valve operating tolerances.

2.05 VALVES

A. Gate Valves:

1. General:
   a. AWWA gate valves to be in full compliance with stated AWWA standard and the following requirements:
      1) Provide 2-inch operating nut and handwheel for AWWA gate valves 12 inches and smaller.
      2) Provide totally enclosed spur or bevel gear operator with indicator for AWWA gate valves 14 inches and larger.
      3) Provide Affidavit of Compliance per the applicable AWWA standard for AWWA gate valves.

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4) Mark AWWA gate valves with manufacturer's name or mark, year of valve casting, valve size, and working water pressure.
5) Repaired AWWA gate valves shall not be submitted or supplied.
6) [Supply AWWA gate valves with stainless steel bolting.]
7) [AWWA C509 and AWWA C515 valves may be substituted for each other.]

2. Type V100 Gate Valve 3 Inches and Smaller:
   a. All-bronze, screwed bonnet, packed gland, single solid wedge gate, nonrising stem, Class 125 rated 200 psi CWP, complies with MSS SP-80 Type 1.
   b. Manufacturers and Products:
      1) Crane; Figure 438, NPT threaded ends.
      2) Stockham; Figure B103, NPT threaded ends.
      3) Crane; Figure 1324, soldered ends.
      4) Stockham; Figure B104, soldered ends.
3. Type V101 Gate Valve 3 Inches and Smaller:
   a. All-bronze, screwed bonnet, packed gland, single solid wedge gate, rising stem, Class 125 rated 200 psi CWP, complies with MSS SP-80 Type 2.
   b. Manufacturers and Products:
      1) Crane; Figure 428, NPT threaded ends.
      2) Stockham; Figure B-100, NPT threaded ends.
      3) Crane; Figure 1334, soldered ends.
      4) Stockham; Figure B-108, soldered ends.
4. Type V102 Gate Valve 3 Inches and Smaller:
   a. All-bronze, screwed bonnet, packed gland, NPT threaded ends, single solid wedge gate, nonrising stem, Class 150 rated 150 psi SWP/300 psi CWP, complies with MSS SP-80 Type 1.
   b. Manufacturers and Products:
      1) Crane; Figure 437.
      2) Stockham; Figure B-128.
5. Type V103 Gate Valve 3 Inches and Smaller:
   a. All-bronze, screwed bonnet, packed gland, NPT threaded ends, single solid wedge gate, rising stem, Class 150 rated 150 psi SWP/300 psi CWP, complies with MSS SP-80 Type 2.
   b. Manufacturers and Products:
      1) Crane; Figure 431.
      2) Stockham; Figure B122.
6. Type V104 Gate Valve 3 Inches and Smaller:
   a. All-bronze, screwed bonnet, packed gland, NPT threaded ends, single solid wedge gate, nonrising stem, stainless steel seat rings, Class 200 rated 200 psi SWP/400 psi CWP, complies with MSS SP-80 Type 1.
   b. Manufacturers and Products:

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1) Crane; Figure 426.
2) Stockham; Figure B-140.

7. Type V105 Gate Valve 3 Inches and Smaller:
   a. All-bronze, screwed bonnet, packed gland, NPT threaded ends, single solid wedge gate, rising stem, Class 200 rated 200 psi SWP/400 psi CWP, complies with MSS SP-80 Type 2.
   b. Manufacturers and Products:
      1) Crane; Figure 424.
      2) Stockham; Figure B-132.
8. Type V106 Gate Valve 2 Inches and Smaller:
   a. All-bronze, screwed bonnet, packed gland, NPT threaded ends, single solid wedge gate, nonrising stem, stainless steel seat rings, Class 300 rated 300 psi SWP/1,000 psi CWP, complies with MSS SP-80 Type 1.
   b. Manufacturers and Products:
      1) Crane; Figure 636E.
      2) Stockham; Figure B-147.
9. Type V107 Gate Valve 2 Inches and Smaller:
   a. All-bronze, screwed bonnet, packed gland, NPT threaded ends, single solid wedge gate, rising stem, stainless steel seat rings, Class 300 rated 300 psi SWP/1,000 psi CWP, complies with MSS SP-80 Type 2.
   b. Manufacturers and Products:
      1) Crane; Figure 634E.
      2) Stockham; Figure B-145.
10. Type V108 Gate Valve 2 Inches to 24 Inches:
   a. Iron body, bronze mounted, flanged ends, solid wedge gate, nonrising bronze stem, Class 125 rated 125 psi SWP, 200 psi CWP for 2 inches through 12 inches and 100 psi SWP, 150 psi CWP for 14 inches through 24 inches.
   b. Manufacturers and Products:
      1) Crane; Figure 461.
      2) Stockham; Figure G612.
11. Type V110 Gate Valve 2 Inches to 24 Inches:
   a. Iron body, bronze mounted, flanged ends, solid wedge gate, outside screw and yoke, Class 125 rated 125 psi SWP, 200 psi CWP for 2 inches through 12 inches and 100 psi SWP, 150 psi CWP for 14 inches through 24 inches.
   b. Manufacturers and Products:
      1) Crane; Figure 465-1/2.
      2) Stockham; Figure G623.
12. Type V120 Gate Valve 3 Inches to 48 Inches for Water Service:
   a. AWWA C500, iron body, bronze mounted, flanged ends, double-disc gate, nonrising bronze stem, working water pressure 200 psi for 3 inches through 12 inches and 150 psi for 14 inches through 48 inches.

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b. Manufacturers and Products:
   1) M&H Valve Company; Style 67.
   2) Clow Valve Company; AWWA C500.

13. Type V122 Gate Valve 3 Inches to 48 Inches for Buried Water Service:
   a. AWWA C500, iron body, bronze mounted, mechanical joint ends, double-disc gate, nonrising bronze stem, 2-inch operating nut, and O-ring sealed stuffing box, working water pressure of 200 psi for 3 inches through 12 inches and 150 psi for 14 inches through 48 inches.
   b. Manufacturers and Products:
      1) M&H Valve Company; Style 67.
      2) Clow Valve Company; AWWA C500.
14. Type V124 Gate Valve 16 Inches and Larger for Low Pressure Water Service:
   a. Iron body, bronze mounted, flanged ends, double disc gate, nonrising bronze stem, rated for 50 psi, working water pressure, 125 psi ASME B16.1 drilling.
   b. Manufacturer and Product: Ludlow-Rensselaer Valve Division of Patterson Industries, Inc.; List 11.
15. Type V126 Gate Valve 4 Inches through 30 Inches for High Pressure Water Service:
   a. Iron body, bronze mounted, flanged ends, double disc gate with [nonrising bronze stem,] [rising bronze stem OS&Y,] rated 250 psi working water pressure.
   b. Operator:
      1) 2 Inches to 14 Inches Valves: Handwheel.
      2) 14 Inches and Larger Valves: [Handwheel.] [Spur gear.] [Bevel gear.]
   c. Options: [Bypass valve.] [Roller tracks and Scrappers.] [_____]
   d. Manufacturer and Product: M&H; Style [871 02] [881 02].
16. Type V128 Gate Valve 4 Inches Through 30 Inches for Buried High Pressure Water Service:
   a. Iron body, bronze mounted, mechanical joint ends, double disc gate, nonrising bronze stem, O-ring sealed stuffing box, 2-inch square wrench nut conforming to AWWA C500, rated 250 psi nonshock cold water.
   b. Manufacturer and Product: M&H; Style 871.
17. Type V130 Resilient Seated Gate Valve 3 Inches to 12 Inches:
   a. Iron body, resilient seat, bronze stem and stem nut, ASME B16.1 Class 125 flanged ends, [nonrising stem] [outside screw and yoke], in accordance with AWWA C509, minimum design working water pressure [200 psig] [250 psig], full port, fusion-epoxy coated inside and outside per AWWA C550, [NSF 61 certified].
   b. Manufacturers and Products:
      1) M&H Valve; AWWA C509.
      2) U.S. Pipe; A-USPO.

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18. Type V132 Resilient Seated Gate Valve 3 Inches to 12 Inches, for Buried Service:
    a. Iron body, resilient seat, bronze stem and stem nut, mechanical joint ends, nonrising stem, in accordance with AWWA C509, 2-inch operating nut, minimum design working water pressure [200 psig] [250 psig], full port, fusion epoxy coated inside and outside per AWWA C550 [, NSF 61 certified].
    b. Manufacturers and Products:
        1) M&H Valve; AWWA C509.
        2) U.S. Pipe; A-USPO.
19. Type V134 Resilient Seated Ductile Iron Gate Valve 3 Inches to 36 Inches:
    a. Ductile iron body, resilient seat, bronze stem and stem nut, ASME B16.1 Class 125 flanged ends, [nonrising stem] [outside screw and yoke], in accordance with AWWA C515, minimum design working water pressure [200 psig] [250 psig], full port, fusion epoxy coated inside and outside per AWWA C550 [, NSF 61 certified].
    b. Manufacturers and Products:
        1) American Flow Control; Series 2500.
        2) M&H; Style 7000 and C515 Large RW Valves.
20. Type V135 Resilient Seated Ductile Iron Gate Valve 3 Inches to 36 Inches:
    a. Ductile iron body, resilient seat, bronze stem and stem nut, mechanical joint ends, nonrising stem, in accordance with AWWA C515, minimum design working water pressure [200 psig] [250 psig], full port, fusion epoxy coated inside and outside per AWWA C550 [, NSF 61 certified].
    b. Manufacturers and Products:
        1) American Flow Control; Series 2500.
        2) M&H; Style 7000 and C515 Large RW Valves.
21. Type V136 Resilient Seated Gate Valve, Flanged Ends 4 Inches to 12 Inches:
    a. UL Listed and FM Approved, iron body, resilient seat, bronze mounted, ASME B16.1 Class 125 flanged ends, outside screw and yoke, handwheel operator, in accordance with AWWA C509, minimum design working water pressure 200 psig, full port, fusion-epoxy coated inside and outside per AWWA C550, NSF 61 certified, [Supervisory switch, as specified in [_____]. Valve supervised in OPEN position so closing results in actuation of alarm.]
    b. Manufacturers and Products:
        1) Kennedy Valve; Ken-Seal II.
        2) M&H Valve; Style 4068.
        3) Mueller; R-2360.
22. Type V137 Resilient Seated Gate Valve 4 Inches to 12 Inches:
    a. UL Listed and FM Approved for fire protection, iron body, resilient seat, bronze mounted, [ASME B16.1 Class 125 flanged ends] [mechanical joint ends], nonrising stem, 2-inch operating nut, in accordance with

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AWWA C509, design working water pressure 200 psig, full port, fusion-epoxy coated inside and outside per AWWA C550, NSF 61 certified [, indicator post flange and indicator post assembly with lockable handle].

b. Manufacturers and Products:
   1) Kennedy Valve; Ken-Seal II.
   2) M&H Valve; Style 4067.
   3) Mueller; P-2360.

23. Type V140 Gate Valve 3/4 Inch to 2 Inches:
   a. UL Listed and FM Approved, all bronze, solid wedge disc, outside screw and yoke, screwed ends rated 175 pound WOG minimum.
   b. [Supervisory switch, as specified in [_____]. Valve supervised in OPEN position so closing results in actuation of alarm.]
   c. Manufacturer and Product: Kennedy; UL/FM.
24. Type V142 Gate Valve 3 Inches to 12 Inches:
   a. UL Listed, iron body, bronze-mounted, designed for fire protection service, rising stem, outside screw and yoke, ASME B16.1 flanged ends, rated 175 pound WOG.
   b. Double disc type gate, bronze wedge pins, parallel seat, gate stem in bronze bushing through stuffing box.
   c. [Supervisory switch, as specified in [_____]. Valve supervised in OPEN position so closing results in actuation of alarm.]
   d. Manufacturer and Product: [_____].
25. Type V144 Indicator Post Valve 3 Inches to 14 Inches:
   a. UL Listed, iron body, bronze mounted, nonrising stem, rated 175 pound WOG, AWWA C111/A21.11 mechanical joint ends.
   b. Double disc type gate, bronze wedge pins, parallel seat, gate stem sealed with double O-ring pressure and dirt seal.
   c. Bolted flanged bonnet for mounting indicator post, indicator post to be locking type with an adjustable barrel and weather-sealed indicator window to display OPEN and SHUT positions.
   d. [Furnish with supervisory switch, as specified in [_____]. Valve supervised in OPEN position so closing results in actuation of alarm.]
   e. Manufacturer and Product: [_____].
26. Type V150 Knife Gate Valve 24 Inches and Smaller:
   a. Bonnetless wafer body type, outside stem and yoke, rated for 150 psi cold water, ASME B16.1 flanged ends, self-cleaning, nonclogging, with round port, resilient neoprene seat, drip-tight shutoff.
   b. Wetted metal parts and stem, Type 316 stainless steel, yoke sleeve bronze, gate finish ground both sides with a sharp knife edge.
   c. Packing system leak-tight seal around gate, valve superstructure and yoke designed for full peripheral access to gland bolts when valve is equipped with manual or power actuator.
   d. In compliance with MSS SP-81.

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e. Manufacturers and Products:
   1) DeZurik; Series L.
   2) Rovang; Model L17.
   3) ITT Fabri-Valve; [Figure 37L] [, with buttons] [Figure C67R].

27. Type V155 Knife Gate Valve 30 Inches and Larger:
   a. Bonnetless wafer body type, outside stem and yoke, rated 50 psi CWP minimum, handwheel or floor stand operator as required, self-cleaning, nonclogging, with round port, resilient neoprene seat, drip-tight shutoff.
   b. Wetted metal parts and stem Type 316 stainless steel, yoke sleeve bronze, gate finish ground both sides with a sharp knife edge.
   c. Packing system leak-tight seal around gate, valve superstructure and yoke designed for full peripheral access to gland bolts when valve is equipped with manual or power actuator.
   d. Manufacturers and Products:
      1) DeZurik; Series L.
      2) Rovang; Model L17.
      3) ITT Fabri-Valve; Figure F37R.

B. Globe Valves:

1. Type V200 Globe Valve 3 Inches and Smaller:
   a. All-bronze, union bonnet, packed gland, inside screw, rising stem, TFE disc, Class 150 rated 150 psi SWP/300 psi CWP, complies with MSS SP-80 Type 2.
   b. Manufacturers and Products:
      1) Stockham; Figure B-22T, NPT threaded end.
      2) Crane Co.; Figure 7TF, NPT threaded end.
      3) Milwaukee; Model 1590T, soldered ends.
      4) NIBCO; Figure S-235-Y, soldered ends.
2. Type V201 Angle Pattern Valve 2 Inches and Smaller:
   a. All-bronze, NPT threaded ends, union bonnet, packed gland, inside screw, rising stem, TFE disc, Class 150 rated 150 psi SWP/300 psi CWP, complies with MSS SP-80 Type 2.
   b. Manufacturers and Products:
      1) Stockham; Figure B-222T.
      2) Crane Co.; Figure 17TF.
3. Type V202 Globe Valve 3 Inches and Smaller:
   a. All-bronze, union bonnet, packed gland, inside screw, rising stem, replaceable stainless steel tapered plug type disc and seat ring, Class 200 rated 200 psi SWP/400 psi CWP, complies with MSS SP-80 Type 3.
   b. Manufacturers and Products:
      1) Stockham; Figure B-62, NPT threaded end.
      2) Crane Co.; Figure 212P, NPT threaded end.

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4. Type V204 Globe Valve 2 Inches and Smaller:
   a. All-bronze, NPT threaded ends, union bonnet, packed gland, inside screw, rising stem, replaceable stainless steel tapered plug type disc and seat ring, Class 300 rated 300 psi SWP/1,000 psi CWP, complies with MSS SP-80 Type 3.
   b. Manufacturers and Products:
      1) Crane; Figure 382P.
      2) Stockham; Figure B-74.
5. Type V205 Angle Pattern Valve 2 Inches and Smaller:
   a. All-bronze, NPT threaded ends, union bonnet, packed gland, inside screw, rising stem, replaceable stainless steel tapered plug type disc and seat ring, Class 300 rated 300 psi SWP/1,000 psi CWP, complies with MSS SP-80 Type 3.
   b. Manufacturers and Products:
      1) Stockham; Figure B-274.
      2) Crane; Figure 384P.
6. Type V208 Needle Disc Type Globe Valve 1/8 Inch to 3/4 Inch:
   a. All-bronze, threaded bonnet, packed gland, rising stem, bronze body and stem, Class 200 rated 200 psi SWP/400 psi CWP, complies with MSS SP-80.
   b. Manufacturers and Products:
      1) Crane Cat.; No. 88.
      2) Stockham; B-64.
7. Type V209 Needle Disc Type Globe Valve 1/8 Inch to 3/4 Inch:
   a. All-bronze, threaded bonnet, packed gland, rising stem, bronze body and stem, Class 200 rated 200 psi SWP/400 psi CWP, complies with MSS SP-80.
   b. Manufacturers and Products:
      1) Crane Cat.; No. 89.
      2) Stockham; B-264.
8. Type V210 Globe Valve 2 Inches to 10 Inches:

a. Iron body, bronze mounted, flanged ends, bronze seat, outside screw and yoke, bolted bonnet, Class 125 rated 125 psi SWP/200 psi CWP, complies with MSS SP-85 Type 1.
b. Manufacturers and Products:
   1) Stockham; G-512.
   2) Crane; Figure 351.

9. Type V234 Angle Type Hose Valve 1/2 Inch to 3/4 Inch:
   a. Bronze or manufacturer’s standard brass, angle sillcock type body, threaded or solder inlet as applicable, pressure rating 125 psi cold water.
   b. Manufacturer and Product: Nibco; QTX Series.
10. Type V235 Angle Type Hose Valve 3/4 Inch:

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a. 3/4-inch NPT female inlet, 3/4-inch male hose thread outlet, heavy rough brass body rated 125 psi, lockshield bonnet, removable handle, atmospheric vacuum breaker conforming to ASSE 1011 and IAPMO code.
b. Manufacturers and Products:
1) Acorn; 8126, surface pipe mount valve, bent nose without flange.
2) Acorn; 8121, surface mount through wall valve, bent nose with flange.
3) Acorn; 8131, pipe and pedestal mounted valve located above 6 inches, straightnose.
4) Acorn; 8136, pedestal mounted valve located lower than 6 inches, inverted nose.

11. Type V236 Globe Style Hose Valve 1 Inch to 3 Inches:
a. All-bronze, NPT threaded ends, inside screw-type rising stem, TFE disc, [cast brass male NPT by male NHT adapter with hexagonal center wrench nut,] [brass cap with chain,] complies with MSS SP-80, rated 300 WOG.
b. Manufacturers and Products:
1) Stockham; Figure B-22T.
2) Crane Co.; Cat. No. 7TF.
3) Nibco; Figure T-235-Y.

12. Type V237 Angle Pattern Hose Valve 1 Inch to 2 Inches:
a. All-bronze, NPT threaded ends, inside screw-type rising stem, TFE disc, [cast brass male NPT by male NHT adapter with hexagonal center wrench nut,] [brass cap with chain,] complies with MSS SP-80, rated 300 WOG.
b. Manufacturers and Products:
1) Stockham; Figure B-222T.
2) Crane Co.; Cat. No. 17TF.
3) Nibco; Figure T-335-Y.

C. Ball Valves:

1. Type V300 Ball Valve 3 Inches and Smaller for General Water and Air Service:
a. Two-piece, standard port, NPT threaded ends, bronze body and end piece, hard chrome-plated solid bronze or brass ball, RTFE seats and packing, blowout-proof stem, adjustable packing gland, zinc-coated steel hand lever operator with vinyl grip, rated 600-pound WOG, 150-pound SWP, complies with MSS SP-110. [For steam service, provide stainless steel ball and stem.]
b. Manufacturers and Products:
1) Threaded:

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a) Conbraco Apollo; 70-100.
b) Nibco; T-580-70.

3) Soldered:
a) Conbraco Apollo; 70-200.
b) Nibco; S-580-70.

2. Type V301 Ball Valve 2 Inches and Smaller for General Water and Air Service:
   a. Two-piece, full port, NPT threaded ends, bronze body and end piece, hard chrome-plated solid bronze or brass ball, RTFE seats and packing, blowout-proof stem, adjustable packing gland, zinc-coated steel hand lever operator with vinyl grip, rated 600-pound WOG, 150-pound SWP, complies with MSS SP-110. [For steam service, provide stainless steel ball and stem.]
   b. Manufacturers and Products:
      1) Threaded:
         a) Conbraco Apollo; 77-100.
         b) Nibco; T-585-70.
      2) Soldered:
         a) Conbraco Apollo; 77-200.
         b) Nibco; S-585-70.
3. Type V302 Actuator Ready Ball Valve 2 Inches and Smaller for General Water and Air Service:
   a. Two-piece, standard port, NPT threaded ends, bronze body and end piece, actuator mounting pad, Type 316 stainless steel ball and stem, vented ball, reinforced PTFE seats and seals, adjustable packing nut, blowout-proof stem, rated 600-pound WOG, 150-pound SWP, complies with MSS SP-110.
   b. Manufacturers and Products:
      1) Conbraco Apollo; 71-140.
      2) Milwaukee; 20BSOR-02.
4. Type V303 Ball Valve 2 Inches and Smaller for Equipment Air System Shutoff:
   a. Two-piece, NPT threaded ends, bronze body and end piece, hard chrome-plated solid bronze or brass ball, RTFE seats and packing, blowout-proof stem, adjustable packing gland, 125 psig rated, safety exhaust port to exhaust downstream side when valve is in closed position, zinc-coated steel locking handle with vinyl grip.
   b. Meets OSHA Regulation 29 CFR Part 1910.147 requirements.
   c. Manufacturers and Products:
      1) Conbraco Apollo; 75-100-41.
      2) Nibco; T-580-70-SV/T-585-70-SV.
5. Type V304 Ball Valve 2 Inches and Smaller for General Water and Air Service:

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a. Three-piece, full port, NPT threaded ends, bronze body and end pieces, hard chrome plated solid bronze or brass ball, RTFE seats and packing, blowout-proof stem, zinc-plated steel hand lever operator with vinyl grip, rated 600-pound WOG, 150 psi SWP, complies with MSS SP-110. [For steam service, provide stainless steel ball and stem.]
b. Manufacturers and Products:
    1) Threaded Ends:
        a) Conbraco Apollo; 82-100.
        b) Nibco; T-595-Y.
        c) Stockham; T-395 Series.
    2) Solder Ends:
        a) Conbraco Apollo; 82-200.
        b) Nibco; S-595-Y.
        c) Stockham; S-395 Series.

6. Type V305 Ball Valve 2 Inches and Smaller for [LP Gas] [Natural Gas] [Fuel Oil] Service:
    a. Two-piece bronze or forged brass body and end piece, NPT threaded ends, hard chrome-plated solid brass ball, RTFE seats and seal, blowout-proof stem, zinc-plated hand lever operator with vinyl grip, UL Listed [Guide YSDT for LP Gas] [Guide YRPV for natural/manufactured gas] [Guide MHKZ for Fuel Oil], 600 WOG.
    b. Manufacturers and Products:
        1) Conbraco Apollo; 80-100.
        2) Nibco; T-585-70-UL/T-580-70-UL.
7. Type V306 Stainless Steel Ball Valve 2 Inches and Smaller:
    a. Two-piece, full port, ASTM A276 GR 316 or ASTM A351/A351M GR CF8M stainless steel body and end piece, NPT threaded ends, ASTM A276 Type 316 stainless steel ball, reinforced PTFE seats, seals, and packing, adjustable packing gland, blowout proof stainless steel stem, stainless steel lever operator with vinyl grip, rated 1,000 psig CWP, complies with MSS SP-110.
    b. Manufacturers and Products:
        1) Conbraco Apollo; 76F-100 Series.
        2) Nibco; T-585-S6-R-66-LL.
8. Type V307 Stainless Steel Ball Valve 2 Inches and Smaller:
    a. Three-piece, full port, ASTM A276 GR 316 or ASTM A351/A351M GR CF8M stainless steel body and end pieces, Type 316 stainless steel ball, NPT threaded ends, reinforced PTFE seats, seals, and packing, adjustable packing gland, blowout-proof stainless steel stem, stainless steel lever operator with vinyl grip, rated 800 psig to 1,000 psig CWP, complies with MSS SP-110.
    b. Manufacturers and Products:
        1) Conbraco Apollo; 86R-100/86-500 Series.

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2) Nibco; T-595-S6-R-66-LL.

9. Type V308 Stainless Steel Ball Valve 2 Inches and Smaller:
   a. Two-piece, standard port, NPT threaded ends, ASTM A351/A351M GR CF8M stainless steel body and end pieces, actuator mounting pad, Type 316 stainless steel ball and stem, vented ball, reinforced PTFE seats and seals, adjustable packing nut, blowout-proof stem, rated 1,500 psig WOG minimum, 150 psi SWP, complies with MSS SP-110.
   b. Manufacturers and Products:
      1) Conbraco Apollo; 76-100.
      2) Nibco; T-580-S6-R-66-LL.
      3) Milwaukee; 20SSOR-02.
10. Type V309 Instrument Air Shutoff Valve 1/8 Inch to 3/4 Inch:
   a. [Brass] [Stainless steel] body ball valve, nylon handle, tube fitting ends, PTFE seats and seals, panel nut, rated 1,500 psi minimum.
   b. Manufacturers and Products:
      1) Swagelok; 40 Series.
      2) Parker Hannifin; B Series.
   c. Type V310 Ball Valve for Chlorine Liquid and Gas:
      1) 600-pound WOG, carbon steel body, monel ball and stem, reinforced Teflon seat, Teflon seals, double stem seal, lever operator, screwed ends, nonlubricated, and comply with the requirements of Chlorine Institute Pamphlet 6.
      2) Manufacturer and Product: ITT Camtite; [_____].
11. Type V318 Ball Valve 1 Inch and Smaller for In-Door Low Pressure Gas Service:
   a. Two-piece bronze or forged brass body and end piece, NPT threaded ends, hard chrome plated brass ball, PTFE seats and packing, yellow or red lever handle, rated pressure to 5 psi.
   b. Fully comply with AGA 3 or ASME B16.44, ANSI Z21.15/CSA 9.1, and CR91-002 for manually operated valves.
   c. Manufacturers and Products:
      1) Conbraco Apollo; Series GB-10.
      2) Nibco; GB-10.
12. Type V319 Ball Valve 2 Inches and Smaller for In-Door Main Burner Low Pressure Gas Service:
   a. Two-piece bronze or forged brass body and end piece, NPT threaded ends, hard chrome plated brass ball, PTFE seats and packing, plated steel lever handle with yellow vinyl grip, rated pressure to 5 psi, with cast-in pilot tap and plug.
   b. CSA approved and in full compliance with AGA 3, ANSI Z21.15/CSA 9.1, and CR91-002for manually operated valves.
   c. Manufacturers and Products: Conbraco Apollo; Series GB-50 Series.
13. Type V320 Vee-Ball Valve 1 Inch to 16 Inches:

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a. ASME B16.1 Class 150-pound flanged ends, [carbon steel] [Type 317 stainless steel] body, heat treated nickel- or hard chromium-plated Type 317 stainless steel ball, splined-type, 17-4 PH stainless steel shafts, reinforced PTFE flow-ring seal, reinforced PTFE with stainless steel or Hastalloy sleeve bearings, and PTFE V-ring packing. Valve to have 300:1 rangeability and equal percentage characteristic.
b. Manufacturers and Products:
   1) Fisher Controls: Design V150.
   2) DeZurik: VPB V-Port Ball Valve.

14. Type V330 PVC Ball Valve 2 Inches and Smaller:
   a. Rated 150 psi at 73 degrees F, with ASTM D1784, Type I, Grade 1 polyvinyl chloride body, ball, and stem, end entry, double union design, solvent-weld socket ends, elastomer seat, Viton or Teflon O-ring stem seals, to block flow in both directions. [Provide pressure relief hole drilled on low pressure side of ball.]
   b. Manufacturers and Products:
      1) Nibco; Chemtrol Tru-Bloc.
      2) ASAHI/America; Type 21.
      3) Spears; True Union.
15. Type V331 PVC Ball Valve 3 Inches and 4 Inches:
   a. Rated 150 psi at 73 degrees F, with ASTM D1784 Type I, Grade 1 PVC full port body, Teflon seat, Viton O-ring stem, face and carrier seals, end entry design with dual union, solvent-weld socket ends, or single union ball valve with flanged ends drilled to ASME B16.1. [Provide pressure relief hole drilled on low pressure side of ball.]
   b. Manufacturers and Products:
      1) Nibco; Chemtrol Tru-Bloc.
      2) ASAHI/America; Type 21.
16. Type V335 CPVC Ball Valve 2 Inches and Smaller:
   a. Rated 150 psi at 100 degrees F, 80 psi at 140 degrees, with ASTM D1784, Type IV, Grade 1 chlorinated polyvinyl chloride (CPVC) body, ball, and stem, end entry, double union design, with solvent-weld socket ends or single union ball with flanged ends drilled to ASME B16.1, replaceable Teflon seat, Viton or Teflon O-ring stem seals, to block flow in both directions. [Provide pressure relief hole drilled on low pressure side of ball.]
   b. Manufacturers and Products:
      1) Nibco; Chemtrol Tru-Bloc.
      2) ASAHI/America; Type 21.
      3) Spears; True Union.

D. Plug Valves:

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1. Type V400 Eccentric Plug Valve 2 Inches and Smaller:
   a. Nonlubricated type rated 175 psig CWP, drip-tight shutoff with pressure from either direction, cast-iron body, threaded ends, lever operator, cast-iron plug with round or rectangular port, plug coated with Buna-N, stem bearing lubricated stainless steel or bronze, stem seal multiple V-rings, or U-cups with O-rings of nitrile rubber.
   b. Manufacturers and Products:
      1) Pratt; Ballcentric.
      2) DeZurik; Style PEC.
      3) Milliken; Millcentric Series 603.
2. Type V405 Eccentric Plug Valve 3 Inches to 12 Inches:
   a. Nonlubricated type rated 175 psig CWP, drip-tight shutoff with pressure from either direction, cast-iron body, exposed service flanged ends per ASME B16.1 or grooved ends in accordance with AWWA C606 for rigid joints, buried service mechanical joint ends, unless otherwise shown.
   b. Plug cast iron with round or rectangular port of no less than 80 percent of connecting pipe area and coated with Buna-N, seats welded nickel, stem bearings lubricated stainless steel or bronze, stem seal multiple V-rings, or U-cups with O-rings of nitrile rubber, grit seals on both upper and lower bearings.
   c. For buried service, provide external epoxy coating.
   d. Operators:
      1) 3-Inch to 4-Inch Valves: Wrench lever manual.
      2) 6-Inch to 12-Inch Valves: Totally enclosed, geared, manual operator with handwheel, 2-inch nut or chain wheel. Size operator for 1.5 times maximum operating shutoff pressure differential for direct and reverse pressure, whichever is higher. For buried service, provide completely sealed operator filled with heavy lubricant and 2-inch nut.
   e. Manufacturers and Products:
      1) Pratt; Ballcentric.
      2) DeZurik; Style PEC.
      3) Milliken; Millcentric Series 600.
3. Type V406 Eccentric Plug Valve 14 Inches to 20 Inches:
   a. Nonlubricated type rated 150 psig CWP, drip-tight shutoff with pressure from either direction, cast-iron body, exposed service flanged ends per ASME B16.1 or grooved ends in accordance with AWWA C606 for rigid joints, buried service mechanical joints ends, unless otherwise shown, plug cast iron with round or rectangular port of no less than 80 percent of connecting pipe area and coated with Buna-N, seats welded nickel, stem bearings lubricated stainless steel or bronze, stem seal

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multiple V-rings or U-cups with O-rings of nitrile rubber, grit seals on both upper and lower bearings.

b. Totally enclosed, geared, manual operator with handwheel, 2-inch nut or chain wheel. Size operator for 1.5 times maximum operating shutoff pressure differential for direct and reverse pressure, whichever is higher. For buried service, provide completely sealed operator filled with heavy lubricant and 2-inch nut.

c. For buried service, provide external epoxy coating.

d. Manufacturers and Products:

1) Pratt; Ballcentric.
2) DeZurik; Style PEC.
3) Milliken; Millcentric Series 600.

4. Type V407 Eccentric Plug Valve 24 Inches to 48 Inches:

a. Nonlubricated type rated 150 psig CWP, drip-tight shutoff with pressure from either direction, cast-iron body, exposed service flanged ends per ASME B16.1, buried service mechanical joints ends unless otherwise shown, plug cast iron port opening of no less than 70 percent of connecting pipe area and coated with Buna-N, seats welded nickel, stem bearings lubricated stainless steel or bronze, stem seal multiple V-rings or U-cups with O-rings of nitrile rubber, grit seals on both upper and lower bearings.

b. Totally enclosed, geared, manual operator with handwheel, 2-inch nut, or chain wheel. Size operator for 1.5 times maximum operating shutoff pressure differential for direct and reverse pressure, whichever is higher. For buried service, provide completely sealed operator filled with heavy lubricant.

c. For buried service, provide external epoxy coating.

d. Manufacturers and Products:

1) Pratt; Ballcentric.
2) DeZurik; Style PEC.
3) Milliken; Millcentric Series 600.

5. Type V408 Eccentric Plug Valve 3 Inches to 12 Inches for Digester Gas Service:

a. Nonlubricated type rated 175 psig working pressure, bubble-tight shutoff with gas pressure from one direction, body cast iron with flanged ends, plug cast iron with round or rectangular port of no less than 80 percent of connecting pipe area and coated with Buna-N, seats welded nickel, stem bearing lubricated stainless steel, stem seal multiple V-rings or U-cups with O-rings of nitrile rubber.

b. Internal surfaces of valve body epoxy lined (except seat).

c. Operators:

1) 3-Inch and 4-Inch Valves: Wrench lever manual.

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2) 6-Inch through 12-Inch Valves: Totally enclosed, geared, manual operator, with handwheel, 2-inch nut, or chain wheel.

d. Manufacturers and Products:
1) Pratt; Ballcentric.
2) DeZurik; Style PEC.
3) Milliken; Millcentric Series 600.

6. Type V410 Three-Way, Nonlubricated, Tapered Plug Valve 3 Inches to 16 Inches:
a. Cast-iron body with Buna-N-coated plug, multiple V-rings or U-cups with O-ring seals, lubricated stainless steel bearings, and nickel- or epoxy-coated seat, rated 125 psi CWP minimum, flanged to ASME B16.1.
b. Operator: [Lever type.] [Gear type, totally enclosed and lubricated, with handwheel.]
c. Manufacturers and Products:
1) DeZurik; Style PTW, Combination [_____].
2) Milliken; Millcentric Series 600, Style [_____].

7. Type V420 Nonlubricated Plug Valve 2 Inches and Smaller:
a. Ductile iron or carbon steel body, Type 316 stainless steel plug with straight-way rectangular ports, Teflon sleeves, screwed ends, wrench operator.
b. Class: [150.] [300.]
c. Rating: [275] [720] psi WOG.
d. Manufacturers and Products:
1) Duriron Co.; Figure No. G432.
2) Tufline; Figure [066] [0366].

8. Type V422 Nonlubricated Plug Valve 2-1/2 Inches to 14 Inches:
a. Ductile iron or carbon steel body, Type 316 stainless steel plug with straight-way rectangular ports, Teflon sleeves, flanged ends.
b. Class: [150.] [300.]
c. Rating: [275] [720] psi WOG.
d. Operator:
1) 4 Inches and Smaller Valve: Wrench type.
2) 6 Inches and Larger Valve: Enclosed gear type.
e. Manufacturers and Products:
1) Duriron Co.; Figure No. [G411] [G431].
2) Tufline; Figure [067] [0367].

9. Type V462 Gauge Cock 1/8 Inch to 1/4 Inch:
a. 1/4-inch bronze body, hexagon end pattern, tee head, male ends, rated 125-pound SWP.
b. Manufacturer and Product: United Brass Works; Figure 973.

10. Type V464 Corporation Stop 1/2 Inch to 2 Inches:

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a. AWWA C800 type, tapered threaded inlet, except when connecting to tapped fittings which require IPS tapered threads, outlet compression connection or IPS threads to suit connecting pipe, stops 1 inch and smaller rated 100 psi, larger stops rated 80 psi.
b. Manufacturers and Products:
1) Ford Meter Box Co.; [_____]
2) Mueller Co.; [_____]

11. Type V466 Buried Service Natural Gas Plug Valve 2 Inches and Smaller:
a. UL Listed, iron body type, rated 125 psi, screwed ends, drilled key head for permanent pinned operating rod.
b. Manufacturers and Products:
1) DeZurik; Figure 425.
2) Mueller; (gas) curb stop H-11104.

12. Type V470 Combination Balancing and Shutoff Valve 2-1/2 Inches and Smaller for Heating, Chilled, and Cooling Water Service:
a. Nonlubricated plug valve, cast-iron body, NPT threaded ends, cast-iron plug with [Chloro-Isobutane-Isoprene] [FKM] [_____] resilient plug facing, PTFE packing, dual stainless steel bearings, PTFE thrust seal, adjustable memory stop, rated 175 psi CWP, lever operator, upstream and downstream 1/8-inch flow taps with air valve fittings and sealing caps.
b. Manufacturer and Product: DeZurik; Style PEC.

13. Type V472 Combination Balancing and Shutoff Valve 3 Inches to 24 Inches for Heating, Chilled, and Cooling Water Service:
a. Nonlubricated plug valve, cast-iron body, ASME B16.1 Class 125 flanged ends, cast-iron plug with [Chloro-Isobutane-Isoprene] [FKM] [_____] resilient plug facing, PTFE packing, dual stainless steel bearings, PTFE thrust seal, adjustable memory stop, rated 150 psi CWP minimum, lever operator for 3-inch and 4-inch valves, totally enclosed and sealed heavy-duty gear operator for 6-inch and larger valves, upstream and downstream 1/8-inch flow taps with air valve fittings and sealing caps.
b. Manufacturer and Product: DeZurik; Style PEC.

E. Butterfly Valves:

1. General:
a. In full compliance with AWWA C504 and following requirements:
1) Suitable for throttling operations and infrequent operation after periods of inactivity.
2) Elastomer seats which are bonded or vulcanized to the body shall have adhesive integrity of bond between seat and body assured by

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testing, with minimum 75-pound pull in accordance with ASTM D429, Method B.

3) Bubble-tight with rated pressure applied from either side. Test valves with pressure applied in both directions.
4) No travel stops for disc on interior of body.
5) Self-adjusting V-type or O-ring shaft seals.
6) Isolate metal-to-metal thrust bearing surfaces from flowstream.
7) Provide traveling nut or worm gear actuator with handwheel. Valve actuators to meet the requirements of AWWA C504.
8) Buried service operators shall withstand 450 foot-pounds of input torque at fully open and fully closed positions.
9) Provide linings and coatings per AWWA, unless otherwise indicated on Drawings or specified herein.
10) Valves to be in full compliance with NSF 61. [Provide NSF 61 certificate for each valve.]

b. Non-AWWA butterfly valves to meet the following actuator requirements:
1) For above ground installations, provide handle and notch plate for valves 6 inches and smaller and heavy-duty, totally enclosed gearbox type operators with handwheel, position indicator and travel stops for valves 8 inches and larger, unless otherwise indicated on Drawings or specified herein.

2. Type V500 Butterfly Valve Water Works Service 3 Inches to 72 Inches:
a. AWWA C504, Class 150B.
b. Short body type, flanged ends.
c. Cast-iron body, cast or ductile iron disc, Type 304 stainless steel shafts, [Buna-N] [EPDM] [_____] rubber seat [bonded or molded in body only], and stainless steel seating surface.
d. [Provide epoxy lining [and coating] in compliance with AWWA C550.]
e. Manufacturers and Products:
1) Pratt; Model 2FII or Triton XR-70.
2) DeZurik; AWWA Valve.

3. Type V501 Butterfly Valve Water Works Service 30 Inches to 72 Inches:
c. AWWA C504, Class [75] [25] [A] [B].
a. Short body type, flanged ends.
b. Cast-iron body, ductile iron disc with Type 316 stainless steel seating edge, Type [304] [316] stainless steel shafts, [Buna-N] [EPDM] [_____] rubber seat [bonded or molded in body only].
c. [Provide epoxy lining [and coating] in compliance with AWWA C550.]
d. Manufacturers and Products:
1) Pratt; Model Triton XR-70.
2) DeZurik; AWWA Valve.

4. Type V502 Butterfly Valve General Service 3 Inches to 20 Inches:

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a. AWWA C504, Class 150B.
b. Wafer style type.
c. [Buna-N] [_____] rubber seat.

5. Type V504 Butterfly Valve General Service 4 Inches to 48 Inches:
   a. AWWA C504, Class 150B.
   b. Mechanical joint end type.
   c. Cast-iron body, cast or ductile iron disc, Type 304 stainless steel shafts, [Buna-N] [EPDM] [_____] rubber seat [bonded or molded in body only], and stainless steel seating surface.
   d. [Provide epoxy lining [and coating] in compliance with AWWA C550.]
   e. Manufacturers and Products:
      1) Pratt; Groundhog.
      2) DeZurik; Buried AWWA Valve.
6. Type V506 Butterfly Valve High Pressure Service 4 Inches to 48 Inches:
   a. AWWA C504, Class 250B.
   b. Short body type, [Class 250] [Class 125] flanged ends.
   c. Cast or ductile iron body, cast or ductile iron disc with Type 316 stainless steel disc edge, ASTM A564/A564M Type 630 Condition H-1100/1150 or Type 316 stainless steel shaft, Buna-N rubber seat bonded or molded in body only, self-adjusting V-type multi-ring seals.
   d. [Provide epoxy lining [and coating] in compliance with AWWA C550.]
   e. Manufacturers and Products:
      1) Pratt; Triton HP-250.
      2) DeZurik; AWWA Flanged Class 250.
      3) Mueller; Lineseal XP Class 250.
7. Type V507 Butterfly Valve High Pressure Service 4 Inches to 48 Inches:
   a. AWWA C504, Class 250B.
   b. Mechanical joint ends.
   c. Cast or ductile iron body, cast or ductile iron disc with Type 316 stainless steel disc edge, ASTM A564/A564M Type 630 Condition H-1100/1150 or Type 316 stainless steel shaft, Buna-N rubber seat bonded or molded in body only, self-adjusting V-type multi-ring seals.
   d. [Provide epoxy lining [and coating] in compliance with AWWA C550.]
   e. Manufacturers and Products:
      1) Pratt; Triton HP-250.
      2) DeZurik; AWWA Mechanical Joint Class 250.
      3) Mueller; Lineseal XP250.
8. Type V510 Lug Style Butterfly Valve, Resilient Seated, 2 Inches to 20 Inches for Low Pressure Process Air Service:
   a. Lug style cast-iron body, aluminum bronze discs, Type 316 stainless steel one-piece stem, self-lubricating sleeve type bushings, EPDM replaceable resilient seat suitable for operating temperatures up to 250 degrees F, 150 psi working pressure rating, bubble-tight at 50 psi

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differential pressure, valve body to fit between ASME B16.1 Class 125/150 flanges.

b. Manufacturers and Products:
   1) Bray Controls; Series 31.
   2) Tyco/Keystone; Model AR2.

9. Type V511 Flanged Style Butterfly Valve, Resilient Seated, 24 Inches to 48 Inches for Low Pressure Process Air Service:
   a. Flanged style cast-iron body, aluminum bronze discs, Type 304 stainless steel one-piece stem, self-lubricating bronze sleeve type bearing, EPDM replaceable resilient seat suitable for operating temperatures up to 250 degrees F, 150 psi working pressure, rating, bubble-tight at 50 psi differential pressure, externally adjustable bronze packing gland with Buna-N packing, valve body to fit between ASME B16.1 Class 125/150 flanges.
   b. Manufacturers and Products:
      1) Bray Controls; Series 35.
      2) Tyco/Keystone; Figure 106.
10. Type V512 Lug Butterfly Valve 2 Inches to 20 Inches for Digester Gas:
   a. Lug style, two-piece cast-iron body, one-piece Type 316 stainless steel thin-profile disc and stem, heavy-duty stem bushing, NBR stem seal, FKM (Viton) replaceable resilient seat, 50 psi pressure bi-directional bubble-tight rating, suitable for temperatures up to 250 degrees F, valve body to fit between ASME B16.1 Class 125/150 flanges. Supply reduced disc diameter, if available.
   b. Manufacturers and Products:
      1) Bray Controls; Model 21.
      2) Tyco/Keystone; Model 920.
11. Type V513 Butterfly Valve 2 Inches to 20 Inches:
   a. [Wafer] [Lug] style, [cast-iron] [ductile iron] body, [aluminum bronze] [ductile iron] [Type 316 stainless steel] disc, Type 316 or Type 18-8 stainless steel one-piece stem, [Buna-N] [EPDM] [FKM (Viton)] replaceable resilient seat, heavy-duty self-lubricating sleeve type bushings, NBR stem seal, 150 psi working pressure rating, valve body to fit between ASME B16.1 Class 125/150 flanges.
   b. Manufacturers and Products:
      1) Bray Controls; Series 30/31.
      2) Tyco/Keystone; Model AR1/AR2.
      3) Crane/Centerline; Series 200.
12. Type V514 High Performance Butterfly Valve 2 Inches to 36 Inches:
   a. ASME B16.1 Class [150] [300] [lug] [wafer] style, high performance type, [carbon steel] [Type 316 stainless steel] body, Type 316 stainless steel single or double offset disc, Type 316 stainless steel shaft and taper

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pins, [PTFE] [EPDM] [Buna-N] seat, PTFE stem packing, stainless steel with RTFE thrust washer.

b. Manufacturers and Products:
   1) Tyco/Keystone; K-Lok Series.
   2) DeZurik; BHP Series.

13. Type V520 Solid Polyvinyl Chloride Butterfly Valve 1-1/2 Inches to 8 Inches:
   a. Wafer body type, pressure rated 150 psi at 70 degrees F CWP, solid ASTM D1784, Type I, Grade 1, PVC body and contoured PVC or polypropylene valve disc, stainless steel valve stem, Viton seat, lever operator.
   b. Manufacturers and Products:
      1) ASAHI/America; Type [57].
      2) Spears.
   c. Type V530 Butterfly Valve 4 Inches to 20 Inches for Fire Protection Service:
   d. UL Listed and FM Approved, [wafer] [flanged] [mechanical joint] style, AWWA C504 Class 150B valve with cast-iron body, aluminum-bronze disc, stainless steel stem, EPDM seat, geared operator with highly visible position indicator and detachable crank handle.
   e. For buried service, provide post indicating assembly with detachable crank handle.
   f. Manufacturer and Product: Pratt; [IBV] [PIVA].

F. Check and Flap Valves:

1. Type V600 Check Valve 2 Inches and Smaller:
   a. All bronze, threaded cap, threaded or soldered ends, swing type replaceable bronze disc, rated 125-pound SWP, 200-pound WOG.
   b. Manufacturers and Products:
      1) Stockham; Figure B-319, threaded ends.
      2) Milwaukee; Figure 509, threaded ends.
      3) Stockham; Figure B-309, soldered ends.
      4) Milwaukee; Figure 1509, soldered ends.
2. Type V602 Check Valve 2 Inches and Smaller:
   a. All bronze, threaded cap, threaded ends, swing type replaceable Teflon disc and bronze disc holder, rated 150-pound SWP, 300-pound WOG.
   b. Manufacturers and Products:
      1) Walworth; Figure 3412.
      2) Milwaukee; Figure 510.
3. Type V604 Check Valve 2-1/2 Inches to 12 Inches:
   a. Flanged end, cast-iron body, bronze mounted swing type, solid bronze or cast-iron disc, bronze seat ring, rated 125-pound SWG, 200-pound WOG.

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b. Manufacturers and Products:
   1) Stockham G-931; List 37, Clearway check valve.
   2) Crane Co.; Cat. No. 373.

4. Type V606 Check Valve 2 Inches to 12 Inches:
   a. Flanged end, cast-iron body, bronze mounted swing type, solid bronze or cast-iron disc, bronze seat ring, outside lever and [weight,] [spring,] rated 125-pound SWP, 200-pound WOG.
   b. Manufacturers and Products:
      1) Stockham; G-931.
      2) Crane Co.; Cat. No. 383.
5. Type V608 Swing Check Valve 2 Inches to 24 Inches:
   a. AWWA C508, 125-pound flanged ends, cast-iron body, bronze body seat, bronze mounted cast-iron clapper with [bronze seat] [rubber facing], stainless steel hinge shaft.
   b. Valves, 2 inches through 12 inches rated 175-pound WWP and 14 inches through 24 inches rated 150-pound WWP. Valves to be [plain fitted] [fitted with adjustable outside lever and weight] [fitted with adjustable outside lever and spring] [fitted with dual adjustable outside levers and springs]. Increasing-pattern body valve may be used where increased outlet piping size is shown.
   c. Manufacturers and Products:
      1) M&H Valve; Style 59, 159, or 259.
      2) Mueller Co.; No. A-2600 Series.
6. Type V610 Swing Check Valve 2-1/2 Inches to 12 Inches for Fire Protection Service:
   a. UL Listed, FM Approved, iron body, bronze-mounted, rated 175 pounds WOG, self-adjusting bronze disc, ends ASME B16.1 flanged, with a 1-inch NPT tapped and plugged boss.
   b. Manufacturers and Products:
      1) Kennedy; Figure 126.
      2) Mueller; A-2120-6.
7. Type V612 Double Disc Swing Check Valve 2 Inches to 48 Inches:
   a. Wafer style, spring loaded, cast-iron body, aluminum-bronze or ductile iron discs, Buna-N resilient seats, and Type 316 stainless steel spring, hinge pin, and stop pin.
   b. Valves 2 inches through 12 inches rated 200 psi nonshock working pressure and valves 14 inches through 48 inches rated 150 psi nonshock working pressure.
   c. Manufacturers and Products:
      1) APCO; Series 9000.
      2) Val-Matic; Dual Disc.
      3) Crane/Stockham; WG-970.
      4) Tyco; Gulf MB Series.

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8. Type V614 Slanting Disc Check Valve 2 Inches to 60 Inches:
   a. Slanting or tilting disc design, off-center pivot, body ductile iron two-piece design, bronze seat on 55 degree angle, disc bronze or ductile iron, pivot pin and bushing Type 304 stainless steel, Class 125, 150 psi rating, Class 125 flange drilling, [bottom mounted buffer cylinder for cushion closing] [valve disc position indicator].
   b. Manufacturers and Products:
      1) APCO; Series 800.
      2) Val-Matic; Series 9800.
9. Type V615 Slanting Disc Check Valve 2 Inches to 60 Inches:
   a. Slanting or tilting disc design, off-center pivot, body ductile iron two-piece design, bronze seat on 55 degree angle, disc bronze or ductile iron, pivot pin and bushing Type 304 stainless steel, Class 250, 300 psi rating, Class 250 flange drilling, flat face, [bottom mounted buffer cylinder for cushion closing] [valve disc position indicator].
   b. Manufacturers and Products:
      1) APCO; Series 800.
      2) Val-Matic; Series 9700.
10. Type V616 Slanting Disc Check Valve 2 Inches to 36 Inches:
   a. Off-center pivoting disc design, wafer style, cast-iron body, ductile iron discs, Type 316 stainless steel pivot pin, spring pin, and bushing, Buna-N disc seal, Type 316 stainless steel or Monel spring, [Class 125] [Class 250].
   b. Manufacturers and Products: Daniel Flow Products; Chexter 1600 Series, Type D.
11. Type V617 Wafer Style Check Valve 2 Inches to 36 Inches:
   a. Wafer style, swing check, one-piece body design, full resilient seal in machined body groove. [Cast-iron] [Carbon steel] [Type 316 stainless steel] body, ASME B16.1 Class [125] [150] [300] rating, Type 316 stainless steel disc, Type 316 stainless steel spring and other internals, Buna-N seal, [outside lever assembly,] [outside lever and weight assembly,] [limit switch assembly,] [external] [and internal epoxy coating].
   b. Manufacturers and Products:
      1) Tyco; Prince Figure 800 Series.
      2) Crane; Uni-Chek II.
12. Type V620 Silent Check Valve 2 Inches to 10 Inches:
   a. Wafer style, iron body, center guided valve, bronze trim, [Buna-N seat,] stainless steel springs, rated 150-pound WOG.
   b. Manufacturers and Products:
      1) Mueller; Steam Specialty 91AP.
      2) APCO; Series 300.
13. Type V622 Silent Check Valve 3 Inches to 24 Inches:

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a. Globe style, center guided, [125-pound] [250-pound] flanges, cast-iron body, bronze trim, [Buna-N seat,] stainless steel spring. Valves to be FM Approved in sizes up to and including 12 inches.
b. Manufacturers and Products:
1) APCO; Series 600.
2) Val-Matic; 1800 Series.
3) Cla-Val; Series 581.

14. Type V624 Silent Check Valve 4 Inches to 12 Inches for Fire Protection Service:
a. UL Listed or FM Approved, center-guided [wafer style valve,] [globe style valve with ASME B16.1, Class 125 flanges,] iron body, bronze trim, stainless steel spring, rated 175-pound nonshock, CWP.
b. Manufacturers and Products:
1) Mueller; Steam Specialty.
2) APCO; [_____]
15. Type V630 PVC Ball Check Valve 4 Inches and Smaller:
a. ASTM D1784, Type I, Grade 1 polyvinyl chloride body, dual union socket weld ends, rated 150 psi at 73 degrees F, and Viton seat and seal.
b. Manufacturers and Products:
1) Nibco; Chemtrol Tru Union.
2) ASAHI/America.
3) Spears; True Union.
16. Type V631 4CPVC Ball Check Valve 4 Inches and Smaller:
a. ASTM D1784 Cell Class 23477B CPVC body, single or dual union socket weld ends, rated 150 psi at 73 degrees F, 110 psi at 140 degrees F, Viton seat and seal.
b. Manufacturers4 and Products:
1) Nibco; Chemtrol Tru Union.
2) ASAHI/America.
3) Spears; True Union.
17. Type V632 Ball Check Valve 3 Inches and Larger:
a. Flanged end, iron body valve with cleanout and [floating] [sinking] type hollow steel ball, vulcanized nitrile rubber exterior, flanges ASME B16.1, Class 125, rated 150-pound working pressure, suitable for vertical up or horizontal flow.
b. Manufacturers and Products:
1) FLYGT Corp; [_____].
2) Flomatic Corp.; [_____].
3) Golden Anderson; [_____].
18. Type V634 Rubber Flapper Check Valve 2 Inches to 24 Inches:
a. Iron body, ASME B16.1, Class 125 flanges, steel-reinforced Buna-N flapper raised seating ring, rated 150-pound CWP.
b. Manufacturers and Products:

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1) APCO; Series 100.
2) Val-Matic; "Swingflex."

19. Type V640 Double Check Valve Backflow Prevention Assembly 3/4 Inch to 10 Inches:
    a. Two resilient seated check valves, two [nonrising stem] [outside screw and yoke] resilient-seated isolation valves, test cocks, in accordance with AWWA C510, rated 175 psi maximum working pressure, meets requirements of USC Foundation For Cross-Connection Control and Hydraulic Research.
    b. Manufacturers and Products:
        1) FEBCO; Model 8540.
        2) Danfoss Flomatic; Model DCVE/DCV.
        3) Watts; Series 007/709.
20. Type V642 Reduced-Pressure Principle Backflow Prevention Assembly 3/4 Inch to 10 Inches:
    a. Two resilient seated check valves with an independent relief valve between the valves, two [nonrising stem] [outside screw and yoke] resilient-seated isolation valves, test cocks, in accordance with AWWA C511, rated 175 psi maximum working pressure, meets requirements of USC Foundation For Cross-Connection Control and Hydraulic Research.
    b. Manufacturers and Products:
        1) FEBCO; Model 860.
        2) Danfoss Flomatic; Model RPZE/RPZ.
        3) Watts; Series 009/909.
21. Type V644 Wet Pipe Alarm Valve:
    a. Valve and Trim:
        1) UL Listed and FM Approved as a complete unit, rated 175 psi working pressure, [125-pound ASME B16.1 flanged inlet] [and] [outlet] [grooved end outlet].
        2) Supplied with full trim for [horizontal flow] [vertical flow] [position as shown on Drawings] including, but not necessarily limited to, water pressure gauges (with test valves), alarm test valve, mechanical sprinkler alarm bell connection (with strainer), pressure switch for electric alarm signal, retarding chamber, alarm and retard chamber drains, and main drain.
        3) Provide with additional valves, piping, and fittings as required for complete and fully functioning arrangement.
    b. Manufacturers and Products:
        1) Reliable Automatic Sprinkler Co., Inc.; Model E Alarm Valve.
        2) Tyco/Central; Model [F] [G].
22. Type V652 Check Valve 2 Inches and Smaller for Fuel Oil Service:

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a. Forged steel, lift-check type integral seat, stainless steel disc, screwed ends, rated 800 psi at 850 degrees F.
b. Manufacturers and Products:
1) Smith; C80.
2) R-P&C; F90.

23. Type V654 Check Valve 2 Inches and Smaller for Heating, Chilled, and Cooling Service:
a. All-bronze type silent check valve, screwed ends, rated 200-pound WOG.
b. Manufacturers and Products:
1) Mueller; Steam Specialty No. 203-BP.
2) Metraflex; [_____].

24. Type V690 Flap Gate 6 Inches to 96 Inches:
a. Cast-iron body and cover, bronze-mounted, flanged frame type, dual pivot-point hinge arms, hinge arms bronze, hinge pins Type 304 stainless steel, seat bronze and impacted into grooves in body and cover flap, lubrication fittings for each pivot, upper and lower pivot adjustment.
b. Manufacturers and Products:
1) Rodney Hunt Co.; Series FV-AC or FV-AR.
2) Hydro Gate; Model 50C or 50.

25. Type V692 Flap Valve 4 Inches to 30 Inches:
a. Flange style frame, cast-iron body, bronze seats on body and cover, bronze hinge pins.
b. Manufacturers and Products:
1) M&H Valve; Style 47-02.
2) Clow Valve; No. F-3012.

26. Type V694 Check Valve 1 Inch to 48 Inches:
a. Elastomer type flanged or slip-on as shown on Drawings, round entry area to match pipe, contoured duckbilled shaped exit, flat bottom and off-set bill design, curved bill for 18 inches and larger, valve open with approximately 2 inches of line pressure and return to CLOSED position under zero flow condition, rated for 50 psi minimum operating pressure; flanges steel backing flange type, drilled to ASME B16.1, Class 125, plain-end valve attached with two Type 316 stainless steel adjustable bands, elastomer nylon-reinforced [neoprene] [Buna-N] [_____].
b. Manufacturer and Product: Red Valve Co.; Tideflex Check Valve Series TF-1 or 35-1.

G. Self-Regulated Automatic Valves:

1. Type V710 Pressure-Reducing Valve 2-1/2 Inches and Smaller:
a. Direct diaphragm operated, spring controlled, bronze body, NPT threaded ends, 200-psig rated minimum.

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b. Size/Rating: [_____] inch, maximum of [_____] gpm, with inlet pressure of [_____] psig. Outlet pressure set at [_____] psig.] [As shown in Valve Schedule.]
c. Manufacturers and Products:
1) Fisher; Type 75A.
2) Watts; Series 223.

2. Type V711 Pressure-Reducing Valve 2 Inches and Smaller:
a. Direct diaphragm, spring controlled, [cast-iron] [_____] body, spring case, [composition] [_____] seat and diaphragm, stainless steel valve stem, NPT threaded ends, 250-psig rated.
b. Size/Rating: [_____] inch, maximum of [_____] gpm, with inlet pressure of [_____] psig. Outlet pressure set at [_____] psig.] [As shown in Valve Schedule.]
c. Manufacturer and Product: Fisher; 95 Series.

3. Type V712 Pressure-Reducing Valve 1-1/2 Inches to 2 Inches:
a. Direct diaphragm, spring controlled, cast-iron body, aluminum diaphragm and spring case, nitrile disc/diaphragm/O-rings, internal relief, NPT threaded ends, 125-psig rated.
b. Size/Rating: [_____] inch, maximum of [_____] scfh, with inlet pressure of [_____] psig. Outlet pressure set at [_____] [As shown in Valve Schedule.]
c. Manufacturer and Product: Fisher; S200 Series.

4. Type V714 Pressure-Reducing Valve 3 Inches and Larger:
a. Hydraulically operated, diaphragm actuated, pilot controlled globe valve, ductile iron body, ASME B16.1 Class 150 flanged ends, rated 250 psi, bronze or stainless steel trim, stainless steel stem, externally mounted strainers with cocks, maintains a constant downstream pressure regardless of fluctuations in flow or upstream pressure.
b. [FDA approved fusion bonded epoxy lining [and coating] installed in accordance with AWWA C550.]
c. Size/Rating: [_____] inch, maximum of [_____] gpm, with inlet pressure of [_____] psig. Outlet pressure set at [_____] psig.] [As shown in Valve Schedule.]
d. Manufacturers and Products:
1) Cla-Val; [90-01] [690-01] Series.
2) Singer; Model [106PR] [206PR].

5. Type V716 Pressure-Reducing/Back-Pressure Sustaining Valve 3 Inches and Larger:
a. Hydraulically operated, diaphragm actuated, pilot controlled globe valve, ductile iron body, ASME B16.1 Class 150 flanged ends, rated 250 psi, bronze or stainless steel trim, stainless steel stem, externally mounted strainers with cocks, maintains a constant downstream pressure while maintaining a minimum upstream pressure.

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b. [FDA approved fusion bonded epoxy lining [and coating] installed in accordance with AWWA C550.]
c. Size/Rating: [_____] inch, maximum of [_____] gpm, with inlet pressure of [_____] psig. Outlet pressure set at [_____] psig.] [As shown in Valve Schedule.]
d. Manufacturers and Products:
1) Cla-Val; [92-01] [692-01] Series.
e. Singer; Model [106PR-R] [206PR-R].

6. Type V720 PVC Pressure Relief, By-Pass Relief, Back-Pressure Regulator, Back-Pressure, Anti-Siphon Valve 1/2 Inch to 2 Inches:
a. Direct acting diaphragm, spring controlled, in-line pattern, NPT threaded inlet and outlet, 150 psi design pressure.
b. PVC body, Teflon or Viton diaphragm, PVC or Teflon piston, high-density polyethylene or stainless steel adjusting bolt and locknut, stainless steel or coated steel spring, stainless steel fasteners.
c. Designed to open when upstream pressure reaches setpoint; set pressure adjustable from 10 psi to 100 psi, minimum. [Factory set pressure setting at [25] [_____] psi for back-pressure and anti-siphon valves, [10] [_____] psi for pressure relief valves, [100] [_____] psi for bypass relief valves], and [50] [_____] psi for back-pressure regulator valves.]
d. Manufacturers and Products:
1) Plast-O-Matic; Series RVDT.
2) Griffco; Series BPV.
3) Primary Fluid Systems; TOP Valve.

7. Type V722 PVC Pressure Regulating Valve, 1/2 Inch to 1-1/2 Inches:
a. Diaphragm operated assembly, spring controlled, in-line pattern, NPT threaded inlet and outlet, 150 psi design pressure.
b. PVC body, Viton seals and diaphragm, coated stainless steel spring, stainless steel adjusting bolt, locknut, and fasteners.
c. Designed to regulate downstream pressure closing when pressure reaches setpoint; set pressure adjustable from 5 psi to 50 psi. [Factory set pressure setting at [_____] psi.]
d. Manufacturers and Products:
1) Plast-O-Matic, Series PR.
2) Hayward; Pressure Regulator.

8. Type V725 Automatic Degassing Valve, 1/2 Inch to 3/4 Inch:
a. PVC or CPVC construction with Viton seals, NPT threaded inlet and outlet, float designed to automatically vent gases, [100] [150] psi design pressure.
b. Manufacturers and Products:
1) Plast-O-Matic; Series DGV.
2) Primary Fluid Systems, Inc.; Accu-Vent.

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9. Type V730 Pressure-Relief Valve 2 Inches and Smaller:
   a. Direct diaphragm, spring controlled, [cast-iron] [_____] body, spring case, [nitrile] [_____] seat [neoprene] [_____] diaphragm, stainless steel valve stem, NPT threaded ends, 200 psi rated.
   b. Opens when upstream pressure reaches a maximum set point.
   c. Size/Rating: [_____] inch, maximum of [_____] gpm, with inlet pressure of [_____] psig. Outlet pressure set at [_____] psig.] [As shown in Valve Schedule.]
   d. Manufacturer and Product: Fisher; 98 Series.
10. Type V732 Pressure-Relief Valve 3 Inches and Larger:
   a. Hydraulically operated, diaphragm actuated, pilot controlled globe valve, ductile iron body, ASME B16.1 Class 150 flanged ends, rated 250 psi, bronze or stainless steel trim, stainless steel stem, externally mounted strainers with cocks, to open when upstream pressure reaches a maximum set point.
   b. [FDA approved fusion-bonded epoxy lining [and coating] installed in accordance with AWWA C550.]
   c. Size/Rating: [_____] inch, set point of [_____] psig.] [As shown in Valve Schedule.]
   d. Manufacturers and Products:
      1) Cla-Val; [50-01] [650-01].
      1) Singer; Model [106-RPS] [206-RPS].
11. Type V740 Air and Vacuum Valve 1/2 Inch to 16 Inches:
   a. 1/2-inch through 3-inch NPT inlets and outlets, 4-inch and larger ASME B16.1 Class [125] [250] flanged inlet with plain outlet and protective hood.
   b. Rated [150] [300] psi working pressure, cast-iron or ductile iron body and cover, stainless steel float and trim, built and tested to AWWA C512. [Operating pressure is [_____] psi.]
   c. Manufacturers and Products:
      1) APCO Valve and Primer Corp.; Series 140 or 150.
      2) Val-Matic Valve; Series 100.
12. Type V741 Air and Vacuum Valve 4 Inches to 16 Inches with Anti-Slam Device:
   a. Equipped with anti-slam device to throttle flow of water into air valve. Design anti-slam device to permit full, unrestricted flow of air into and out of air valve but reduce flow area for water to approximately 10 percent.
   b. Rated [150] [300] psi working pressure, cast-iron or ductile iron body and cover, stainless steel float and trim, built and tested to AWWA C512, ASME B16.1 Class [125] [250] flanged inlet and plain outlet with protective hood.

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c. [Provide air release valve and isolation gate valve to meet rated working pressure. Operating pressure is [_____].]
d. Manufacturers and Products:
1) APCO Valve and Primer Corp.; Series 1900.
2) Val-Matic Valve; Series 1200/100.

13. Type V742 Air and Vacuum Valve 1/2 Inch to 16 Inches for Vertical Turbine Service:
a. Equip 1/2 inch through 3 inches with stainless steel diffuser screen to break up solid water column before coming in contact with float, manufacturer's standard double acting throttling device in outlet for throttling, NPT threaded inlet and outlet.
b. Equip 4 inches and larger with anti-slam device to throttle flow of water into air valve. Design anti-slam device to permit full, unrestricted flow of air into and out of air valve, but reduce flow area for water to approximately 10 percent. ASME B16.1 Class [125] [250] flanged inlet and NPT threaded outlet.
c. Rated [150] [300] psi working pressure, cast-iron or ductile iron body and cover, stainless steel float and trim, built and tested to AWWA C512.
d. Manufacturers and Products:
1) APCO Valve and Primer Corp.; Series 141DAT to 146DAT or Series 1904 to 1916.
2) Val-Matic Valve; Series 100WS to 116WS.

14. Type V744 Air Release Valve 1/2 Inch to 2 Inches:
a. Suitable for water service, automatically exhaust small amounts of entrained air that accumulates in a system. In CLOSED position, seat against resilient seat to prevent water leakage.
b. Rated [150] [300] psi working pressure, cast-iron or ductile iron body and cover, stainless steel float and trim, NPT threaded inlet and outlet, built and tested to AWWA C512. [Operating pressure is [_____] psi.]
c. Manufacturers and Products:
1) APCO Valve and Primer Corp.; Series 50, 200, and 200A.
2) Val-Matic Valve; Series 15A to 45.6.

15. Type V745 Air Release Valve 1/2 Inch to 1 Inch:
a. Suitable for water service, automatically exhaust small amounts of entrained air that accumulates in system. In CLOSED position, seat against resilient seat to prevent water leakage.
b. Rated 230-psi working pressure, [reinforced nylon body] [cast-iron body with brass base], foamed polypropylene float, EPDM rolling seal, Buna-N O-ring, NPT threaded inlet. [Operating pressure is [_____] psi.]
c. Manufacturer and Product: ARI Valves; [S-050] [S-050-C].

16. Type V746 Combination Air Release Valve 1 Inch to 16 Inches:

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a. Suitable for water service, combines operating features of air and vacuum valve and air release valve. Air and vacuum portion to automatically exhaust air during filling of system and allow air to re-enter during draining or when vacuum occurs. Air release portion to automatically exhaust entrained air that accumulates in system.
b. Valve single body or dual body, air release valve mounted on air and vacuum valve, isolation valve mounted between the dual valves. 1-inch through 3-inch valves with NPT threaded inlet and outlet, 4-inch and larger valves with ASME B16.1 Class [125] [250] flanged inlet and cover outlet.
c. Rated [150] [300] psi working pressure, cast-iron or ductile iron body and cover, stainless steel float and trim, built and tested to AWWA C512.
d. Manufacturers and Products:
    1) APCO Valve and Primer Corp.; Series 143C to 147C or 1804 to 1816.
    2) Val-Matic Valve; Series 201C to 203C or 104/22 to 116/38.

17. Type V747 Rolling Seal Combination Air Valve 3/4 Inch to 2 Inches:
    a. Designed for water service and uses rolling seal to allow smaller and larger amounts of air to automatically exhaust under pressure and air to enter when vacuum occurs in a single valve body.
    b. [Reinforced nylon] [Cast-iron] body with polypropylene discharge elbow, NPT inlet, 230 psi working pressure.
    c. Foamed polypropylene float, EPDM rubber rolling seal mechanism with reinforced nylon plug, plug cover, and clamping stem, Buna-N O-ring.
    d. Manufacturer and Product: ARI Valves; D-040 or D-040-C.
18. Type V748 Rolling Seal Combination Air Valve 2 Inches to 8 Inches:
    a. Suitable for water service, combines operating features of air and vacuum valve and air release valve. Air and vacuum portion to automatically exhaust air at a high rate during filling of system and allow air to re-enter during draining or when vacuum occurs. Air release portion to automatically exhaust entrained air that accumulates in system. Air release uses rolling seal mechanism.
    b. High flow air/vacuum valve, cast-iron body with stainless steel float and seat, EPDM seal, ASME B16.1 Class 125 flanged inlet, 230-psi working pressure [nonslam feature].
    c. Air release valve with foamed polypropylene float, EPDM rubber rolling seal mechanism with reinforced nylon plug, plug cover, and clamping stem, Buna-N O-ring.
    d. Manufacturer and Product: ARI Valves; D-060-C HF [NS].
19. Type V750 Sewage Air and Vacuum Valve 2 Inches to 14 Inches:
    a. Suitable for sewage service; automatically exhausts air during system filling and allows air to re-enter during draining or when vacuum occurs.

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b. Rated working pressure of 150 psi, 1-inch through 3-inch valves with NPT threaded inlet and outlet, 4-inch and larger valves with ASME B16.1 Class 125 flanged inlet and threaded cover outlet, built and tested to AWWA C512.
c. Materials: Cast-iron or ductile iron body and cover, concave or skirted stainless steel float and trim, Buna-N seat.
d. [Sewage air and vacuum valve fitted with blowoff valve, flushing valve with quick disconnect couplings, and a minimum 5 feet of hose with quick disconnect couplings to permit backflushing after installation without dismantling valve.]
e. Manufacturers and Products:
   1) APCO Valve and Primer Corp.; Series 401 SAVV to 414 SAVV.
   2) Val-Matic Valve; Series 301 to 306.

20. Type V752 Sewage Air Release Valve 2 Inches to 4 Inches:
   a. Suitable for sewage service; automatically exhausts entrained air that accumulates in a system.
   b. Rated working pressure of 150 psi, operating pressure of [_____], built and tested to AWWA C512.
   c. Materials: Cast-iron or ductile iron body and cover with NPT threaded inlet and [1/2-inch] [1-inch] NPT threaded outlet, concave or skirted stainless steel float and trim; Buna-N resilient seat.
   d. [Sewage air release valve fitted with blowoff valve, flushing valve with quick disconnect couplings, and a minimum 5 feet of hose with quick disconnect couplings to permit backflushing after installation without dismantling valve.]
   e. Manufacturers and Products:
      1) APCO Valve and Primer Corp.; Series 400 SARV or 450 SARV.
      2) Val-Matic Valve; Series 48 or 49.
21. Type V754 Sewage Combination Air Valve 2 Inches to 6 Inches:
   a. Suitable for sewage service; combines operating functions of air and vacuum valve and an air release valve. Air and vacuum portion shall automatically exhaust air during filling of a system and allow air to re-enter during draining or when a vacuum occurs. Air release portion to automatically exhaust entrained air that accumulates in system. Single body unit with air and vacuum valve and an air release valve in a single housing.
   b. Rated working pressure of 150 psi, built and tested to AWWA C512.
   c. Materials: Cast-iron or ductile iron body and covers, NTP threaded inlet and outlet, with concave or skirted stainless steel float and trim.
   d. [Sewage air release valve fitted with blowoff valve, flushing valve with quick disconnect couplings, and a minimum 5 feet of hose with quick disconnect couplings to permit backflushing after installation without dismantling valve.]

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e. Manufacturers and Products:
   1) APCO Valve and Primer Corp.; Series 440 SCAV.
   2) Val-Matic Valve; Series 800.

22. Type V756 Sewage Combination Air and Vacuum Valve 6 Inches to 14 Inches:
   a. Suitable for sewage service; combines operating functions of air and vacuum valve and an air release valve using separate valves connected together. Air and vacuum valve shall automatically exhaust large quantities of air during system filling and allow air to re-enter during draining or when a vacuum occurs. Air release valve to automatically exhaust small quantities of entrained air that accumulates in system.
   b. Rated working pressure of [150 psi, operating pressure of [_____]] [300 psi].
   c. Materials: Cast-Iron or Ductile Iron Body:
      1) Air and Vacuum Valve:
         a) Upper and lower concave or skirted stainless steel float and trim.
         b) Inlet Flanges: ASME B16.1 Class [125] [250] pound.
         c) Outlet: [Hooded.] [Flanged.]
         d) Seat: Buna-N.
      2) Air Release Valve: 2-inch NPT threaded inlet and 1/2-inch NPT threaded outlet; Buna-N seat.
   d. Provide with all-bronze blow-off and flushing gate valves for each valve, all-bronze isolation gate valve between air and vacuum valve and air release valve; 5-foot rubber hose with quick disconnect couplings.
   e. [Provide with inlet butterfly isolation valve.]
   f. Manufacturer and Product: APCO Valve and Primer Corp.; Series 400C.
23. Type V757 Sewage Rolling Seal Combination Air Valve 2 Inches to 8 Inches:
   a. Designed for sewage service, uses rolling seal to allow smaller and larger amounts of air to automatically exhaust under pressure and air to enter when a vacuum occurs in a single valve body. Body designed to allow sewage solids to flow out of valve.
   b. [Stainless steel] [Epoxy coated steel] funnel shaped body with ASME B16.1 Class 150 flanged inlet and access flanges, reinforced nylon combination air and vacuum valve assembly and polypropylene discharge elbow, 250-psi working pressure, all-bronze drain/flush valve, flushing connection.
   c. Foamed polypropylene float, EPDM rubber rolling seal mechanism with reinforced nylon plug, plug cover, and clamping stem, Buna-N O-ring.
   d. Manufacturer and Product: ARI Valves; D-020.
24. Type V760 Dual Chamber Booster Pump Control Valve 2-1/2 Inches to 16 Inches:

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a. Hydraulically operated, diaphragm actuated, pilot controlled globe valve with ductile iron body, ASME B16.1 Class 150 flanged ends, rated 250 psi, bronze or stainless steel trim, stainless steel stem, externally mounted strainer with cock. [FDA approved fusion bonded epoxy lining [and coating] installed in accordance with AWWA C550.]
b. Manufacturers and Products:
1) Cla-Val; Model 60-11.
2) Singer; Model 106-BPC.

25. Type V770 Dual Chamber Deep Well Pump Control Valve 2-1/2 Inches to 16 Inches:
a. Hydraulically operated, diaphragm actuated, solenoid controlled globe valve with ductile iron body, ASME B16.1 Class 150 flanged ends, rated 250 psi, bronze or stainless steel trim, stainless steel stem, and externally mounted strainer with cock.
b. [FDA approved fusion bonded epoxy lining [and coating] installed in accordance with AWWA C550.]
c. Manufacturers and Products:
1) Cla-Val; Model 61-02.
2) Singer; Model 106-DW.

H. Miscellaneous Valves:

1. Type V900 Diaphragm Valve 1/2 Inch to 12 Inches:
a. Weir type, [polypropylene-lined] [hard rubber-lined] [_____-lined] cast-iron body, ASME B16.1 flanged ends, manual operator indicating, rising stem type with handwheel, diaphragm [ethylene propylene,] [neoprene,] [Buna-N,] in accordance with MSS SP-88 Category B.
b. Manufacturers and Products:
1) ITT Engineered Valves; [_____].
2) Saunders Valve, Inc.; [_____].
2. Type V901 Diaphragm Valve 1/2 Inch to 12 Inches:
a. Straight-through type, [polypropylene-lined] [hard rubber-lined] [_____-lined] cast-iron body, ASME B16.1 flanged ends, manual operator indicating, rising stem type with handwheel, diaphragm [ethylene propylene,] [neoprene,] [Buna-N,] in accordance with MSS SP-88, Category B.
b. Manufacturers and Products:
1) ITT Engineered Valves; [_____].
2) Saunders Valve, Inc.; [_____].
3. Type V903 Diaphragm Valve, 1/2 Inch to 4 Inches:
a. Weir type with [PVC Type 1, Grade 1] [CPVC Type 4, Grade 1] [PVDF] body, [Viton (FKM) diaphragm] [PTFE with EPDM backing diaphragm] [PTFE with EPDM or Viton backing and with PVDF gas barrier

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diaphragm], [double union design, solvent weld socket ends] [flanged ends], handwheel operator, position indicator, adjustable travel stop, clear molded acrylic stem cap.

b. Manufacturers and Products:
   1) ASAHI/AMERICA; Diaphragm Valve Type 14.
   2) ITT Engineered Valves; Dia-Flo.
   3) Saunders Valve; Diaphragm Valve.

4. Type V905 Pinch Valve 1 Inch to 12 Inches:
   a. Cast-iron fully enclosed body, epoxy lined and coated, ASME B16.1 Class 125 flanged ends, one-piece molded Buna-N elastomer tube, full-port design, 90 psi minimum working pressure, double-acting upper and lower pinch bars that close on centerline, stainless steel stem, handwheel operator, position indicator, geared operator for valves 6 inches and larger.
   b. Manufacturers and Products:
      1) Red Valve Co.; Series 75.
      2) RF Technologies, Inc.; RF Valve.
5. Type V910 Telescoping Scum Collection Valve:
   a. Rack and pinion type with offset floor stand and cast-iron offset floor stem incorporating rack guides, pinion, and handwheel supports. Rack and pinion and connecting rods Type 304 stainless steel, slip pipe brass with flat weir-crest skimming funnel, cast-iron pipe companion flange, O-ring seal and gasket for connection to discharge pipe. Skimming funnel minimum top diameter of 8 inches.
   b. Valve, 4 inches nominal and continuously adjustable from a high point of [1.5] [_____] feet below bottom of floor stand to a low point [5.50] [_____] feet below bottom of floor stand.
   c. Anchor Bolts: Type 316 stainless steel.
   d. Manufacturers and Products:
      1) Link-Belt Division of FMC Corp.; [_____].
      2) Envirex Division of Rexnord Corp.; [_____].
6. Type V915 Mud Valve 4 Inches to 24 Inches:
   a. Cast-iron frame, yoke, and gate; heavy-duty 125-pound flange style, bronze seat, Buna-N seal, [nonrising stem] [rising stem], bronze stem and stem nut, 2-inch square operating nut, [cast-iron floor box,] [Type 304 stainless steel extension stem; stem guides spaced for L/R of 200 maximum].
   b. Manufacturers:
      1) Troy Valve.
      2) Trumbull Industries, Inc.
      3) Clow Valve Company.
7. Type V916 Cast Stainless Steel Mud Valve 4 Inches to 20 Inches:

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a. Heavy-duty cast Type 316 stainless steel yoke, flange, guides, and gate; SBR rubber seat mechanically retained with Type 316 stainless steel fasteners, [nonrising stem] [rising stem]. Stainless steel casting to be passivated per ASTM A380. Type 316 stainless steel one-piece stem with integral thrust collar and coated with antigalling compound.
b. [Stem extension one-piece Type 316 stainless steel,] [2-inch operating nut,] [14-inch diameter ductile iron handwheel,] [indicating stainless steel floorstand and wall bracket.] [floor box with position indicator.] [wall bracket with position indicator.] Stem guides Type 316 stainless steel with bronze bushings for L/R of 200 maximum. Cast top and bottom stem couplings Type 316 stainless steel.
c. Manufacturer: Trumbull Industries, Inc.

8. Type V920 Hydrostatic Pressure Relief Valve, Floor Type 4 Inches:
   a. Floor type, cast-iron body, grate, and cover, removable cover and strainer, body with integral seep ring, body length as shown on Drawings, neoprene rubber cover seat, epoxy body seat.
   b. Manufacturers and Products:
      1) M&H Valve; Style 147, F-1493.
      2) Clow Valve; Figure F-1493.
9. Type V921 Hydrostatic Pressure Relief Valve, Wall Type 4 Inches:
   a. Wall type, flange style frame, cast-iron body and cover, bronze seat body, resilient rubber seat on cover, bronze hinge pins, cast-iron wall pipe with integral seep ring and strainer, length as shown on Drawings.
   b. Manufacturers and Products:
      1) M&H Valve; Style 147, F-1494/F-1496.
      2) Clow Valve; Figure F-1494/F-1496.
10. Type V925 Sampling Valve:
    a. Type 316 stainless steel wetted parts, hand operated iron crank, piston to extend to inner surface of vessel or pipe, sealed by two compressible replaceable Teflon rings, one above discharge port and other below discharge port, [3/4-inch NPT inlet and 3/4-inch NPT outlet] [1-inch NPT inlet and 1-inch NPT outlet].
    b. Manufacturers and Products:
       1) Strahman Valves, Inc.; Piston Type Sampling Valve.
       2) Fetterolf Corporation; Rod-Seal Sampling Valve.
11. Type V930 Fire Hydrant: (Describe agency standard.)
12. Type V940 Solenoid Valve 1/4 Inch to 2 Inches:
    a. Two-way internal pilot operated diaphragm type, brass body, resilient seat suitable for air or water, solenoid coil molded epoxy, NEMA insulation Class F, 120 volts ac, 60-Hz, unless otherwise indicated. Solenoid enclosure NEMA 250, Type 4 unless otherwise indicated. Size and normal position [[(OPEN] [or CLOSED] when de-energized)] as indicated.

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b. Minimum operating pressure differential no greater than 5 psig, maximum operating pressure differential not less than 125 psig.
c. Manufacturers and Products:
1) ASCO; [_____]
2) Skinner; [_____]

13. Type V950 Manual In-Line Lockout/Tagout Valve 1/4 Inch to 1-1/4 Inches for Air Service:
a. Manual in-line, three-port, heavy-duty cast aluminum body, NPT threaded ports, tee-handle, aluminum spool, stainless steel spring, nitrile seals, suitable for air pressures 0 psig to 250 psig. Safety yellow body with contrasting black, red or blue handle.
b. Lockout/tagout valve for compliance to OSHA 29 CFR Part 1910.147. Full flow in open position, exhausts downstream air in closed position, lockable in closed position.
c. Complete with NPT male threaded aluminum exhaust silencer with internal mesh element, lockout hasp.
d. Manufacturers and Products:
1) Norgren; In-Line Lockout Valve Series C00.
2) Parker Pneumatic; LV Series.
3) Ross Controls; L-O-X Valve.

14. Type V951 Manual Soft-Start In-Line Lockout/Tagout Valve 1/4 Inch to 1-1/4 Inches for Air Service:
a. Manual in-line, three-port, single unit type, heavy-duty cast aluminum body, NPT threaded ports, tee-handle, aluminum spool, stainless steel spring, nitrile seals, suitable for air pressures 30 psig to 150 psig. Safety yellow body with contrasting black, red or blue handle.
b. Lockout/tagout valve with soft start feature for compliance to OSHA 29 CFR Part 1910.147. Full flow in open position, exhausts downstream air in closed position, lockable in closed position, soft-start feature to allow gradual air pressure buildup.
c. Complete with NPT male threaded aluminum exhaust silencer with internal mesh element, lockout hasp.
d. Manufacturers and Products:
1) Parker Pneumatic; EZ Series.
2) Ross Controls; L-O-X/EEZ-ON Valve.

2.06 OPERATORS AND ACTUATORS

A. Manual Operators:

1. General:

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a. For AWWA valves, operator force not to exceed requirements of applicable valve standard. Provide gear reduction operator when force exceeds requirements.
b. For non-AWWA valves, operator force not to exceed applicable industry standard or 80 pounds, whichever is less, under operating condition, including initial breakaway. Provide gear reduction operator when force exceeds requirements.
c. Operator self-locking type or equipped with self-locking device.
d. Position indicator on quarter-turn valves.
e. Worm and gear operators one-piece design, worm-gears of gear bronze material. Worm of hardened alloy steel with thread ground and polished. Traveling nut type operator's threaded steel reach rod with internally threaded bronze or ductile iron nut.

2. Exposed Operator:
   a. Galvanized and painted handwheel.
   b. Cranks on gear type operator.
   c. Chain wheel operator with tieback, extension stem, floor stand, and other accessories to permit operation from normal operation level.
   d. Valve handles to take a padlock, and wheels a chain and padlock.
3. Buried Operator:
   a. Buried service operators on valves larger than 2-1/2 inches shall have a 2-inch AWWA operating nut. Buried operators on valves 2 inches and smaller shall have cross handle for operation by forked key. Enclose moving parts of valve and operator in housing to prevent contact with the soil.
   b. Buried service operators to be grease packed and gasketed to withstand submersion in water to 20 feet minimum.
   c. Buried valves shall have extension stems, bonnets, and valve boxes.

B. Electric Motor Actuators:

1. General:
   a. Comply with latest version of AWWA C542.
   b. Size to 1-1/2 times required operating torque. Motor stall torque not to exceed torque capacity of valve.
   c. Controls integral with actuator and fully equipped as specified in AWWA C542.
   d. Stem protection for rising stem valves.
2. Actuator Operation—General:
   a. Suitable for full 90-degree rotation of quarter-turn valves or for use on multiturn valves, as applicable.
   b. Manual override handwheel.
   c. Valve position indication.

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d. Operate from FULL CLOSED to FULL OPEN positions or the reverse in the number of seconds given in Electric Motor Actuator Schedule.
e. [Nonintrusive Electronics: Local controls, diagnostics, and calibration, including limit and torque switch settings, shall be accomplished nonintrusively. Electronic valve position display with capability to show continuous torque output. If applicable, provide two hand-held configuration units for every 10 actuators provided, two minimum.]

3. Open-Close(O/C)/Throttling(T) Service:
   a. Size motors for one complete OPEN-CLOSE-OPEN cycle no less than once every 10 minutes.
   b. Actuator suitable for throttling operation of valve at intermediate positions.
   c. LOCAL-OFF-REMOTE Selector Switch, padlockable in each position:
      1) Integral OPEN-STOP-CLOSE momentary pushbuttons with seal-in circuits to control valve in LOCAL position.
      2) Remote OPEN-STOP-CLOSE momentary control dry contact inputs in REMOTE position. Integral seal-in circuits for remote OPEN and CLOSE commands; valve travel stops when remote STOP contact opens.
      3) Auxiliary contact that closes in REMOTE position.
   d. OPEN and CLOSED indicating lights.
   e. Integral reversing motor starter with built-in overload protection.
   f. Valve shall remain in last position on loss of operator power.
4. Modulating (M) Service:
   a. Size motors for continuous duty.
   b. Feedback potentiometer, or equivalent, and integral electronic positioner/comparator circuit to maintain valve position.
   c. HAND-OFF-AUTO (Local-Off-Remote) Selector Switch, padlockable in each position:
      1) Integral OPEN-STOP-CLOSE momentary pushbuttons with seal-in circuits to control valve in HAND (Local) position.
      2) 4 to 20 mA dc input signal to control valve in AUTO (Remote) position.
      3) Auxiliary contact that closes in AUTO (Remote) position.
   d. Valve shall close upon loss of signal, unless otherwise indicated.
   e. OPEN and CLOSED indicating lights.
   f. Ac motor with solid state reversing starter or dc motor with solid state reversing controller, and built-in overload protection. Controller capable of 1,200 starts per hour.
   g. Duty cycle limit timer and adjustable band width, or equivalent, to prevent actuator hunting.

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h. Valve position output converter that generates isolated 4 mA to 20 mA dc signal in proportion to valve position, and is capable of driving into loads of up to 500 ohms at 24 volts dc.

5. Actuator Power Supply:
   a. 480 volts, three-phase, unless otherwise indicated.
   b. Control power transformer, 120-volt secondary.
   c. Externally operable power disconnect switch.
6. Enclosure:
   a. As defined in NEMA 250, Type 4, unless otherwise indicated.
   b. Contain 120-volt space heaters, if required to prevent condensation.
7. Limit Switch:
   a. Single-pole, double-throw (SPDT) type, field adjustable, with contacts rated for 5 amps at 120 volts ac.
   b. Each valve actuator to have a minimum of two auxiliary transfer contacts at end position, one for valve FULL OPEN and one for valve FULL CLOSED.
   c. Housed in actuator control enclosure.
8. Control Features: Electric motor actuators with features as noted above, and as modified/supplemented in Electric Motor Actuator Schedule.
9. Manufacturers and Products:
   a. Rotork Controls; [_____].
   b. Flowserve Limitorque; [_____].

C. Pneumatic Actuators:

1. General:
   a. Actuator complete with air sets, exhaust mufflers, speed controls, pilot solenoids, safety vented isolation valves, and accessories.
   b. Suitable for full operation range of valve at air supply pressure indicated.
   c. Position indication and stop limiting devices on all actuators.
2. Vane Style Actuator:
   a. In compliance with AWWA C541.
   b. Air supply of [80 psig] [_____].
   c. Pressure die-cast aluminum housing with corrosion resistant fusion bonded epoxy finish, stainless steel bolting, stainless steel adjustable end stops.
   d. Electroless nickel-plated steel shaft and vane, single-component machined or cast part.
   e. Dual-opposed polyurethane lip seals with stainless steel expander.
   f. Double Acting:
      1) Complete with mounting hardware.
      2) Suitable for non-lubrication air.
   g. Spring Return:

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1) Wound stainless steel spring type in separate housing.
2) Attached to pneumatic actuator housing.

3. Geared Manual Override: Geared type with de-clutchable handwheel, torque rated for application.
   a. Visual Indicator: High visibility, OPEN-CLOSED indication, color coded, chemical resistant, clear polycarbonate cover.
   b. Manufacturers:
      1) Kinetrol.
      2) K-Tork.
4. Cylinder Actuator:
   a. In compliance with AWWA C541.
   b. Air supply pressure of [80 psig] [_____].
   c. Nonswivel type totally enclosed:
      1) Travel stops and position indicator.
      2) Factory lubricated and sealed requiring no additional lubrication.
   d. Double Acting:
      1) Nonmetallic for operation on nonlubricated air.
      2) Handwheel override independent of cylinder.
   e. Spring Return:
      1) Open, closed, or throttling, steel cylinder with air line lubricators. Nonlubricated air may be used if certified by manufacturer.
      2) Modulating: Nonmetallic for operation on nonlubricated air.
      3) Manual override manufacturer's standard.
   f. Actuators used on quarter-turn valves to include a totally enclosed valve actuating mechanism. Actuating mechanism to be factory lubricated and sealed.
   g. Manufacturers and Products:
      1) Rotork.
      2) DeZurik.
5. Diaphragm Actuator:
   a. Spring return with steel or aluminum diaphragm case and spring barrel, steel spring and actuator stem, and fabric-reinforced neoprene diaphragm.
   b. Actuators used on quarter-turn valves to include a totally enclosed valve actuating mechanism. Actuating mechanism to be factory lubricated and sealed.
   c. Diaphragm actuators sized and configured for service indicated and air supply pressure of [35 psig] [_____].
   d. Manufacturers and Products:
      1) Fisher Controls; Type 1051.
      2) Keystone Valve; Figure 723.
   e. Accessories:

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1) Air Set: Pressure regulator with internal relief, filter, outlet pressure gauge, and adjustable reduced pressure range as required by valve actuator.
2) Aluminum body and handwheel.
3) Safety vented lockout isolation valve.
4) Gauge range 1-1/3 to 2 times maximum operating pressure.
5) Manufacturers and Products:
   a) Fisher Controls; Type 67 AFR.
   b) Masoneilan; No. 77-4.

f. Air Exhaust Muffler:
1) In the exhaust port of actuator pilot solenoid valves.
2) Manufacturers and Products:
   a) Barry Wright Corp.; [_____].
   b) Allied Witan Co.; [_____].

g. Limit Switch:
1) Single-pole, double-throw (SPDT) type, rated 10 amps at 120 volts ac.
2) Housed in NEMA 4X enclosure.
3) Adjustable for OPEN and CLOSED valve positions.

h. Positioner:
1) For modulating actuators, shall be pneumatic force balance instruments to control valve position as a function of input signal. Accomplish positive positioning of valve by a mechanical feedback connection from valve actuating mechanism. Position feedback through a characterized linear cam to allow adjustment of valve positioning and input signal. Positioner suitable for double acting or spring return actuator.
2) Positioner to have zero and span adjustment and be field reversible for direct or reverse action.
3) Gauges for supply and output pressure and for input signal pressure.
4) Positioner for 3 psig to 15 psig pneumatic input signal or 4 mA to 20 mA dc input signal as indicated.
5) Positioner for dc input signal with transducers shall convert electrical signal to appropriate pneumatic signal. Transducer integral with positioner or separate component. If separate, factory mount transducer on pneumatic operator. Line electric power not required for transducer.
6) Corrosion-resistant enclosures for positioners and transducers to be splash-proof and moisture-proof with gasketed covers.

i. Pilot Solenoid Valve:
1) Solenoid valve shall pilot control actuator in appropriate configuration for type of open-close actuator being controlled.

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Double acting actuator shall have four-way solenoid valve, and spring return actuator shall have three-way solenoid valve. Dual coil valve shall not change position unless one coil is energized while the other is de-energized.

2) Pilot operated diaphragm type solenoid valve with brass body and resilient seat. Valve with minimum operating pressure differential no greater than 10 psig and maximum operating pressure differential no less than 150 psig. Internal parts corrosion-resistant. Solenoid valve to have Class F molded coils for operation on 120 volts ac, 60-Hz, unless otherwise indicated. Solenoid enclosure as defined in [NEMA 250, Type 4X] [_____].

3) Manufacturers and Products:
   a) Asco Red Hat; [_____].
   b) C. A. Norgren Co.; [_____].

j. Open-Close and Throttling Valve:
k. Double Acting Cylinders: Four-way solenoid with dual coils.
l. Spring Return Cylinders: Three-way solenoids, spring return.

6. Modulating Valve: Positioner with 4 mA to 20 mA input signal, unless otherwise indicated.
7. Control Features: Pneumatic actuators with features noted in the Pneumatic Actuator Schedule.

2.07 ACCESSORIES

A. Tagging: 1-1/2-inch diameter heavy brass or stainless steel tag attached with No. 16 solid brass or stainless steel jack chain for each [valve operator] [valve] [valve [_____] inch and larger], bearing valve tag number shown on [Electric Motor Actuator Schedule] [Pneumatic Actuator Schedule] [Self-Regulated Valve Schedule] [Drawings].

B. Limit Switch:

1. Factory installed NEMA 4X limit switch by actuator manufacturer.
2. [SPST, rated at 5 amps, 120 volts ac.] [_____]

C. T-Handled Operating Wrench:

1. [_____] each galvanized operating wrenches, 4 feet long.
2. Manufacturers and Products:
3. Mueller; No. A-24610.
4. Clow No.; F-2520.
5. [_____] each galvanized operating keys for cross handled valves.

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D. Extension Bonnet for Valve Operator: Complete with enclosed stem, extension, support brackets, and accessories for valve and operator.

1. Manufacturers and Products:
    a. Pratt; [_____].
        1) DeZurik; [_____].

E. Floor Stand:

1. Nonrising, heavy pattern, indicating type.
2. Complete with solid extension stem, coupling, handwheel, stem guide brackets, and yoke attachment. Stem length as required to connect valve operating nut and floor stand.
3. Stem Guide: Space such that stem L/R ratio does not exceed 200.
4. Anchor Bolts: Type 304 stainless steel.
5. Manufacturers and Products:
    a. Clow; Figure F-5515.
    b. Mueller, Figure A-26426.

F. Floor Box:

1. Plain type, for support of nonrising type stem.
2. Complete with solid extension stem, operating nut, and stem guide brackets. Stem length as required to extend valve operating nut to within 3 inches of finish floor.
3. Stem Guide: Space such that stem L/R ratio does not exceed 200.
4. Anchor Bolts: Type 304 stainless steel.
5. Manufacturers and Products:
    a. Neenah Foundry; R 7506.
    b. Clow; No. F5690.

G. Chain Wheel and Guide:

1. Handwheel direct-mount type.
2. Complete with chain.
3. Galvanized or cadmium-plated.
4. Manufacturers and Products:
    a. Clow Corp.; Figure F-5680.
    b. Walworth Co.; Figure 804.
    c. DeZurik Corp.; Series W or LWG.

H. Cast-Iron Valve Box: Designed for traffic loads, sliding type, with minimum of 5-1/4-inch ID shaft.

1. Box: Cast iron with minimum depth of 9 inches.

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2. Lid: Cast iron, minimum depth 3 inches, [nonlocking type,] [locking type,] marked [WATER] [SEWER] [GAS] [_____].
3. Extensions: [Cast iron.] [Cast iron, ABS, or PVC pipe.]
4. Two-piece box and lid for valves 4 inches through 12 inches, three-piece box and lid for valves larger than 12 inches with base sized for valve.
5. Valve extension stem for valves with operating nuts 3 feet or greater below finish grade.
6. Manufacturers and Products:
   a. East Jordan Iron Works; Cast-Iron Valve Boxes.
   b. Bingham & Taylor; Cast-Iron Valve Boxes.

I. Concrete Valve Box: Designed for traffic loads, sliding type, with minimum of 10-inch ID shaft.

1. Box: High-density, reinforced concrete, minimum depth 12 inches, cast-iron ring seat.
2. Lid: Cast iron, minimum depth 3 inches, marked [WATER] [SEWER] [GAS] [_____].
3. Extensions: [Concrete.] [ABS, PVC, or cast-iron pipe.]
4. Manufacturers and Products:
   a. Christy Concrete Products; G Series.
   b. BES Concrete Products; G Series.

J. Indicator Post Assembly:

1. Cast or ductile iron post head, bell, and wrench with cast or ductile iron or steel barrel.
2. Plexiglas or equal protected window to indicate OPEN and CLOSED position.
3. Padlockable eye bolt for wrench.
4. Adjustable bury depth. Bury depth as required for valve installation.
5. UL Listed and FM Approved.
6. Manufacturers and Products:
   a. Clow; Style 2945.
   b. Mueller; A-20806.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Flange Ends:

1. Flanged valve bolt holes shall straddle vertical centerline of pipe.
2. Clean flanged faces, insert gasket and bolts, and tighten nuts progressively and uniformly.

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B. Screwed Ends:

1. Clean threads by wire brushing or swabbing.
2. Apply joint compound.

C. PVC and CPVC Valves: Install using solvents approved for valve service conditions.

D. Valve Installation and Orientation:

1. General:
   a. Install valves so handles operate from fully open to fully closed without encountering obstructions.
   b. Install valves in location for easy access for routine operation and maintenance.
   c. Install valves per manufacturer's recommendations.
2. Gate, Globe, and Ball Valves:
   a. Install operating stem vertical when valve is installed in horizontal runs of pipe having centerline elevations 4 feet 6 inches or less above finished floor, unless otherwise shown.
   b. Install operating stem horizontal in horizontal runs of pipe having centerline elevations greater than 4 feet 6 inches above finish floor, unless otherwise shown.
3. Eccentric Plug Valves:
   a. Unless otherwise restricted or shown on Drawings, install valve as follows:
      1) Liquids with suspended solids service with horizontal flow: Install valve with stem in horizontal position with plug up when valve is open. Install valve with seat end upstream (flow to produce unseating pressure).
      2) Liquids with suspended solids service with vertical flow: Install valve with seat in highest portion of valve (seat up).
      3) Clean Liquids and Gas Service: Install valve with seat end downstream of higher pressure when valve is closed (higher pressure forces plug into seat).
4. Butterfly Valves:
   a. Unless otherwise restricted or shown on Drawings, install valve a minimum of 8 diameters downstream of a horizontal elbow or branch tee with shaft in horizontal position.
   b. For vertical elbow or branch tee immediately upstream of valve, install valve with shaft in vertical position.
   c. For horizontal elbow or branch tee immediately upstream of valve, install valve with shaft in horizontal position.

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d. When installed immediately downstream of swing check, install valve with shaft perpendicular to swing check shaft.
e. For free inlet or discharge into basins and tanks, install valve with shaft in vertical position.

5. Check Valves:
   a. Install valve in horizontal or vertical flow (up) flow piping only for liquid services.
   b. Install valve in vertical flow (up) piping only for gas services.
   c. Install swing check valve with shaft in horizontal position.

E. Install line size ball valve and union upstream of each solenoid valve, in-line flow switch, or other in-line electrical device, excluding magnetic flowmeters, for isolation during maintenance.

F. Install safety isolation valves on [compressed air] [fuel oil] [_____].

G. Locate valve to provide accessibility for control and maintenance. Install access doors in finished walls and plaster ceilings for valve access.

H. Extension Stem for Operator: Where depth of valve operating nut is 3 feet or greater below finish grade, furnish operating extension stem with 2-inch operating nut to bring operating nut to a point within 6 inches of finish grade.

I. Torque Tube: Where operator for quarter-turn valve is located on floor stand, furnish extension stem torque tube of a type properly sized for maximum torque capacity of valve.

J. Floor Box and Stem: Steel extension stem length shall locate operating nut in floor box.

K. Chain Wheel and Guide: Install chain wheel and guide assemblies or chain lever assemblies on manually operated valves over 6 feet 9 inches above finish floor. Install chain to within 3 feet of finish floor. Where chains hang in normally traveled areas, use appropriate “L” type tie-back anchors. Install chains to within operator horizontal reach of 2 feet 6 inches maximum, measured from normal operator standing location or station.

3.02 TESTS AND INSPECTION

A. Valve may be either tested while testing pipelines, or as a separate step.

B. Test that valves open and close smoothly under operating pressure conditions. Test that two-way valves open and close smoothly under operating pressure conditions from both directions.

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C. Inspect air and vacuum valves as pipe is being filled to verify venting and seating is fully functional.

D. Count and record number of turns to open and close valve; account for discrepancies with manufacturer's data.

E. Set, verify, and record set pressures for relief and regulating valves.

F. Automatic valves to be tested in conjunction with control system testing. Set opening and closing speeds, limit switches, as required or recommended by ENGINEER.

G. Test hydrostatic relief valve seating; record leakage. Adjust and retest to maximum leakage of 0.1 gpm per foot of seat periphery.

3.03 MANUFACTURER'S SERVICES

A. Valve(s) as listed below require manufacturer's field services:

1. [V504,] [V754,] [_____]

B. Manufacturer's Representative: Present at Site for minimum person-days listed below, travel time excluded:

1. [_____] person-days for [installation assistance] [and] [inspection].
2. [_____] person-days for [functional] [and] [performance] testing and completion of Manufacturer's Certificate of Proper Installation.

C. See [Section 01 43 33, Manufacturers' Field Services,] [and] [Section 01 91 14, Equipment Testing and Facility Startup.]

3.04 SUPPLEMENTS

A. The supplements listed below, following "End of Section," are part of this Specification.

1. Electric Motor Actuator Schedule.
2. Pneumatic Actuator Schedule.
3. Self-Regulated Valve Schedule.

END OF SECTION

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ELECTRIC MOTOR ACTUATOR SCHEDULE

Tag Number	Valve Type	Valve Size (inches)	Process Fluid	Maximum Operating Flow (gpm)	Maximum ΔP (psi)	Service	Travel Time (Seconds)	Control Feature Modifications/ Supplements

Service: O/C = Open-Close, T = Throttling, M = Modulating

Control Feature Modifications/Supplements:

A = Actuator shall open valve upon loss of signal.

B = Actuator shall remain in last position upon loss of signal.

C = Local OPEN-CLOSE momentary pushbuttons that must be continuously depressed to initiate/maintain valve travel; travel stops when pushbutton is released or when end of travel limit is reached.

D = Remote OPEN-CLOSE maintained dry contacts; travel stops when remote contact opens, or when end of travel limit is reached.

E = Three 24-volt dc interposing relays for remote OPEN-STOP-CLOSE control. Relays powered externally, thereby permitting valve control from greater distances.

F = Motor and control enclosure(s) NEMA 250, Type 6 (IP 68).

G = Motor and control enclosure(s) NEMA 250, Type 7.

H = Valve position output converter that generates isolated 4 to 20 mA dc signal in proportion to valve position, and is capable of driving into loads of up to 500 ohms at 24 volts dc.

I= Operation from 120-volt, single-phase power.

J = Operation from [_____-volt], single-phase power.

K = Operation from [_____-volt], three-phase power.

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PNEUMATIC ACTUATOR SCHEDULE

Tag Number	Valve Type	Size (inches)	Fluid	Maximum Operating Flow	Maximum ΔP (psi)	Service	Travel Time (Seconds)	Actuator Type and Control Features

Service: O/C = Open-Close, T = Throttling, M = Modulating

Actuator Type and Control Features:

A = Vane Type Actuator

B = Cylinder Type Actuator

C = Diaphragm Type Actuator

D = Valve shall open upon loss of signal.

E = Valve shall remain in last position upon loss of signal.

FC = Fail Close on loss of air supply (Air to open, spring to close).

FO = Fail Open on loss of air supply (Air to close, spring to open).

G = Positioner with 3 to 15 psig pneumatic input signal.

H = Valve position output converter that generates isolated 4 to 20 mA dc signal in proportion to valve position, and is capable of driving into loads of up to 500 ohms at 24 volts dc.

I = Visual indicator

J = Manual handwheel override

L = Limit Switch

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SELF-REGULATED VALVE SCHEDULE							
Tag No.	**Valve Type No.**	**Size (inches)**	**Inlet* Pressure**	**Outlet* Pressure**	**Maximum psig**	**Flow (gpm)**	**Fluid**
*Inlet Pressure = Set pressure for pressure relief valve or downstream set pressure for pressure reducing valve.							

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SECTION 40 50 00
POWER PLANT PIPING MATERIALS

PART 1 - GENERAL

1.01 SUMMARY

A. The following is a list of standards which may be referenced in this section:

1. American Petroleum Institute (API): SPEC 5L, Specification for Line Pipe.
2. American Society of Mechanical Engineers (ASME):
   a. B16.5, Pipe Flanges and Flanged Fittings.
   b. B16.20, Metallic Gaskets for Pipe Flanges - Ring Joint, Spiral-Wound, and Jacketed.
   c. B16.21, Nonmetallic Flat Gaskets for Pipe Flanges.
   d. B31.1, Power Piping.
3. ASTM International (ASTM):
   a. A193/A193M, Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service.
   b. A194/A194M, Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure or High-Temperature Service or Both.
   c. D1785, Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120.
   d. D2467, Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80.
   e. F441, Standard Specification for Chlorinated Polyvinyl Chloride (CPVC) Plastic Pipe, Schedules 40 and 80
   f. F439, Standard Specification for Socket-Type Chlorinated Polyvinyl Chloride (CPVC) Plastic Pipe Fittings, Schedule 80
1. Manufacturers Standardization Society of the Valve and Fittings Industry, Inc. (MSS): SP-95, Swage (D) Nipples and Bull Plugs.
2. Uniform Plumbing Code (UPC).

1.02 SYSTEM DESCRIPTION

A. Design Requirements: In accordance with this Section, ASME B31.1, NFPA 24, and the Uniform Plumbing Code (UPC), as applicable. Deviations and alternates are not permitted.

1.03 SUBMITTALS

A. Quality Control Submittals: Certificates of Compliance for all other materials.

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1.04 DEFINITIONS

A. Certificates of Compliance (COCs):

B. Certify that materials are new and comply with requirements of Pipe Data Sheets material specification and grade, class, or type designation.

1. Certify manufacturing standard that applies to components.
2. Be signed by Manager of pipe manufacturer's Quality Control Department and shall indicate both the purchase order number and the engineer's project number.

PART 2 - PRODUCTS

2.01 GENERAL

A. Piping materials and components shall be in accordance with pipe data sheets at end of Section.

PART 3 - EXECUTION

3.01 SUPPLEMENTS

A. The supplements listed below, following "END OF SECTION," are a part of this Specification:

1. Power Plant Piping System Index.
2. Power Pipe Material Specifications:
   a. CSLF – A53 B CS, Class 125
   b. HALE – HDPE, SDR 11
   c. HLAD – HDPE, Solvay Eltex TUB 124
   d. HSLF – HDPE, SDR 9 (FM Approved)
   e. LCLF – A53 B Cement Lined CS, Class 125
   f. PULK – CPVC, Class 150
   g. PVLK – PVC, Class 150
   h. SABD – A312 TP304/304L SS, Class 300
   i. SUTK – A213 Type 316L, SS Tubing

END OF SECTION

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SECTION NO. 40 50 00
POWER PLANT PIPE INDEX

Rev No.	Rev Date	Spec Design	Valve Rating	Pipe Material	Specification Limits	Size Range	Shut-off Valves		Check Valves		Service Code – Service
							≤2”	≥3”	≤2”	≥3”	
A		CSLF	CL 125 CI UL/FM	Carbon Steel	150 psig @ 150°F 175 psig @ 120°F	1/2”-16”	Ball	Gate	Swing	Wafer	EW – Emergency/Fire Water
A		HALE	--	HDPE, SDR 11	160 psig @ 75°F 82 psig @ 140°F	2”-12”	Gate	Gate	--	--	Underground: FW - Freshwater TW – Treated Water
A		HLAD	--	HDPE, Blue	230 psig @ 68°F 150 psig @ 140°F	2”-4”	--	--	--	--	Underground: IA – Instrument Air UA – Utility Air
A		HSLF	CL 125 CI UL/FM	HDPE, UL/FM	200 psig @ 73°F 100 psig @ 140°F	4”-14”	Gate	Gate	Swing	Swing	Underground: EW – Emergency/Fire Water
A		LCLF	CL 125 CI UL/FM	Cement Lined Carbon Steel	150 psig @ 150°F 175 psig @ 120°F	4”-24”	--	--	--	--	EW – Emergency/Fire Water (Underground)
A		PULK	CL 150	CPVC	150 psig @ 73°F 75 psig @ 150°F	1/2”-12”	Ball	Ball	Swing	Swing	CAU- Caustic COG – Coagulant DR – Drain RW - Remedy Water SL – Slurry WS –Waste Stream

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SECTION NO. 40 50 00
POWER PLANT PIPE INDEX

Rev No.	Rev Date	Spec Design	Valve Rating	Pipe Material	Specification Limits	Size Range	Shut-off Valves		Check Valves		Service Code – Service
							≤2”	≥3”	≤2”	≥3”	
A		PVLK	CL 150	PVC	150 psig @ 73°F 69 psig @ 120°F	1/2”-12”	Ball	Ball	Swing	Swing	Process
A		SABD	CL 300	304/304L SS	720 psig @ 100°F 420 psig @ 700°F	1/2”-12”	Ball	Ball	Swing	Swing	CO2 – Carbon Dioxide
A		SUTK	1500#	316L Stainless Steel Tubing	600 psig @ 100°F 250 psig @ 300°F	1/4"-1”	Ball	--	Poppet	--	IA – Instrument Air

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POWER PIPING SPECIFICATION DESIGNATOR		
Piping Material	**Pressure Class**	**Service**
CS = Seamless Carbon Steel, A106-B, thru 24”	A = Class 150	ACD = 19% HCl
HA = HDPE w/ No Stripe, all Black	B = Class 300	CA = Riverbank Extraction Water (may be Carbon Amended)
HL = HDPE, Solvay Blue	L = Class 125 (ASME B16.1)	CAU = 25% Caustic
HS = HDPE w/ Red Stripe – FM Class 200	T = 1500 CWP (Tubing Valves)	CO2 = Carbon Dioxide
LC = Cement-lined Carbon Steel		COG = Coagulant
PU = CPVC (Chlorinated Polyvinyl Chloride)		DR = Drain
PV = PVC (Polyvinyl Chloride)		EW = Emergency/Fire Water
SA = Type 304/304L Stainless Steel		EX = Extracted Groundwater (Transwestern or East Ravine)
SU = Type 316L Stainless Steel		FW = Fresh Water
		IA = Instrument Air
		RW = Remedy Produced Water
		SL = Slurry/solids
		TW = Treated (Filtered) Remedy Produced Water
		UA = Utility Air
		VT = Vent
		WS = Waste Stream

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SECTION 40 50 00-CSLF CARBON STEEL							
MAXIMUM ALLOWABLE PRESSURE/TEMPERATURE							
Pressure, psig		150	175				
Temperature, Degrees°F		150	120				
Corrosion Allowance: 0.063”							
Notes:							
Item	**Size**	**Description**					
Pipe	1/2” – 2”	Carbon steel, ASTM A106, Grade B, seamless, ASME B36.10M, Schedule XS, PE.					
	4” – 16”	Carbon steel, ASTM A53/A53M, Grade B, ERW, ASME B36.10M, Std Wt, BE.					
Nipples	1/2” – 2”	Carbon Steel, ASTM A733 and ASTM A106, Grade B, seamless, ASME B36.10M, Schedule 160. Close nipples are not allowed.					
Fittings	1/2” – 2”	Forged Carbon steel, ASTM A105/A105M, socketweld, ASME B16.11, Class 3000.					
	4” – 16”	Carbon steel, ASTM A234/A234M, WPB, seamless, buttweld, ASME B16.9, Std Wt.					
	Sockolet	Forged carbon steel, ASTM A105/A105M, socketweld, MSS-SP-97, ASME B16.11, Class 3000.					
	Threadolet	Forged carbon steel, ASTM A105/A105M, threaded, MSS-SP-97, ANSI/ASME B1.20.1, ASME B16.11, Class 3000.					
	Weldolet	Forged carbon steel, ASTM A105/A105M, buttweld, MSS-SP-97, ASME B16.9, ASME B16.25, ASME B36.10M.					
Branch Connections	All Sizes	See Branch Connection Table.					
Bushings		Threaded bushings are not allowed.					
Reducing Inserts	1/2” – 2”	Forged Carbon steel, ASTM A105/A105M, socketweld, MSS-SP-79, Class 3000.					
Plugs	1/2” – 2”	Forged Carbon steel, ASTM A105/A105M, solid hex head, MNPT, ASME B16.11.					
Unions	1/2” – 2”	Forged Carbon steel, ASTM A105/A105M, socketweld, MSS-SP-83, Class 3000, bronze/steel seats, cadmium plated union ring.					
Flanges	1/2” – 2”	Forged carbon steel, ASTM A105/A105M, Class 150,					

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SECTION 40 50 00-CSLF CARBON STEEL							
MAXIMUM ALLOWABLE PRESSURE/TEMPERATURE							
Pressure, psig		150	175				
Temperature, Degrees°F		150	120				
Corrosion Allowance: 0.063”							
Notes:							
Item	**Size**	**Description**					
		ASME B16.5, flat face, socket weld, Schedule XS.					
	4” – 16”	Forged carbon steel, ASTM A105/A105M, Class 150, ASME B16.5, flat face, weld neck, Std Wt.					
	1/2” – 16”	Blind, Forged carbon steel, ASTM A105/A105M, Class 150, ASME B16.5, flat face.					
Bolting	1/2” – 16”	Alloy steel stud bolts, ASTM A193/A193M, Grade B7 w/2 heavy hex nuts, ASTM A194/A194M, Grade 2H (use cap screws with lug type butterfly valves).					
Gaskets	1/2” – 16”	Red rubber, 1/8” thick, 80 Durometer, full face, ASME B16.21, Class 150; Garlock Style 22.					
Valves	1/2” – 2”	Gate, VG1RBTHB02, bronze, CL 200, TE, UL/FM.					
	4” – 12”	Gate, VG1NSFHB02, CI, CL 125, flg’d, handwheel operator, UL/FM.					
	1/2” – 2”	Ball, VB2QBTLB02, bronze, 600 psi WOG, TE., UL/FM.					
	4” – 12”	Check, VC1NEFNB02, CI, CL 125, flg’d, UL/FM.					

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BRANCH CONNECTION TABLE

	HEADER NOMINAL SIZE																					
SIZE	.5	.75	1	1.5	2	4	6	8	10	12	14	16	18	20	24	26	28	30	36	42	48	SIZE
.5	T	TR	TR	TR	SO	SO	SO	SO	SO	SO	SO	SO										.5
.75		T	TR	TR	TR	SO	SO	SO	SO	SO	SO	SO										.75
1			T	TR	TR	SO	SO	SO	SO	SO	SO	SO										1
1.5				T	TR	SO	SO	SO	SO	SO	SO	SO										1.5
2					T	SO	SO	SO	SO	SO	SO	SO										2
4						T	TR	TR	TR	W	W	W										4
6							T	TR	TR	TR	TR	TR										6
8								T	TR	TR	TR	TR										8
									T	TR	TR	TR										10
										T	TR	TR										12
											T	TR										14
												T										16
																						18
																						20
																						24
																						26
																						28
																						30
																						36
																						42
																						48

BRANCH NOMINAL SIZE

LEGEND

SO = SOCKOLET (NOTE 1)
T = FULL SIZED TEE
TR = REDUCING TEE, W/ SWAGE OR REDUCER IF REQUIRED
W = WELDOLET

NOTES

1. THREADOLETS ARE REQUIRED FOR TEMPERATURE, INSTRUMENT, AND SAMPLE CONNECTIONS

SPEC CSLF

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SECTION 40 50 00-HALE: SINGLE WALL HDPE							
MAXIMUM ALLOWABLE PRESSURE/TEMPERATURE							
Pressure, psig		160	133	101	82		
Temperature, Degrees°F		75	100	125	140		
Corrosion Allowance: 0.0”							
Notes:							
Item	**Size**	**Description**					
Pipe	2” – 12”	High Density Polyethylene, ASTM D3350 Class 345464C, SDR 11, plain end					
Fittings	2” – 12”	Molded fittings, ASTM D3261, Match Pipe SDR Pressure Rating, IPS					
Bolting	2” – 12”	Stainless steel stud bolts, ASTM A193/A193M, Grade B8M w/2 heavy hex nuts, ASTM A194/A194M, Grade 8M					
Gaskets	2” – 12”	EPDM, 1/8” thick, 65 Durometer A, ASTM D1330, full face, ASME B16.21					
Flanges	2” – 12”	Flange Adapter, Match Pipe SDR Pressure Rating, ASTM D3261 with medium pressure ductile iron back-up rings, ASTM 536-80, ANSI B16.5, Class 150					
Valve Box		Cast Iron, Screw Type, 5-1/4” shaft with base and lid marked “WATER”, complete with extension stem and couplings for valve, and T-handle valve wrench (wrench length shall be sized such that the T-handle is 3’-0” above finished grade), specify depth of burial (centerline of valve to grade), 18” of Adjustment; EJIW 8550 Series,					
Valves	2” – 12”	Gate, VG1NSFTB01, cast iron, CL 125, flg’d, sq nut operator.					

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BRANCH CONNECTION TABLE

BRANCH NOMINAL SIZE	HEADER NOMINAL SIZE																					
SIZE	.5	.75	1	1.5	2	3	4	6	8	10	12	14	16	18	20	24	28	30	36	42	48	SIZE
.5																						.5
.75																						.75
1																						1
1.5																						1.5
2					T	TR	TR	TR	TR	TR	TR											2
3						T	TR	TR	TR	TR	TR											3
4							T	TR	TR	TR	TR											4
6								T	TR	TR	TR											6
									T	TR	TR											8
										T	TR											10
											T											12
																						14
																						16
																						18
																						20
																						24
																						28
																						30
																						36
																						42
																						48

LEGEND

T = FULL SIZED TEE

TR = REDUCING TEE, W/ REDUCER IF REQUIRED

SPEC HALE

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SECTION 40 50 00-HLAD: SOLVAY ELTEX TUB 124 BLUE HDPE							
MAXIMUM ALLOWABLE PRESSURE/TEMPERATURE							
Pressure, psig		230	200	180	150		
Temperature, Degrees°F		68	86	104	140		
Corrosion Allowance: 0.0”							
Notes:							
Item	**Size**	**Description**					
Pipe	2” – 4”	Solvay Eltex TUB 124 Blue HDPE, ASTM D3350 Class 346544C and ASTM D3035, PE100, plain end					
Fittings	2” – 4”	Injection Molded, Match Pipe Pressure Rating, socket fusion					
Bolting	2” – 4”	Stainless steel stud bolts, ASTM A193/A193M, Grade B8M w/2 heavy hex nuts, ASTM A194/A194M, Grade 8M					
Gaskets	2” – 4”	EPDM, 1/8” thick, 65 Durometer A, ASTM D1330, full face, ASME B16.21					
Flanges	2” – 4”	Flange Adapter, carbon steel backing rings with polypropylene covering, Class 150, ASME B16.5					

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BRANCH CONNECTION TABLE

BRANCH NOMINAL SIZE	HEADER NOMINAL SIZE																					
SIZE	.5	.75	1	1.5	2	3	4	6	8	10	12	14	16	18	20	24	28	30	36	42	48	SIZE
.5																						.5
.75																						.75
1																						1
1.5																						1.5
2					T	TWR	TWR															2
3						T	TWR															3
4							T															4
6																						6
																						8
																						10
																						12
																						14
																						16
																						18
																						20
																						24
																						28
																						30
																						36
																						42
																						48

LEGEND

T = FULL SIZED TEE

TR = REDUCING TEE

TWR = TEE WITH REDUCER

SPEC HLAD

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SECTION 40 50 00-HSLF: SINGLE WALL HDPE							
MAXIMUM ALLOWABLE PRESSURE/TEMPERATURE							
Pressure, psig		200	162	132	100		
Temperature, Degrees°F		73	100	120	140		
Corrosion Allowance: 0.0”							
Notes:Pressure/Temp Rating is based on a 50 year life.							
Item	**Size**	**Description**					
Pipe	4” – 14”	High Density Polyethylene FM Approved, ASTM D3350 Class 345464C, Class 200, SDR 9, plain end.					
Fittings	4” – 6”	FM Molded Fittings, ASTM D3261, Match Pipe Pressure Rating, IPS.					
	8” – 14”	FM Fabricated Fittings, ASTM D3261, Match Pipe Pressure Rating, IPS.					
Branch Connections	All sizes	See Branch Connection Table.					
Bolting	4” – 14”	Stainless steel stud bolts, ASTM A193/A193M, Grade B8M w/2 heavy hex nuts, ASTM A194/A194M, Grade 8M.					
Gaskets	4” – 14”	EPDM, 1/8” thick, 65 Durometer A, ASTM D1330, full face, ASME B16.21.					
Flanges	4” – 14”	FM Flange Adapter, Match Pipe SDR Pressure Rating, ASTM D3261 with medium pressure ductile iron back-up rings, ASTM 536, Grade 65-45-12, ANSI B16.5, Class 150.					
Mechanical Joint Adapter Kit	4” – 14”	FM Mechanical Joint Adapter, AWWA C153/A21.53, ASTM D3216, SDR 9, IPS, with metal insert, metal gland, gasket, and attachment bolts and nuts.					
Valve Box		Cast Iron, Slide Type, 5-1/4” shaft with base and lid marked “WATER”, complete with extension stem and couplings for valve, and T-handle valve wrench (wrench length shall be sized such that the T-handle is 3’-0” above finished grade), specify depth of burial (centerline of valve to grade); Tyler 6860 (or approved equal).					

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SECTION 40 50 00-HSLF: SINGLE WALL HDPE							
MAXIMUM ALLOWABLE PRESSURE/TEMPERATURE							
Pressure, psig		200	162	132	100		
Temperature, Degrees°F		73	100	120	140		
Corrosion Allowance: 0.0”							
Notes:Pressure/Temp Rating is based on a 50 year life.							
Item	**Size**	**Description**					
Fire Hydrants		250 psig working pressure, UL Listed/FM approved, AWWA C502, with 5-1/4” valve opening, one 4-1/2” pumper connection, two 2-1/2” hose connections with National Standard hose coupling threads, 1-1/4” pentagon operating nut, counterclockwise opening direction, 6” mechanical joint inlet; Mueller No. A-423 Super Centurion 250 (or approved equal).					
Indicator Posts		Adjustable type, UL Listed/FM approved, counterclockwise opening direction; Mueller No. A-20806 (or approved equal).					
Valves	4” – 12”	Gate, VG1NSFHB02, CI, CL 125, flg’d, handwheel operator, UL/FM.					
	4” – 12”	Gate, VG1NSMTB02, CI, CL 125, mechanical joint, sq nut, UL/FM (U/G service) with valve box.					
	4” – 12”	Gate, VG1NSMPB02, CI, CL 125, mechanical joint, sq nut, UL/FM (U/G service) with post indicator.					
	4” – 12”	Check, VC1NEFNB02, CI, CL 125, flg’d, UL/FM.					

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BRANCH CONNECTION TABLE

BRANCH NOMINAL SIZE	HEADER NOMINAL SIZE																					
SIZE	.5	.75	1	1.5	2	3	4	6	8	10	12	14	16	18	20	24	28	30	36	42	48	SIZE
.5																						.5
.75																						.75
1																						1
1.5																						1.5
2					T	TR	TR	TR	TR	TR	TR	TR										2
3						T	TR	TR	TR	TR	TR	TR										3
4							T	TR	TR	TR	TR	TR										4
6								T	TR	TR	TR	TR										6
									T	TR	TR	TR										8
										T	TR	TR										10
											T	TR										12
												T										14
																						16
																						18
																						20
																						24
																						28
																						30
																						36
																						42
																						48

LEGEND

T = FULL SIZED TEE

TR = REDUCING TEE, W/ REDUCER IF REQUIRED

			SPEC HSLF

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SECTION 40 50 00-LCLF CEMENT LINED CARBON STEEL							
MAXIMUM ALLOWABLE PRESSURE/TEMPERATURE							
Pressure, psig		150	175				
Temperature, Degrees°F		150	120				
Corrosion Allowance: 0.063”							
Notes:							
Item	**Size**	**Description**					
Pipe	4” – 24”	Carbon steel, Cement Lined, ASTM A53/A53M, Grade B, ERW, ASME B36.10M, AWWA C205, Std Wt, BE.					
Fittings	4” – 24”	Carbon steel, Cement Lined, ASTM A234/A234M, WPB, seamless, buttweld, ASME B16.9, AWWA C205, Std Wt.					
Bushings		Threaded bushings are not allowed.					
Flanges	4” – 24”	Forged carbon steel, ASTM A105/A105M, Class 150, ASME B16.5, slip-on, flat face.					
	4” – 24”	Blind, Forged carbon steel, ASTM A105/A105M, Class 150, ASME B16.5, flat face.					
Bolting	4” – 24”	Alloy steel stud bolts, ASTM A193/A193M, Grade B7 w/2 heavy hex nuts, ASTM A194/A194M, Grade 2H.					
Gaskets	4” – 24”	Red rubber, 1/8” thick, 80 Durometer, full face, ASME B16.21, Class 150; Garlock Style 22.					

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SECTION 40 50 00-NBAS HASTELLOY B2							
MAXIMUM ALLOWABLE PRESSURE/TEMPERATURE							
Pressure, psig		290	290	260	230	215	
Temperature, Degrees°F		32	100	200	300	350	
Corrosion Allowance: 0.0”							
Notes: 1. Only use flanges or threaded fittings at equipment connections. 2. Wall thickness based on B31.3 allowable stress.							
Item	**Size**	**Description**					
Pipe	1/2” – 2”	Hastelloy B2, ASTM B622 UNS N10665, seamless pipe, ASME B36.19M, Schedule 40S, BE.					
Fittings	1/2” – 2”	Hastelloy B2, ASTM B462 UNS N10665, WP20CB-S, buttweld, ASME B16.9, Schedule 40S.					
Flanges	1/2” – 2”	Hastelloy B2, ASTM B462 UNS N10665, Class 150, ASME B16.5, raised face, weld neck, Schedule 40S.					
Bolting	1/2” – 2”	Alloy steel stud bolts, ASTM A193/A193M, Grade B7 w/2 heavy hex nuts, ASTM A194/A194M, Grade 2H.					
Gaskets	1/2” – 2”	1/8” thick, TFE, envelope style with non-asbestos filler, ASME B16.21.					

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SECTION 40 50 00-NTAK ALLOY 20							
MAXIMUM ALLOWABLE PRESSURE/TEMPERATURE							
Pressure, psig		150					
Temperature, Degrees°F		150					
Corrosion Allowance: 0.0”							
Notes: 1. Only use flanges or threaded fittings at equipment connections.							
Item	**Size**	**Description**					
Pipe	1/2” – 2”	Alloy 20, ASTM B464 UNS N08020, welded pipe, ASME B36.19M, Schedule 40S, BE.					
	3” – 6”	Alloy 20, ASTM B464 UNS N08020, welded pipe, ASME B36.19M, Schedule 10S, BE.					
Fittings	1/2” – 2”	Alloy 20, ASTM B366 UNS N08020, WP20CB-S, buttweld, ASME B16.9, Schedule 40S.					
	3” – 6”	Alloy 20, ASTM B366 UNS N08020, WP20CB-S, buttweld, ASME B16.9, Schedule 10S.					
Branch Connections	All Sizes	See Branch Connection Table					
Flanges	1/2” – 2”	Alloy 20, ASTM B462 UNS N08020, Class 150, ASME B16.5, raised face, weld neck, Schedule 40S.					
	3” – 6”	Alloy 20, ASTM B462 UNS N08020, Class 150, ASME B16.5, raised face, weld neck, Schedule 10S.					
Bolting	1/2” – 6”	Alloy steel stud bolts, ASTM A193/A193M, Grade B7 w/2 heavy hex nuts, ASTM A194/A194M, Grade 2H.					
Gaskets	1/2” – 6”	1/8” thick, TFE, envelope style with non-asbestos filler, ASME B16.21.					
Valves	1” – 3”	Check, VC7QLRNR01, PFA Lined DI, flg’d.					
	1/2” – 6”	Ball, VB1QLRLP01, PFA Lined DI, flg’d.					

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BRANCH CONNECTION TABLE

BRANCH NOMINAL SIZE \ HEADER NOMINAL SIZE	.5	.75	1	1.5	2	3	4	6	8	10	12	14	16	18	20	24	28	30	36	42	48
.5	T	TR	TR	TR	TR	TR	TR	TR													
.75		T	TR	TR	TR	TR	TR	TR													
1			T	TR	TR	TR	TR	TR													
1.5				T	TR	TR	TR	TR													
2					T	TR	TR	TR													
3						T	TR	TR													
4							T	TR													
6								T													
8																					
10																					
12																					
14																					
16																					
18																					
20																					
24																					
28																					
30																					
36																					
42																					
48																					

LEGEND

T = FULL SIZED TEE

TR = REDUCING TEE, W/ SWAGE OR REDUCER IF REQUIRED

NOTES

1. THREADOLETS ARE REQUIRED FOR TEMPERATURE, INSTRUMENT, AND SAMPLE CONNECTIONS

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SECTION 40 50 00-PULK CPVC							
MAXIMUM ALLOWABLE PRESSURE/TEMPERATURE							
Pressure, psig		150	115	75			
Temperature, Degrees°F		73	130	150			
Corrosion Allowance: 0.0”							
Notes:							
Item	**Size**	**Description**					
Pipe	1/2” – 12”	CPVC, rigid, ASTM D1784 Class 23447-B and ASTM F441, Schedule 80, PE					
Fittings	1/2” – 12”	CPVC, solvent ends, socket type, ASTM D1784 Class 23447-B and ASTM F439, Schedule 80					
Branch Connections	All Sizes	See Branch Connection Table					
Reducing Inserts	1/2” – 12”	CPVC, solvent ends, socket type, ASTM D1784 Class 23447-B and ASTM F439, Schedule 80					
Unions	1/2” – 3”	CPVC, solvent ends, socket type, ASTM D1784 Class 23447-B and ASTM F439, Schedule 80, with EPDM O-Rings. (Note: Depending on chemicals in pipe O-Rings can be EPDM or Viton.)					
Flanges	1/2” – 12”	CPVC, solvent ends, socket type, ASTM D1784 Class 23447-B and ASTM F439, Schedule 80, ASME Class 150 bolt pattern (match ANSI B16.5)					
Bolting	1/2” – 12”	Alloy steel stud bolts, ASTM A193/A194M, Grade B7 w/2 heavy hex nuts, ASTM A194/A194M, Grade 2H					
Gaskets	1/2” – 12”	EPDM, 1/8” thick, 65 Durometer A, ASTM D1330, full face, ASME B16.21, Class 150. (Note: depending on chemicals in pipe gasket material can be EPDM or Viton.)					
Valves	1/2” – 2”	Ball, VB2QVGTR01, CPVC, union ends					
	3” – 4”	Ball, VB2QVFTR01, CPVC, flg’d					
	2” – 8”	Butterfly, VF2QVFLR01, CPVC, flg’d					
	1/2” – 2”	Check, VC7QVGNR01, CPVC, union ends					
	1” – 6”	Diaphragm, VD1QVFHB01, CPVC, flg’d					

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BRANCH CONNECTION TABLE

HEADER NOMINAL SIZE

SIZE	.5	.75	1	1.5	2	3	4	6	8	10	12	14	16	18	20	24	28	30	36	42	48	SIZE
.5	T	TR	TR	TR	TR	TR	TR	TR	TR	TR	TR											.5
.75		T	TR	TR	TR	TR	TR	TR	TR	TR	TR											.75
1			T	TR	TR	TR	TR	TR	TR	TR	TR											1
1.5				T	TR	TR	TR	TR	TR	TR	TR											1.5
2					T	TR	TR	TR	TR	TR	TR											2
3						T	TR	TR	TR	TR	TR											3
4							T	TR	TR	TR	TR											4
6								T	TR	TR	TR											6
									T	TR	TR											8
										T	TR											10
											T											12
																						14
																						16
																						18
																						20
																						24
																						28
																						30
																						36
																						42
																						48

BRANCH NOMINAL SIZE

LEGEND

T = FULL SIZED TEE

TR = REDUCING TEE, W/ REDUCER IF REQUIRED

SPEC PULK

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SECTION 40 50 00-PVLK PVC							
MAXIMUM ALLOWABLE PRESSURE/TEMPERATURE							
Pressure, psig		150	140	69			
Temperature, Degrees°F		73	100	120			
Corrosion Allowance: 0.0”							
Notes:							
Item	**Size**	**Description**					
Pipe	1-1/2” – 12”	PVC, rigid, ASTM D1784 Class 12454-B and ASTM D1785, Schedule 80, PE.					
Fittings	1-1/2” – 12”	PVC, socket type, ASTM D1784 Class 12454-B and ASTM D2467, Schedule 80.					
Branch Connections	All Sizes	See Branch Connection Table.					
Bushings		Threaded bushings are not allowed.					
Reducing Inserts	1-1/2” – 12”	PVC, socket type, ASTM D1784 Class 12454-B and ASTM D2467, Schedule 80.					
Unions	1-1/2” – 3”	PVC, socket type, ASTM D1784 Class 12454-B and ASTM D2467, Schedule 80, with EPDM O-Rings. (Note: depending on chemicals in pipe O-Rings can be EPDM or Viton.)					
Flanges	1-1/2” – 12”	PVC, socket type, FF, ASTM D1784 Class 12454-B and ASTM D2467, Schedule 80, Class 150 (match ANSI B16.5).					
Bolting	1-1/2” – 12”	Alloy steel stud bolts, ASTM A193/A194M, Grade B7 w/2 heavy hex nuts, ASTM A194/A194M, Grade 2H.					
Gaskets	1-1/2” – 12”	EPDM, 1/8” thick, 65 Durometer A, full face, ASME B16.21, Class 150. (Note: depending on chemicals in pipe gasket material can be EPDM or Viton.)					
Valves	3” – 8”	Gate, VG1NEFHB01, CI, CL 125, flg’d, handwheel operator, (UG service).					
	10” – 12”	Gate, VG1NEFGB01, CI, CL 125, flg’d, gear operator, (UG service).					
	1/2” – 4”	Ball, VB2QUGLR01, PVC, CL 150, socket type					
	1/2” – 4”	Check, VC7QUGNR01, PVC, CL 150, socket type					
	2” – 12”	Check, VC1NEFNB01, CI, CL 125, flg’d, (UG service).					

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BRANCH CONNECTION TABLE

BRANCH NOMINAL SIZE	HEADER NOMINAL SIZE																					
SIZE	.5	.75	1	1.5	2	3	4	6	8	10	12	14	16	18	20	24	28	30	36	42	48	SIZE
.5																						.5
.75																						.75
1																						1
1.5				T	TR	TR	TR	TR	TR	TR	TR											1.5
2					T	TR	TR	TR	TR	TR	TR											2
3						T	TR	TR	TR	TR	TR											3
4							T	TR	TR	TR	TR											4
6								T	TR	TR	TR											6
									T	TR	TR											8
										T	TR											10
											T											12
																						14
																						16
																						18
																						20
																						24
																						28
																						30
																						36
																						42
																						48

LEGEND

T = FULL SIZED TEE

TR = REDUCING TEE, W/ REDUCER IF REQUIRED

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SECTION 40 50 00-SABD TYPE 304/304L STAINLESS STEEL							
MAXIMUM ALLOWABLE PRESSURE/TEMPERATURE							
Pressure, psig		720	600	510			
Temperature, Degrees°F		100	200	350			
Corrosion Allowance: 0.0”							
Notes:							
Item	**Size**	**Description**					
Pipe	1/2” – 2”	Stainless steel, ASTM A312/A312M, TP304/304L (dual certified), fusion welded, ASME B36.19M, Schedule 40S, PE.					
	3” – 12”	Stainless steel, ASTM A312/A312M, TP304/304L (dual certified), fusion welded, ASME B36.19M, Schedule 40S, BE.					
Nipples	1/2” – 2”	Stainless steel, ASTM A733 and ASTM A312/A312M, TP316/316L (dual certified), seamless, ASME B36.19M, Schedule 40S, close nipples are not allowed. Threaded nipples shall not be larger than 1”.					
Swages	1/2” – 4”	Stainless steel, seamless, solution annealed, ASTM A403/A403M, WP304/304L (dual certified), MSS SP-95. Swage ends shall match wall thickness of connecting pipe. Threaded ends shall not exceed 1” NPS and shall be Schedule 80S.					
Fittings	1/2” – 2”	Forged stainless steel, ASTM A182/A182M, F304/304L (dual certified), socketweld, ASME B16.11, Class 3000.					
	3” – 12”	Stainless steel, ASTM A403/A403M, WP304/304L-S, buttweld, ASME B16.9, Schedule 40S.					
	Sockolet	Forged stainless steel, ASTM A182/A182M, F304/304L (dual certified), socketweld, MSS-SP-97, ASME B16.11, Class 3000.					
	Threadolet	Forged stainless steel, ASTM A182/A182M, F304/304L (dual certified), threaded, MSS-SP-97, ANSI/ASME B1.20.1, ASME B16.11, Class 3000					
	Weldolet	Forged stainless steel, ASTM A182/A182M, F304/304L (dual certified), buttweld, MSS-SP-97, ASME B16.9, ASME B16.25, ASME B36.10M.					
Branch Connections	All Sizes	See Branch Connection Table.					
Bushings		Threaded bushings are not allowed.					

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SECTION 40 50 00-SABD TYPE 304/304L STAINLESS STEEL							
MAXIMUM ALLOWABLE PRESSURE/TEMPERATURE							
Pressure, psig		720	600	510			
Temperature, Degrees°F		100	200	350			
Corrosion Allowance: 0.0”							
Notes:							
Item	**Size**	**Description**					
Reducing Inserts	1/2” – 2”	Forged stainless steel, ASTM A182/A182M, F304/304L (dual certified), socketweld, MSS-SP-79, Class 3000.					
Plugs	1/2” – 2”	Forged stainless steel, ASTM A182/A182M, F304/304L (dual certified), solid hex head, MNPT, ASME B16.11.					
Unions	1/2” – 2”	Forged stainless steel, ASTM A182/A182M, F304/304L (dual certified), socketweld, MSS-SP-83, Class 3000.					
Flanges	1/2” – 2”	Forged stainless steel, ASTM A182/A182M, F304/304L (dual certified), raised face, socketweld, Schedule 40S, Class 300, ASME B16.5.					
	3” – 12”	Forged stainless steel, ASTM A182/A182M, F304/304L (dual certified), raised face, weld neck, Schedule 40S, Class 300, ASME B16.5.					
	1/2” – 12”	Blind, forged stainless steel, ASTM A182/A182M, F304/304L (dual certified), raised face, Class 300, ASME B16.5.					
Orifice Flanges	3” – 12”	Forged Stainless Steel, ASTM A182/A182M, F304/F304L (dual certified), Class 300, ASME B16.36, raised face, weld neck, schedule 40S, 1/2" NPS socket weld pressure taps.					
Bolting	1/2” – 12”	Alloy steel stud bolts, ASTM A193/A193M, Grade B7 w/2 heavy hex nuts, ASTM A194/A194M, Grade 2H.					
Gaskets	1/2” – 12”	1/8” thick, reinforced teflon, ring type, Class 300, ASME B16.5; Garlock Style 3510.					
Insulating Gasket Set	1/2” – 12”	1/8” thick insulating gasket set, consisting of plain faced phenolic with EPDM seal, ring type gasket, mylar bolt sleeves and washers, suitable for 225°F, Class 300, ASME B16.5; Step-Ko Products.					
Valves	1/2” – 3/4”	Ball, VB2DNTLC01, 316 SS, CL 600, TE.					
	1/2” – 2”	Ball, VB2DNSLC01, 316L SS, CL 600, SW.					

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SECTION 40 50 00-SABD TYPE 304/304L STAINLESS STEEL						
MAXIMUM ALLOWABLE PRESSURE/TEMPERATURE						
Pressure, psig	720	600	510			
Temperature, Degrees°F	100	200	350			
Corrosion Allowance: 0.0”						
Notes:						
Item	**Size**	**Description**				
	1/2” – 2”	Ball, VB2DNWLC01, 316L SS, CL 600, SW x FNPT.				
	3” - 4”	Ball, VB4BNRLC03, 316L SS, CL 300, flg’d, lever operator.				
	6” – 12”	Ball, VB4BNRGC03, 316L SS, CL 300, flg’d, gear operator.				

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BRANCH CONNECTION TABLE

HEADER NOMINAL SIZE

BRANCH NOMINAL SIZE	.5	.75	1	1.5	2	3	4	6	8	10	12	14	16	18	20	24	28	30	36	42	48
.5	T	TR	TR	TR	SO	SO	SO	SO	SO	SO	SO										
.75		T	TR	TR	TR	SO	SO	SO	SO	SO	SO										
1			T	TR	TR	SO	SO	SO	SO	SO	SO										
1.5				T	TR	SO	SO	SO	SO	SO	SO										
2					T	SO	SO	SO	SO	SO	SO										
3						T	TR	TR	TR	W	W										
4							T	TR	TR	W	W										
6								T	TR	TR	TR										
8									T	TR	TR										
10										T	TR										
12											T										
14																					
16																					
18																					
20																					
24																					
28																					
30																					
36																					
42																					
48																					

LEGEND

SO = SOCKOLET (NOTE 1)
T = FULL SIZED TEE
TR = REDUCING TEE. W/ SWAGE OR REDUCER IF REQUIRED
W = WELDOLET

NOTES

1. THREADOLETS ARE REQUIRED FOR TEMPERATURE CONNECTIONS

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SECTION 40 50 00-SUTK TYPE 316L STAINLESS STEEL (TUBING)							
MAXIMUM ALLOWABLE PRESSURE/TEMPERATURE							
Pressure, psig		1500	1500	800	330	100	
Temperature, Degrees°F		100	200	300	400	450	
Corrosion Allowance: 0.0”							
Notes:							
Item	**Size**	**Description**					
Tubing	1/4” – 1”	Stainless steel, ASTM A213/A213M, Type 316, seamless, fully annealed, stress relieved, tubing to be free of scratches, suitable for bending and flaring.					
Tubing Schedule	Size, OD	1/4”	3/8”	1/2”	3/4”	1”	
	Min. Wall Thickness	0.035”	0.035”	0.049”	0.065”	0.083”	
Tube Fittings	All Sizes	Stainless steel, Type 316, tube fittings; Swagelok, or Equal.					
Valves	1/4” – 1/2”	Check, VCAVNCNP01, 316 SS, 2000 psig, tube fittings.					
	1/4" – 1”	Ball, VB1UNRLC01, 316 SS, 1500 psig, flg’d.					

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SECTION 40 50 10
UNDERGROUND PIPING

PART 1 - GENERAL

1.01 SUMMARY

A. This Specification covers minimum requirements for procuring, receiving, storing, handling, fabricating, assembling, erecting, cleaning, filling, flushing, examining, testing, restoring and inspecting of underground piping systems.

B. For underground fire protection piping, the SUB-ENGINEER shall comply with all applicable licensure requirements.

C. SUB-ENGINEER's Work shall include fabrication and installation of all underground piping systems as defined on Drawings.

1.02 REFERENCES

A. The following is a list of standards which may be referenced in this Section:

1. American Society of Mechanical Engineer's (ASME):
   a. B1.20.1, Pipe Threads, General Purpose (Inch).
   b. B31.1, Power Piping.
   c. BPVC Section II, Materials Part C, Specifications for Welding Rods, Electrodes, and Filler Metals.
   d. BPVC Section IX, Welding and Brazing Qualifications
2. ASTM International (ASTM): D2774, Standard Practice for Underground Installation of Thermoplastic Pressure Piping.
   a. D2774, Standard Practice for Underground Installation of Thermoplastic Pressure Piping.
   b. F2164, Field Leak Testing of Polyethylene Pressure Piping Systems Using Hydrostatic Pressure.
3. U.S. Department of Labor Occupational Safety and Health Administration (OSHA): 29 CFR Parts 1926/1910 as applicable.

1.03 SUBMITTALS

A. Action Submittals: Testing fluid data.

B. Informational Submittals

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1. As-built mark-ups of Engineer furnished drawings showing any modifications made by Engineer in the field.
2. Bonding Procedure Specifications and Bonding Performance Qualification Test results in accordance with ASME B31.1, Appendix III.
3. Braxing Procedure Specifications and Brazing Performance Qualification Test results in accordance with ASME BPVC, Appendix IX.
4. Hydrotest procedures.
5. Hydrotst reports, containing at least the following information:
    a. Complete description of pipe system including boundary limits, complete line numbers, Drawings and P&ID's indicating test boundaries.
    b. Test description including test pressure, test medium, temperature of test medium, ambient temperature, time of day, test duration, leakage rate, and date of test.
    c. Record of joint repairs including date, extent of repairs, and responsible individual.
    d. Record of cleaning including date and responsible individual.
    e. Signature, date, and title of ENGINEER's and OWNER's representative witnessing operation.
6. Quality Control Manual and Quality Assurance Manual
7. Manufacturer's recommendations for handling, storage, and installation of components.

1.04 QUALITY ASSURANCE

A. Welders and welding procedures shall be in accordance with Section 485868, Welding of Power Plant Piping.

B. Bonders and bonding procedures shall be qualified in accordance with requirements of ASME B31.1, Appendix III, Paragraph III-5.0.

C. Qualification Test:

1. May be required of any heat fusion operator or bonder at discretion of ENGINEER
2. Personnel who fails test shall be prohibited from working on Project or be re-qualified at option of ENGINEER.

1.05 STORAGE AND HANDLING

A. General:

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1. Store and handle materials in manner that will minimize corrosion and prevent damage to pipe and piping components, including their end connections and coatings.
2. Do not allow pipe to roll or fall from conveyance (e.g., truck, trailer).
3. Store pipe above ground on wooden supports. Until ready for installation use sufficient number of supports to prevent pipe from sagging or coming into contact with ground. Either contoured or padded blocks shall also be used with coated pipe to prevent damage to coatings.
4. Store and handle valves, hydrants, and post indicators in accordance with manufacturer's recommendations and with aid of lifting lugs when provided by manufacturer.

B. Plastic Piping: In accordance with ASTM D2321 and ASTM D2774 and manufacturer's recommendations.

C. End Protection: Material furnished by SUB-ENGINEER in accordance with this Specification shall have machined surfaces protected until installation as follows:

1. Flange Faces:
   a. Cover with bolted or clamped plastic, wood or sheet metal cover of adequate size and strength to prevent damage to face.
   b. Coat carbon steel faces with suitable rust preventative.
2. Buttweld Ends: Cover with sheet metal or plastic protectors to prevent damage to bevels.
3. End protectors for stainless steel material shall be nonmetallic.
4. Threaded Connections:
   a. Plugged or capped.
   b. If the plugs or caps are shown on Drawings, they shall be of material specified.
   c. Temporary thread protectors used during shipment and handling shall be plastic or sheet metal.

D. Acceptance at Job Site:

1. Repair damage to pipe, fittings, specialty items, coatings, or linings to ENGINEER's satisfaction at no extra cost.
2. Damaged items not repaired to ENGINEER's satisfaction shall be removed from Site and replaced.

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PART 2 - PRODUCTS

2.01 MATERIALS

A. Pipe, fittings, flanges: In accordance with Section 405000M, Power Plant Piping Materials.

B. Valves:

1. In accordance with Section 40 55 00M, Power Plant Valves.
2. Provide necessary grease and lubricant.

2.02 PIPE BEDDING

A. Bedding materials shall be as specified in Section 31 23 33, Trench Excavation

1.1 CONCRETE

A. Materials: ASTM C387 packaged, dry, combined ingredients with Type I cement.

B. Mixing: In a clean metal container, mix package of dry materials by hand or machine. Following manufacturer's instructions, add clean water in sufficient quantity to produce slump of 2 to 3 inches.

PART 3 - EXECUTION

3.01 GENERAL

A. The Work required by this Specification shall be conducted in compliance with applicable OSHA Standards.

3.02 PIPE TRENCHING

A. Perform in accordance with Section 312333, Trench Excavation.

3.03 PIPE BEDDING

A. Bed preparation shall be performed in accordance with Section 312333, Trench Excavation.

B. Plastic (PVC, CPVC, HDPE) pipe shall be bedded in accordance with ASTM D2321 and ASTM D2774 and manufacturer's recommendations.

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3.04 TRENCH BACKFILL

A. Backfill and compaction shall be performed in accordance with Section 312333, Trench Excavation.

B. Plastic (PVC, CPVC, HDPE) pipe shall be backfilled in accordance with ASTM D2321 and ASTM D2774 and manufacturer's recommendations.

C. Backfill and compaction shall not be performed until after successful field pressure test or radiographic examination and completion of coating and lining activities.

D. Obtain written approval from ENGINEER prior to backfilling trenches.

3.05 INSTALLATION

A. General:

1. Inspect pipe and clean all debris from interior and exterior surfaces prior to installation.
2. Install potable water piping and floor drain piping in accordance with IPC International Plumbing Code.
3. Install fire protection piping in accordance with NFPA 24 and AWWA C600.
4. Install all other underground piping in accordance with ASME B31.1.
5. Lower pipe and fittings carefully into trench.
6. Pipe shall not be laid in water or when trench conditions are unsuitable to perform the Work.
7. Lay pipe true to line and grade. Lay pipe on its permanent bedding, without block supports, to attain required grade. Remove and re-lay pipe if grade deviates by 1/4 inch or more from grade indicated. Remove bedding as required around flanges and bell joints to allow pipe to lay solidly on bedding.
8. When liquid must be drained from piping system due to flushing, pressure testing, or for leak repair, drainage operation shall be as directed by ENGINEER, but in no case shall liquid be drained into trench.
9. When Work is not in progress, open ends of pipe and fittings shall be securely closed so that no water, earth, or other foreign material enters pipe.
10. Pipe ends left for future connections shall be blind flanged, capped, or closed in accordance with Drawings.
11. Pipe Penetrations: Through or under concrete and masonry surfaces:
    a. Protect pipe from breakage.

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b. Pipe passing under footing or through foundation wall shall be provided with relieving arch; or provide steel or cast iron wall sleeve 2 pipe sizes greater than pipe passing through.
c. Unless otherwise specified on Drawings, annular space between sleeve and pipe shall be caulked with coal tar, asphaltum compound, or other approved noncombustible sealant material.

B. Plastic Pipe:

1. PVC, CPVC, and HDPE piping shall be installed in accordance with ASTM D2321 and ASTM D2774 and manufacturer's recommendations.
2. Care shall be taken to ensure that bending and lowering of pipe into trench does not result in kinking or buckling.

C. Flanged Joints:

1. Make up with flange faces parallel, and bolt holes straddling normal horizontal and vertical centerlines of flanges, unless otherwise shown on Drawings.
2. Gaskets and gasket surfaces on flanges shall be clean, unpainted, and undamaged.
3. Bolt threads shall be coated with lubricant suitable for service temperature.
4. Flanges shall be made up by tightening diametrically opposite bolts in succession to load gasket evenly.
5. When flanged joint has been made up and subsequently loosened, install new gasket prior to retightening.

D. Polyethylene Butt Fusion Joints:

1. Fabricate and assemble in accordance with the manufacturer's recommendations.
2. Shall not be threaded, cemented or solvent welded.
3. Join by thermal butt fusion method with equipment manufactured by McElroy Manufacturing, Inc., Tulsa, Oklahoma.

E. Bonded Joints:

1. Bond plastic piping systems (e.g., PVC, CPVC, FRP) with either solvent cement or adhesive.
2. Qualified bonders shall make joints using qualified bonding procedures and in accordance with the pipe manufacturer's recommendations.

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F. Valves:

1. Install in accordance with manufacturer's recommendations. Particular attention should be given to manufacturer's recommendations for weld end type valves utilizing resilient seats.

3.06 FIELD QUALITY CONTROL

A. General:

1. Inspect, examine, clean, and test piping in accordance with requirements of ASME B31.1, NFPA 24, and this Specification.
2. Procedures shall be subject to approval of ENGINEER.
3. Engineer shall witness each critical operation (e.g., pressure testing, cleaning, disinfection).

B. Bonded and Brazed Joint Inspection and Testing:

1. Visually inspect each system prior to pressure testing for material defects and improper installation. Correct defects and installation problems before performing pressure test.
2. Engineer reserves right to have any joints cut out and tested (e.g., weld, heat fusion, bonded), irrespective of defects.
3. Furnish equipment and personnel to cut out joints designated by ENGINEER for testing.
4. Bonded joints shall be tested in accordance with ASME B31.1, Appendix III, Paragraph 5.1.2.

C. Pressure Tests:

1. General:
   a. Piping Line Report specifies test pressure of piping systems. All pressure tests shall be hydrostatic unless otherwise stated on Report.
   b. Notify ENGINEER minimum of 48 hours prior to pressure tests. For Fire Protection piping, the authority having jurisdiction shall also be notified prior to the pressure tests.
   c. Document pressure tests with test report witnessed by ENGINEER.
   d. A safety valve or relief valve may be used at the pressure source to protect systems under test. The test crew shall be responsible for venting all sections of piping systems not under direct test to prevent overpressuring any part of system through valve leakage or excess flows.
   e. In event piping system cannot be successfully pressure tested, correct problem and retest.

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2. Pressure Test:
   a. Pretest Inspection:
      1) Notify ENGINEER when piping system is ready for pretest inspection.
      2) Verify components in piping system conform to appropriate Pipe Material Specification in Section 405000, Power Plant Piping Materials (e.g., material, wall thickness, valve numbers, valve ratings, flange ratings) and latest revision of Piping and Instrumentation Diagrams, and is ready for pressurization.
      3) ENGINEER will inspect each piping system using copy of Appendix A, Piping Pretest Checklist located at end of section.
      4) Joints shall be left exposed (uncoated and unpainted) and accessible until pressure testing has been completed.
      5) Inspect plugs and caps for conformance to Specification.
      6) To prevent movement during testing, place sufficient backfill over plastic pipe and pipe utilizing bell and spigot type joints.
   b. Testing shall be performed as soon as possible after installation Hydrotest Procedure: In accordance with requirements of ASME B31.1, ASTM F2164, or NFPA 24 and this Specification.
      1) Plastic Pipe:
         a) Do not pressure test with compressible fluid (e.g., air, gas).
         b) Follow manufacturer's recommendations for pressurization rates and holding times.
         c) Joints in plastic piping shall be set, cured, or hardened in accordance with manufacturer's recommendations prior to testing.
         d) Do not perform hydrostatic test when temperature is above 80 degrees F.
      2) Polyethylene Pipe:
         a) Initial pressure test for polyethylene pipe shall be applied and allowed to stand without makeup pressure for approximately 2 to 3 hours to allow for diametric expansion or pipe stretching to stabilize.
         b) After this equilibrium period, test section shall be returned to original test pressure and maintained for minimum of one hour.
      3) Quality of test fluid shall not be detrimental to equipment or pipe system materials. Obtain approval by ENGINEER before using any test fluid.
         a) Water for testing equipment and piping containing austenitic stainless steel materials shall contain less than 50 ppm chloride ion.

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b) Do not perform hydrostatic test when temperature is below 32 degrees F, without ENGINEER approval.

c. Pneumatic Test:
   1) Pneumatic testing shall be done with compressed air or nitrogen.
   2) Do not perform pneumatic test when temperature is below 60 degrees F, without ENGINEER approval.
   3) Test joints with soap bubble method.

d. Post Pressure Test Inspection:
   1) Notify ENGINEER when piping system is ready for post-test inspection.
   2) Verify piping system has been flushed, dried, restored, and connected to satisfaction of ENGINEER, and is ready for operation.
   3) ENGINEER will inspect each piping system using Appendix B, Piping Test and Post-Test Checklist located at end of section.

D. Repair of Leaks and Defects:

1. Repair leaks, and perform additional examination and retest.
2. Remove or repair defective joints as required by ENGINEER.
3. Repairs shall be made in accordance with procedures approved by ENGINEER.
4. Examination and inspection of completed joint repair shall be same as required for original joint or by alternate method that will ensure equal or greater soundness of joint.

E. Restoration:

1. After successful completion of hydrostatic testing, flush and drain lines. Water used for flushing and pressure testing shall be disposed of as directed by ENGINEER.
2. Open valves that were closed during hydrostatic test, for drainage of bonnet cavity. Partially open and close valves during flushing operation to flush foreign material out of system.
3. Care shall be exercised in draining piping so as not to create a vacuum. Open vents within system prior to draining. After piping systems are drained, close vents or drains that were opened prior to testing.
4. Remove temporary blanks and blinds.
5. Valves:
   a. Notify ENGINEER prior to valve restoration so ENGINEER may witness restoration.
   b. Restore, if required, valves after successful pressure testing.

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c. Restoration shall include removal of jacks; reinstallation of flappers, balls, and pistons; and replacing of bonnet gaskets on valves that were disassembled.
d. ENGINEER will sign tag that was previously placed on valve and indicate that valve is ready for operation.

6. Each system shall be connected to equipment where applicable and be ready for operation.
7. Protection of flanges and drain hubs.
   a. Flanges - Cover with bolted or clamped plastic, wood or sheet metal cover of adequate size and strength to prevent damage to face. Coat carbon steel flange faces with suitable rust preventative.
   b. Drain Hubs – Cover with plastic or sheet metal caps.
   c. All covers shall be securely taped to prevent the intrusion of water or foreign materials.

F. Special Cleaning and Drying: Oil, gas, air, and chemical piping which has been flushed or hydrostatically tested shall be pigged to push the water out immediately after the flush or test, and thoroughly purged and dried with air or nitrogen before placing in service.

3.07 SUPPLEMENTS

A. The supplements listed below, following "End of Section," are a part of this Specification:

1. Piping Pretest Checklist.
2. Piping Test and Post-Test Checklist.
3. Power Piping Standard PP-1, - Dielectric Flanged Joint.

END OF SECTION

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PIPING PRETEST CHECKLIST

INSPECTION DATE _____

INSPECTED BY _____

PLANT _____ SUB-ENGINEER ____

SYSTEM/LINE NO. ____ DWG REF. ____

	Description	Engineer/ Owner Initials	Sub-Engineer Initials	Date
1.	All material/equipment (valve numbers, piping materials, flange ratings) complies with specifications, Drawings and P&ID's.			
2.	All flange bolting and gaskets correctly installed.			
3.	Vents installed at system high points.			
4.	Gauges calibrated and installed.			
5.	Blinds correctly installed.			
6.	Temporary plugs and caps have been installed.			

REMARKS

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PIPING TEST AND POST-TEST CHECKLIST

INSPECTION DATE _____ TEST PACKAGE NO._____

INSPECTED BY _____

PLANT _____ SUB-ENGINEER ____

SYSTEM/ LINE NO. ____ DWG REF. _____

TEST MEDIUM _____ TEST PRESSURE, PSIG _____ TEST TEMP, °F _____

TEST PRESSURE HOLDING TIME _____MIN AMBIENT TEMP _____

Description	Engineer/ Owner Initials	Sub-Engineer Initials	Date
1. Test Complete and Acceptable			
2. If partial tests were made, define:			
a.			
b.			
3. System ready for post-test check:			
a. Test blinds removed.			
b. Final line flush complete.			

REMARKS

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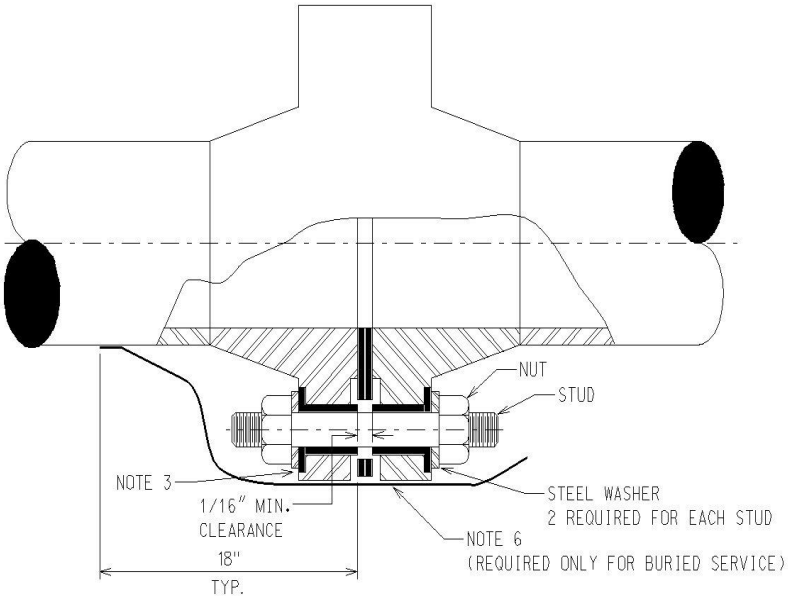
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NOTES:

1. GASKET SHALL BE OF NON-METALIC OR NON-GRAPHITE-IMPREGNATED MATERIAL. MATERIAL TO BE PHENOLIC LAMINATE AS SUITABLE TO SERVICE TEMPERATURE OF LINE AND THE FLANGE TYPE, PSIPRODUCTS, F. H. MALONEY OR EQUAL.

2. SLEEVES AND WASHERS SHALL BE ONE PIECE OF ACETAL RESIN OR NYLON MATERIAL. USE TWO FOR EACH STUD.

3. REMOVE BURRS OR OTHER FOREIGN PARTICLES FROM FLANGE FACES, BOLT HOLES AND STUDS.

4. FOLLOW MANUFACTURER'S RECOMMENDED PRACTICE FOR INSTALLATION.

5. TEST FLANGE AFTER INSTALLATION AND REPLACE ANY CRACKED SLEEVES OR WASHERS WHICH MAY CAUSE "SHORTING OUT." USE CONTINUITY TESTER, FLASHLIGHT WITH LEADS, ETC.

6. AFTER INSTALLATION IS COMPLETE, PRIMER AND THREE WRAPS OF TAPE SHALL BE APPLIED TO FLANGE PERIMETERS AND EXTENDED 18" ON BOTH SIDES OF FLANGES. USE SCOTCHRAP, POLYKEN, OR EQUAL TO MANUFACTURER'S INSTRUCTIONS.

POWER PIPING STANDARD

PP-1
DIELECTRIC FLANGED JOINT

PP1.DGN 1 NONE

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SECTION 40 50 20
ABOVEGROUND PIPING

PART 1 - GENERAL

1.01 SUMMARY

A. This Section covers minimum requirements for receiving, storing, handling, fabrication, assembly, erection, cleaning, filling, flushing, examination, testing, restoration and inspection of complete aboveground piping systems.

B. Contractor's Work shall include fabrication of piping system, including loose piping furnished with equipment and miscellaneous structural attachments for supports

C. Piping 2 1/2 inches and larger will be shown on the drawings. Piping and tubing 2 inches and smaller shall be routed and designed by contractor.

1.02 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Society of Mechanical Engineer's (ASME):
   a. A13.1, Scheme for the Identification of Piping Systems.
   b. B1.20.1, Pipe Threads, General Purpose (Inch).
   c. B31.1, Power Piping.
   d. BPVC Section II, Materials Part C Specification for Welding Rods, Electrodes, and Filler Metals.
   e. BPVC Section IX, Boiler and Pressure Vessel Code - Welding and Brazing Qualifications.

2. ASTM International (ASTM):
   a. A153, Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.
   b. A525, Standard Specification for General Requirements for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process.
3. Pipe Fabrication Institute (PFI): ES-3, Fabricating Tolerances.
4. Manufacturers' Standardization Society of the Valve and Fittings Industry (MSS):
   a. SP-58, Pipe Hangers and Supports - Materials, Design and Manufacture.
   b. SP-69, Pipe Hangers and Supports - Selection and Application.

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c. SP-89, Pipe Hangers and Supports - Fabrication and Installation Practices.

5. BOCA, Basic Plumbing Code and Local Plumbing Code
6. U.S. Department of Labor Occupational Safety and Health Administration (OSHA): 29 CFR Parts 1926/1910.

1.03 SUBMITTALS

A. Action Submittals:

1. Isometric Drawings:
   a. Proposed field routing of Contractor Designed pipe.
   b. Show identification by line number and include bill of material,
   c. Include pipe support types and locations
2. Contractor designed pipe support systems
3. Testing fluid data.

B. Informational Submittals:

1. Hydrotest procedures.
2. Hydrotest reports, containing at least the following information:
   a. Complete description of pipe system including boundary limits, complete line numbers, Drawings and P&ID's indicating test boundaries.
   b. Record of Cleaning including date and responsible individual.
   c. Test description including test pressure, test medium, temperature of test medium, ambient temperature, time of day, test duration, leakage rate, and date of test.
   d. Record of joint repairs including date, extent of repairs, and responsible individual.
   e. Record of cleaning including date and responsible individual.
   f. Signature, date, and title of ENGINEER's and OWNER's representative witnessing operation.
3. Quality Control Manual and Quality Assurance Manual
4. Liquid penetrate evaluations, magnetic particle examinations, and any other examinations performed.
5. Manufacturer's recommendations for handling, storage, and installation of components.
6. Record drawing mark ups of engineer furnished drawings showing any modifications made by Contactor in field. Manufacturer's recommendation for handling, storage, and installation of components.

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1.04 QUALITY ASSURANCE

A. Bonders and bonding procedures shall be qualified in accordance with requirements of ASME B31.1, Appendix III, Paragraph III-5.0.

B. Brazers and brazing procedures shall be qualified in accordance with ASME Section IX of the Boiler and Pressure Vessel Code.

C. Check Test:

1. May be required of any heat fusion operator, binder, or brazer at discretion of Engineer.
2. Personnel who fails test shall be prohibited from working in Project or be requalified at option of Engineer.

1.05 DELIVERY, STORAGE, AND HANDLING

A. General:

1. Store and handle materials in manner that will minimize corrosion and prevent damage to pipe and piping components, including their end connections and coatings.
2. Store pipe aboveground on SUBCONTRACTOR furnished dunnage. Use sufficient number of supports to prevent pipe from sagging or coming into contact with ground. Either contoured or padded blocks shall also be used with coated pipe to prevent damage to coatings.
3. If pipe shall be partially or completely submerged due to rainfall, or any other cause, pipe shall be carefully examined, and water, together with any dirt, trash, or other foreign matter that may have entered shall be removed.

B. Special Piping (e.g., PVC, CPVC, polyethylene) materials shall be handled and stored in accordance with manufacturer's recommendations.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Piping materials: Provide as specified in Section 40 50 00, Power Plant Piping Materials.

B. Valves:

1. As specified in Power Plant Valves section.

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2. Provide necessary grease and lubricant required.

C. Pipe Supports/Hangers:

1. Supports and hangers for CONTRACTOR designed piping shall be as shown on Engineer's standard support drawings.
2. Design of supports not shown on drawings shall be performed by designers experienced in design of pipe supports for process plant piping. Pipe support and hangers shall be approved by engineer prior to installation
3. Fabricate in accordance with MSS-SP-89.
4. Conform to MSS-SP-89.
5. Miscellaneous attachments for hangers, supports, guilds shall be of material similar to pipe and suitable for operating temperature.
6. Support assemblies shall have minimum yield strength safety factor of two and minimum ultimate strength factor for four.\
7. Manufactures:
   a. Anvil International
   b. Bergen-Power.

PART 3 - EXECUTION

3.01 GENERAL

A. The Work required by this Specification shall be conducted in compliance with applicable OSHA Standards.

3.02 INSTALLATION

A. General: Preinstallation Inspection: Inspect each pipe spool, valve, threaded opening and gasket surface for damage and internal cleanliness prior to installing

B. Piping:

1. In accordance with requirements of ASME B31.1 and this Section.
2. Install perpendicular or parallel to major equipment, building structure, and floor levels.
3. Piping, including tubing, shall be installed in accordance with the following requirements:
   a. Do not install above or within horizontal distance of 3 feet from electrical equipment such as switchgear, switchboard, control panel, motor control, contactor, communication equipment, batteries, battery charger, and motor generator.

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b. Install with minimum of 7 feet 6 inches of headroom over passageway and walkway. Pipe shall not be run near the floor, nor across walkways or working spaces where they would be a hazard.
c. Where piping is specified to be field routed clearances shall be maintained to allow installation, operation, and maintenance of equipment.

4. Thermal Expansion: Install piping so that excessive or destructive expansion forces will not exist in either cold condition or under conditions of maximum temperature.

C. Joints:

1. Threaded:
   a. Tapered and conforming to ASME B1.20.1.
   b. Use Teflon as joint sealant for threaded joints and Never Seez lubricating compound for lines operating between 400 and 900 degrees F that will not be seal welded.
2. Flanged Joints:
   a. Make up with flange faces parallel, and bolt holes straddling normal horizontal and vertical centerlines of flanges, unless otherwise shown on Drawings.
   b. Protect gaskets and flange faces from damage until installation is complete.
   c. Special precautions must be taken when making up steel-to-cast iron flanged joints. Steel flange shall be flat faced or have its raised face removed.
   d. Gaskets:
      1) Temporary Flanged Joint: May be made up with less expensive sheet gaskets and special gaskets saved for permanent installation.
      2) Verify that proper gaskets are installed for permanent installation.
      3) Special care shall be taken during installation of spiral wound gaskets so gasket is not rendered ineffective by misalignment or overstressing.
   e. Gaskets and gasket surfaces on flanges shall be clean, unpainted, and undamaged.
   f. Bolt threads shall be coated with lubricant suitable for service temperature. The lubricant shall be applied to the full length of all bolt threads. All bolts shall extend completely through their nuts by at least one full effective thread, but not more than 3/8 inches.

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g. Flanges shall be made up by tightening diametrically opposite bolts in succession to load gasket evenly.
h. Replace cap screws and machine bolts that have bottomed out before joint is tight with proper length screws or bolts.
i. When flanged joint has been made up and subsequently loosened, install new gasket prior to retightening.
j. Dielectric flanged joints shall be installed in accordance with Power Piping Standard PP-1, Dielectric Flanged Joints located at end of section

3. Bonded Joints (PVC, CPVC, RTRP): Make in accordance with manufacturer's recommendations and by qualified bonders using qualified bonding procedures.

D. Cutting and Drilling Structures:

1. Drilling and cutting of structures required for proper installation of piping or bolts shall be performed only with written permission of CONTRACTOR.
2. Holes in grating or floor plate shall be banded and reinforced as required for strength and safety.

E. Equipment Connections:

1. When attaching piping to equipment connections, special care shall be taken that excessive stresses are not transmitted to, and imposed upon, such connections.
2. Field heating to accommodate minor fit-up problems is not allowed.
3. Owner's Inspector shall witness installation.
   a. After startup, if connecting piping is exerting excessive strains on equipment, contact Engineer for further instructions.
   b. Piping which vibrates excessively shall be anchored or snubbed as directed by the Engineer.

F. Tie-ins: Verify all tie-in dimensions before fabrication of final tie-in spools.

G. Piping Tolerances:

1. Dimensional tolerances for fabricated piping shall be in accordance with PFI ES-3 and this Specification.
2. Internal misalignment of buttweld ends in critical piping to be joined shall not exceed 1/16 inch for NPS 24 and smaller and 1/8-inch for NPS 26 and larger.

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3. Dimensions of installed piping shall be in accordance with PFI Standard ES-3 unless otherwise noted.
4. Flanges in pipe runs shall not be out of square more than 3/64 inch per foot of outside diameter of flange.
5. Angular tolerances shall be plus or minus 1/2 degree.
6. After piping has been positioned, check flanges and connections to mechanical rotating equipment for alignment. Flanges shall be parallel within 1/64 inch per foot of flange diameter and not put any strain on equipment casings.
7. Flex hoses and expansion joints shall be installed straight and without strain or as indicated on Drawings.
8. No cold springing will be allowed for pipe fit-up.
9. Remove improperly fitted pipe and replace.

H. Branch and Instrument Connections: Conform to requirements of appropriate Material Specifications in Section 405000, Power Plant Piping Materials.

I. Special Piping: Install PVC, CPVC, polyethylene, fiberglass, plastic-lined steel, or preinsulated, in strict accordance with this Section and manufacturer's recommendations.

J. Valves:

1. In accordance with Section on Power Plant Valves
2. Control valves shall be installed in such a manner that they can be operated from main operating floors or platforms. Use of ladders or special operating devices may be used for valves not normally operated.

K. Pipe Supports/Hangers:

1. General:
   a. Weld pipe supports to structural steel framing by shielded metal arc method only and in accordance with Section 485868, Welding of Power Plant Piping, and AWS D1.1. Welds shall run parallel to axis of beam span and shall be staggered, with cooling allowed between subsequent deposits.
   b. Make weldments of attachments to piping prior to postweld heat treatment.

3.03 FIELD FINISHING

A. Piping, Components and Supports:

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1. All PVC and CPVC pipe and fittings located outdoors or within 5 of the exterior boundary of the roof and sunshade shall be coated with the 2 coats of semi-glass acrylic latex.
2. Prepare surface by hand sanding with medium grit sandpaper.
3. Apply coasting in accordance with manufacturer's instructions (min 2 coats)

4. Color determined by Engineer.

3.04 FIELD QUALITY CONTROL

A. General:

1. Inspect, examine, clean, and test piping in accordance with requirements of ASME B31.1, Chapter VI, and this Section.
2. Procedures shall be subject to approval of CONTRACTOR.
3. Engineer shall witness each critical operation (e.g., pressure testing, cleaning and drying, disinfection).

B. Pressure Tests:

1. General:
   a. Piping Line Report specifies which piping systems are to be pressure tested and test pressure. All pressure tests shall be hydrostatic, unless otherwise specified on the Piping Line Report.
   b. Notify CONTRACTOR minimum of 48 hours prior to pressure test.
   c. Document field tests with test report witnessed by CONTRACTOR.
   d. Vents and drains that are downstream of last block valve and open to atmosphere do not require pressure testing.
   e. A safety valve or relief valve shall be used at the pressure source to protect systems under test. The SUBCONTRACTOR shall be responsible for venting all sections of piping systems and vessels not under direct test to prevent overpressuring any part of system through valve leakage or excess flows.
   f. Flanged joints at which test blinds have been removed do not require testing.
   g. Remove filter elements from system prior to pressure testing.
   h. Equipment appurtenances such as level bridles, shall be tested separately when equipment is excluded from pressure testing.
   i. Control valves shall be included in pressure test with valves in open position.

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j. Verify pressure relief devices have test gags and components included in test can withstand test pressure.
k. Tag all valves included in test boundaries to indicate status, i.e., open for block and control valves, internals removed or blocked open for check valves.
l. In event piping system cannot be successfully pressure tested, correct problem and retest.

2. Test Records: Records shall be made of each piping system test utilizing the Piping Checklists, or approved substitute
3. Hydro Test:
   a. Pretest Inspection:
      1) Notify Engineer when piping system is ready for pretest inspection.
      2) Verify components in piping system conform to requirements of appropriate Pipe Material Specification in Section 405000, Power Plant Piping Materials (e.g., material, wall thickness, valve numbers, valve ratings, flange ratings, etc.) and latest revision of Piping and Instrumentation Diagrams, and is ready for pressurization.
         a) Engineer will inspect each piping system using copy of Piping Pretest Checklist located at end of section.
         b) Joints shall be left exposed (uninsulated and unpainted) until testing has been completed.
         c) Isolate equipment listed in the Supplement, Status of Equipment during Pressure Test, located at end of section, from piping systems that will be pressure tested.
      3) Supports, shoes, guides, and anchors shall be inspected for proper type, installation, and location.
      4) Spring supports shall have their hydrotest pins installed.
      5) Inspect plugs and caps for conformance to Specification.
      6) Valve tags shall be inspected for purpose of identifying status. Tag shall indicate block and control valves are open or that check valves have had their internals removed, jacked open, or left unaltered.
   b. Hydrotest Procedure: In accordance with requirements of ASME B31.1 and this Specification.
      1) Plastic Pipe:
         a) Do not pressure test with compressible fluid (e.g., air, gas).

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b) Joints in plastic piping shall be set, cured, or hardened in accordance with manufacturer's recommendations prior to testing.
c) Temperature of plastic piping shall not exceed 80 degrees F during pressure testing without prior approval of CONTRACTOR.

2) Quality of test fluid shall not be detrimental to equipment or pipe system materials. Obtain approval by CONTRACTOR before using any test fluid.
3) Water for testing equipment and piping containing austenitic stainless steel materials shall contain less than 50 ppm chloride ion.
4) Do not perform hydrostatic test on metallic systems when temperature is below 32 degrees F, without Engineer approval.
5) Observe each pipe system to ensure that supports, including spring supports, are not overloaded due to weight of test medium.
6) Remove insulation that becomes wet during hydrostatic testing.

c. Pneumatic Test:
1) Pneumatic testing shall be done with compressed air or nitrogen.
2) Do not perform pneumatic test when temperature is below 60 degrees F, without Engineer approval.
3) Lines to be pressure tested by pneumatic testing shall be given an application of a leak detection fluid which shall reveal the presence of leaks by an easily visible means, such as bubble formation. Generally pneumatic test pressures shall be limited to 100 psig. When specified, pneumatic tests with a test pressure that is above 100 psig, the piping shall be taken to test pressure, held for a suitable time, then lowered to system operating pressure to conduct visual inspection.
4) Air compressors shall be equipped with discharge filters for removal of water, oil and foreign matter. Maximum discharge temperature of oil lubricated air compressors shall be 300 degrees F.

d. Initial Service Testing
1) In accordance with ASME B31.1.
2) Permissible only with prior written authorization from CONTRACTOR.

e. Notify Engineer minimum of 48 hours prior to Initial Service Tests.

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f. Post-Pressure Test Inspection:
   1) Notify CONTRACTOR when piping system is ready for post-test inspection.
   2) Verify piping system has been flushed, dried, restored, and connected to satisfaction of CONTRACTOR, and is ready for operation.
   3) Pressure relief valves, spring hangers, and expansion joints shall be inspected to see that gags, hydrotest pins, shipping spacers, and shipping ties have been removed. Spring hangers shall be set to the Cold position.
   4) CONTRACTOR will inspect each piping system using Piping Test and Post-Test Checklist located at end of section.

C. Repair of Leaks and Defects:

1. Repair leaks, and perform additional examination and retest.
2. Remove or repair defective joints as required by CONTRACTOR.
3. Repairs shall be made in accordance with procedures approved by CONTRACTOR.
4. Examination and inspection of completed joint repair shall be same as required for original joint or by alternate method that will ensure equal or greater soundness of joint.

D. Restoration:

1. After successful completion of hydrostatic testing, flush and drain lines. Water used for flushing and pressure testing shall be disposed of as directed by CONTRACTOR.
2. Open valves that were closed during hydrostatic test, for drainage of bonnet cavity. Partially open and close valves during flushing operation to flush foreign material out of system.
3. Care shall be exercised in draining vessels and piping so as not to create a vacuum. Open vents within system prior to draining. After piping systems and vessels are drained, close vents, drains, and other internals that were opened prior to testing.
4. Remove temporary blanks and blinds.
5. Valves, orifice plates, expansion joints, and short pieces of piping which have been removed shall be reinstalled with proper gaskets in place.
6. Valves:
   a. Notify CONTRACTOR prior to valve restoration so CONTRACTOR may witness restoration.
   b. Restore, if required, valves after successful pressure testing.

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c. Restoration shall include removal of jacks; reinstallation of flappers, balls, and pistons; and replacing of bonnet gaskets on valves that were disassembled.
d. CONTRACTOR will sign tag that was previously placed on valve and indicate that valve is ready for operation.

7. Remove temporary piping supports after lines have been drained. Restraining parts that were supplied with hangers and expansion joints for their protection when carrying test loads shall be removed upon completion of system test and permanently reattached to supports with 3/16-inch minimum stainless steel wire.
8. Remove and replace special length bolting and temporary gaskets with line class bolts and gaskets.
9. Each system shall be connected to equipment where applicable and be ready for operation.
10. Seal terminal points of piping systems that are left for future connections with blinds or plugs.

1.1 SUPPLEMENTS

A. The supplements listed below or CONTRACTOR approved alternates, following "End of Section," are part of this Specification:
1. Piping Pretest Checklist.
2. Status of Instruments During Pressure Test.
3. Piping Test and Post-Test Checklist.
4. Power Piping Standard PP-1, - Dielectric Flanged Joint.

END OF SECTION

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PIPING PRETEST CHECKLIST

INSPECTION DATE _____

INSPECTED BY _____

PLANT _____ SUBCONTRACTOR _____

SYSTEM/LINE NO. _____ DWG REF. _____

	Description	Contractor Initials	Sub-Contractor Initials	Date
1.	All material/equipment (valve, pipe materials, specialty items) comply with Specifications and Piping and Instrumentation Diagrams.			
2.	All threaded connections, flange bolting, gaskets, and socket welds correctly installed.			
3.	All PWHT completed and acceptable.			
4.	All NDE (hardness, MT, PT, RT, UT) acceptable			
5.	Instrumentation protected/secure.			
6.	Rotating equipment internals protected/secure.			
7.	Expansion joints, relief valves, orifice plates, meters, control valves, filter elements, internal refractories, and other special items protected/secure.			
8.	Gauges calibrated and installed.			
9.	Status of block and control valves and check valve internals have been tagged.			
10.	Blinds correctly installed.			
11.	Temporary plugs and caps have been replaced.			
12.	Low point drains are installed as needed.			
13.	High point vents are installed as needed.			

REMARKS

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STATUS OF INSTRUMENTS DURING PRESSURE TEST (1)

	Block & Vent	Remove	Blind Off	Include In Test	Refer to Notes
Analyzers	X				
Control Valves				X	
Flow Indicating Switches, Bellows Type	X				
Flow Instruments-D/P Cell & Bellows Type	X				
Flow Instruments-Rotameters		X			2
Flow Meters-Positive Displacement Type			X		2
Flow Meters-Turbine Type			X		2
Flow Switches-Vane Type		X			
Gauge Glasses				X	3
Level Instruments-Displacer Type				X	3
Level Instruments-D/P Cell & Bellows Type	X				
Level Switches-Float Type				X	3
Orifice Plates		X			4
Pressure Gauges	X				
Pressure Instruments-All Types	X				
Pressure Regulators		X			
Pressure Switches	X				
PSV's			X		5,2
PSV's-3/4" and 1" Screwed		X			2
Rupture Discs		X			
Steam Traps		X			2
Thermowells				X	

NOTES:

1. All instruments shall be protected from damage due to freezing. In preparation for cold weather and during cold weather all instruments must be drained and process lead lines blown out with air or nitrogen.
2. Fabricate and install temporary spool or cap if necessary for test.
3. Caution - do not overpressure instrument. Check with CONTRACTOR for maximum test pressure allowed by manufacturer.
4. Install after hydrotesting and line flushing.
5. Blinds are not required on PSV outlets discharging into a system being tested at 15 psig or less.

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PIPING TEST AND POST-TEST CHECKLIST

INSPECTION DATE _____ TEST PACKAGE NO._____

INSPECTED BY _____

PLANT _____ SUB-CONTRACTOR _____

SYSTEM/LINE NO. _____ DWG REF. _____

TEST MEDIUM _____ TEST PRESSURE, PSIG _____ TEST TEMP, °F _____

TEST PRESSURE HOLDING TIME _____MIN AMBIENT TEMP _____

Description	Contractor Initials	Sub-Contractor Initials	Date
1. Test Complete and Acceptable			
2. If partial tests were made, define:			
3. System ready for post-test check:			
a. Test blinds removed.			
b. Final line flush complete.			
c. Vents properly plugged.			
d. Drains properly valved and plugged.			
e. Instruments properly installed.			
f. Expansion joints, relief valves, control valves, in-line meters, filter elements, orifice plates, in-line strainers, and other special items clean and properly installed			
g. Rotating equipment properly in-line.			
h. Temporary supports removed.			
i. Permanent supports restored			

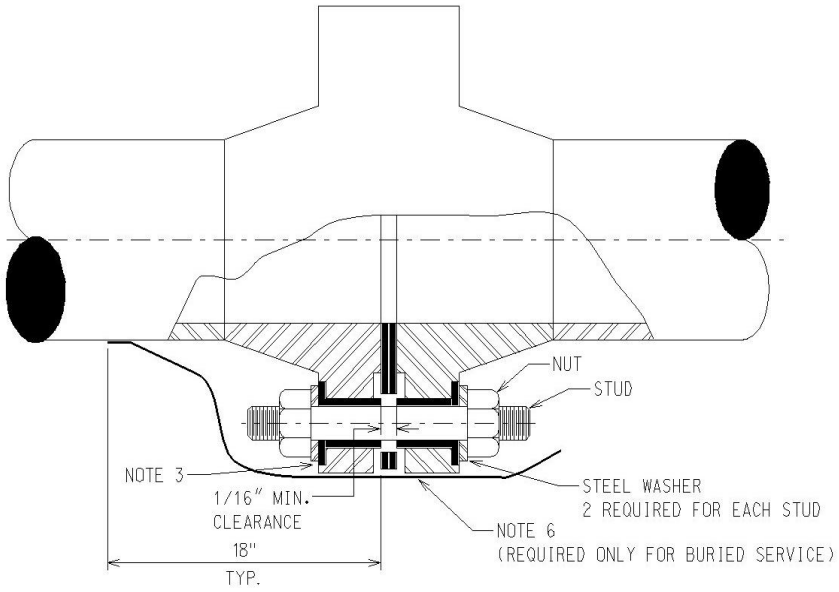
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NOTES:

1. GASKET SHALL BE OF NON-METALIC OR NON-GRAPHITE-IMPREGNATED MATERIAL. MATERIAL TO BE PHENOLIC LAMINATE AS SUITABLE TO SERVICE TEMPERATURE OF LINE AND THE FLANGE TYPE, PSIPRODUCTS, F. H. MALONEY OR EQUAL.

2. SLEEVES AND WASHERS SHALL BE ONE PIECE OF ACETAL RESIN OR NYLON MATERIAL. USE TWO FOR EACH STUD.

3. REMOVE BURRS OR OTHER FOREIGN PARTICLES FROM FLANGE FACES, BOLT HOLES AND STUDS.

4. FOLLOW MANUFACTURER'S RECOMMENDED PRACTICE FOR INSTALLATION.

5. TEST FLANGE AFTER INSTALLATION AND REPLACE ANY CRACKED SLEEVES OR WASHERS WHICH MAY CAUSE "SHORTING OUT." USE CONTINUITY TESTER, FLASHLIGHT WITH LEADS, ETC.

6. AFTER INSTALLATION IS COMPLETE, PRIMER AND THREE WRAPS OF TAPE SHALL BE APPLIED TO FLANGE PERIMETERS AND EXTENDED 18" ON BOTH SIDES OF FLANGES. USE SCOTCHRAP, POLYKEN, OR EQUAL TO MANUFACTURER'S INSTRUCTIONS.

POWER PIPING STANDARD

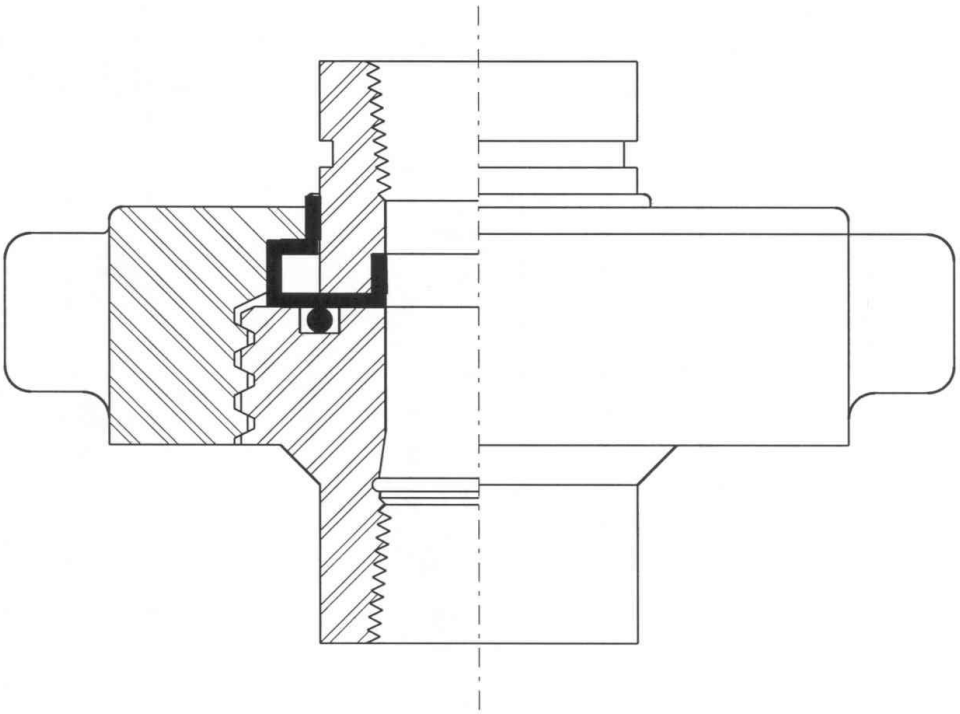
PP-1
DIELECTRIC FLANGED JOINT

PP1.DGN 1 NONE

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POSITIVE PRESSURE SEAL PROVIDED BY "O" RING FOR USE WITH GAS, CRUDE, BRINE, WATER, AIR, AMMONIA AND LUBRICATING OILS - UP TO 275 DEG. F.

SIZES: 1000# CWP OCTAGON NUT
1/2" - 3/4" - 1" - 1 1/4" - 1 1/2" - 2"

SIZES: 3000# CWP HANDLE BAR OR OCTAGON NUT
1/2" - 3/4" - 1" - 1 1/4" - 1 1/2" - 2" - 2 1/2" - 3"

AFTER INSTALLATION IS COMPLETE, PRIMER AND THREE WRAPS OF TAPE SHALL BE APPLIED TO UNION AND EXTENDED 18" ON BOTH SIDES OF UNION. USE SCOTCHRAP, POLYKEN, OR EQUAL TO MANUFACTURER'S INSTRUCTIONS. COATING IS ONLY REQUIRED FOR BURIED SERVICE.

POWER PIPING STANDARD

PP-2
DIELECTRIC THREADED JOINT

PP2.DGN	0	NONE

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SDH 11/12/01
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NA / /

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SECTION 40 55 00
POWER PLANT VALVES

PART 1 - GENERAL

1.01 SUMMARY

A. This Specification defines the requirements for manual and motor operated valves and supplements the Purchase Order.

B. Standard valves consist of ball, butterfly, gate, globe, check and plug valves of cast iron, bronze, carbon steel, stainless steel, alloy steel, or plastic.

1.02 REFERENCES

A. The following is a list of standards that may be referenced in this section.

1. American Petroleum Institute (API):
2. American Society of Mechanical Engineers (ASME):
3. ASTM International (ASTM):
4. American Water Works Association (AWWA):
5. Factory Mutual (FM).
6. Manufacturers Standardization Society of the Valve and Fittings Industry, Inc. (MSS):
7. National Electrical Manufacturers Association (NEMA).
8. Underwriters Laboratories (UL).
9. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
10. National Electrical Manufacturers' Association (NEMA):

1.03 SUBMITTALS

A. Action Submittals:

1. Shop Drawings: Provide for each type and size of valve:
   a. Complete descriptive literature, including dimensions, weights and centers of gravity, bevel detail of butt weld end connection, and materials of construction.
   b. For motor operated valves:
      1) Complete Specifications, catalog cut sheets, descriptive literature.
      2) Principal dimensions, incoming power, general construction, and outline of the actuator mechanism.

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3) Operating Characteristics:
   a) Output torque or thrust.
   b) Voltage and frequency.
   c) Number of phases.
   d) Nominal power at running torque.
   e) Nominal power at locked rotor.
   f) Current at running torque.
   g) Current at locked rotor.
   h) Speed or travel time.
4) Actuator options being supplied.
   a) Electrical wiring diagrams with list of symbols.
   b) Recommended spare parts for 1 year's operation with unit prices.

B. Informational Submittals:

1. Operation and Maintenance Data.
2. Certified Material Test Report (CMTR):
   a. Furnish for both body and bonnet material.
   b. Signed by manager of valve manufacturer's quality control department and shall show the name of supplier, name of prime material manufacturer and plant location, purchase order number, actual test results of chemical analysis and mechanical properties in accordance with the material specification, and BUYER's project number.
3. Certificate of Compliance (COC):
   a. Required for valves not covered by CMTR.
   b. Furnish for both body and bonnet material.
   c. Certify that valve is new and complies with requirements of this Specification.
   d. Certifies manufacturing standard that applies to valve.
   e. Signed by manager of valve manufacturer's quality control department and shall show the name of supplier, name of prime material manufacturer and plant location, purchase order number, actual test results of chemical analysis and mechanical properties in accordance with the material specification, and BUYER's project number.
4. Certified Test Report: Furnish for valves in Class 300 and higher.
5. Gear Operated Valve: Erection and installation instructions.
6. Motor Operated Valve:
   a. Manufacturer's test reports for the following:
      1) Voltage, phase, and frequency.

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2) Stroke time (seconds).
3) Seating (or maximum dynamic) torque.
4) Seating load amps.
5) Torque-switch and limit-switch function

7. Erection and installation instructions.
8. Hydrotest Certification.
9. Repair records complete with inspection and welding procedures and qualifications.

1.04 MARKING AND IDENTIFICATION

A. Marking: The following marking requirements are in addition to those required by applicable manufacturing standard:

1. Nonmetallic valves shall be marked with manufacturer's name, valve size, and pressure class.
2. Mark check valves with arrow indicating required direction of flow. Check valves that are suitable only for horizontal service shall be identified as such.
3. Butterfly, ball, globe, and plug valves shall be marked with arrow indicating preferred direction of flow.

B. Nameplates:

1. Durable metal nameplate permanently attached to yoke, cover, or top of valve.
2. Include at least manufacturer's name, figure number, serial number, size, and pressure class.

C. Identification Tags:

1. In addition to nameplates, each valve accessory and loose item shall be furnished with a permanently attached metal identification tag stamped with applicable Valve Data Sheet number.
2. A second metal identification tag stamped with the unique valve Tag number shall be provided for each valve. Tags shall be sorted and packaged by Service Code (IA, RW, etc.) by the SELLER prior to shipment. SELLER shall furnish individual wires and holding devices for each tag plus 2 percent spares. SELLER shall furnish 1 percent spare blank tags.
3. Valve Data Sheet and Tag numbers are specified on Valve List.
4. Tag shall be 18-gauge stainless steel, permanently attached to the valve with 18-gauge braided monel or stainless steel wire, and meter seal or similar wire holding device.

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5. Characters on stamp shall be 3/16 inch, minimum, in height.
6. Location of tag shall not interfere with installation or operation of valve.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Shipping:

1. When items are shipped in containers, identify each container with at least manufacturer's name, material description, size, purchase order number, and applicable valve tag number.
2. Protect flange faces and butt weld ends with wood, wood fiber, or plastic covers.
3. Close female threaded and socket weld openings with plastic or metal plugs.
4. Drain unit of liquid prior to shipment.
5. Unit shall be disassembled only to such extent as may be necessary to facilitate field handling and to prevent damage during shipment.
6. Loose components shall be strung on wire and securely attached to valve or be furnished in a box.
7. Ship metal seated valves in closed position.
8. Ship resilient seated valves in open position.
9. Metal seated swing check valves shall be blocked closed and furnished with instructions (attached to valve) to remove blocking before installation.
10. Valves for chlorine service shall be individually packaged with desiccant in clear polyethylene bags or BUYER approved substitute.

B. Storage: Protect valves to withstand at least 6 months of unsheltered storage at Job Site before installation.

PART 2 - PRODUCTS

2.01 COMPONENTS

A. Valve Data Sheets: See supplemental information attached at end of section.

B. Valves:

1. General:
   a. Valves and accessories shall conform to the Valve List, applicable Valve Data Sheet, and requirements of this Specification.
   b. Valve List specifies quantity, size, and type of valves and accessories.
   c. Valve Data Sheets specify pressure rating, end connection, and materials for each type of valve.

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d. Valves shall be new and shall not contain asbestos materials (e.g., bonnet gaskets, stem packing).
e. Butt Weld Ends:
    1) Beveled in accordance with ASME B16.25.
    2) Bored to match pipe schedule specified on Valve Data Sheet.
    3) Schedule bore ends shall be beveled in accordance with ASME B16.25 Fig. 2(b) or 3(b).

2. Valve Accessories: When accessories are specified on Valve List, they shall be manufacturer's standard, unless otherwise specified herein, and shall consist of but not be limited to, the following:
    a. Chain Wheels and Chain:
        1) High quality malleable iron, designed so chain has positive grip on wheel at all times.
        2) Complete unit shall be suitable for specified operating conditions.
        3) Chain wheel operated valves, without gear operators, shall be furnished complete with impact wheel type operator.
        4) Complete with chain guides and nonrusting chain.
        5) Chain shall be forged link construction. Chain lengths, when specified, are given in feet in continuous chain.
    b. Drain Connections: Size for each valve in accordance with MSS-SP-45 and shall be plugged.
    c. Bypasses: Size in accordance with Series A of MSS-SP-45.
3. Valve Operators:
    a. As specified on Valve Data Sheet.
    b. Operators shall provide external indication of disc position and open counterclockwise.
    c. Gear Operators
        1) Gear operators shall be manufacturer's standard design and materials for type of valve specified herein.
        2) Orientation will be determined by BUYER after receipt of Supplier's drawings.
        3) Totally enclosed type.
        4) Provide with handwheel and provision for air wrench operation.
    d. Motor Operators: Refer to Part 2.01.D of this Specification.
4. Adjustable Limit Switches:
    a. NAMCO snap action switches for manually operated valves.
    b. Enclosure:
        1) Clean Dry Locations: NEMA 12.
        2) Normally Wet or Damp Locations: NEMA 4.
        3) Outdoor Locations: NEMA 4.
        4) Corrosice Environment; NEMA 4.

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c. Devices that interface with BUYER's equipment shall have the following minimum contact ratings:
   1) AC: NEMA A300 rated, Form C contacts suitable for 300V ac, 10 amperes continuous, 60 amperes make, 6 amperes break at 120V ac. These ratings are based on inductive loads.
   2) DC: NEMA P300 rated, Form C contacts suitable for 125V dc, 5 amperes continuous, 1.1 amperes make or break at 125V dc.

5. Locking Devices:
   a. Allows valve to be locked open or closed with standard padlock.
   b. Permanent and integral part of handwheel and yoke or lever.
6. Extension Stems: Complete with required couplings, universal joints, supporting brackets, and extra strong pipe stems.
7. Floor Stands and Indicators: Manufacturer's standard.

C. Factory Finish:

1. Surface Preparation:
   a. Cast iron, steel, or alloy valve shall be painted in accordance with manufacturer's standard practice.
   b. Nameplates, identification tags, machined mating surfaces, and stainless steel material shall not be painted.
   c. Stem of rising stem valves and exposed threads shall be coated with antiseize lubricant.

D. Electric Valve Operator:

1. General:
   a. Comply with ANSI C540.
   b. Size to 1-1/2 times required operating torque. Motor stall torque not to exceed torque capacity of the valve.
   c. Controls integral with the actuator electrical compartment and fully equipped as specified in ANSI C540.
   d. Stem protection for rising stem valves.
2. Actuator Operation - General:
   a. Suitable for full 90-degree rotation of quarter-turn valves or for use on multiturn valves.
   b. Manually over-ride handwheel.
   c. Valve position indication.
   d. Operate from fully CLOSED to fully OPENED positions or the reverse in the number of seconds given in the Valve List.
3. Electronic Control Module:

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a. Integrated control circuit with intrinsically safe infra-red interface and infra-red communicator.
b. Communicator used to configure valve parameters and setup limit switches without opening the actuator's enclosure.
c. All configurable settings stored in EEPROM.
d. Battery for LCD and status while valve is not powered.
e. Over-torque detection and protection.
f. Jammed-valve detection and protection.
g. Motor over-temperature detection and protection.
h. Incorrect phase rotation detection and protection.
i. Lost phase detection and protection.
j. Instantaneous reversal detection and protection.
k. Automatic self test and diagnostics.
l. On-board data logger for torque and position profiles and statistics, time and date stamped.
m. Capable of downloading data logs and statistics to a personal computer via infra-red port or other communication device for troubleshooting and analysis.

4. OPEN-CLOSE Service:
   a. Motor conforms with NEMA MG 1, rated up to 60 starts per hour at a rate not exceeding 600 starts per hour, with embedded thermostats.
   b. Electro-mechanical reversing motor controller.
   c. Local Indication and Control:
      1) Integral valve POSITION indication, 0 to 100 percent OPENED.
      2) Integral OPENED and CLOSED indication lights; red/OPEN, green/CLOSED.
      3) Integral LOCAL-OFF-REMOTE (LOR) lockable maintained switch. OFF disables all other switches and prevents the valve from stroking.
      4) Integral OPEN maintained switch which causes the valve to stroke full OPENED, even if the OPEN switch is released, while the LOR switch is in LOCAL.
      5) Integral CLOSE maintained switch which causes the valve to stroke full CLOSED, even if the CLOSED switch is released, while the LOR switch is in LOCAL.
   d. Remote Indication and Control:
      1) Monitor relay that closes when the valve is capable of being controlled remotely (LOR switch in REMOTE, etc.) for connection to and monitoring by the Distributed Control System (DCS).

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2) Limit switch that closes when the valve is fully OPENED for connection to and monitoring by the DCS.
3) Limit switch that closes when the valve is fully CLOSED for connection to and monitoring by the DCS.
4) OPEN terminal which causes the valve to stroke fully OPENED, even if the OPEN signal is momentary, while the LOR switch is in REMOTE, for connection to and control by the DCS.
5) CLOSE terminal which causes the valve to stroke fully CLOSED, even if the CLOSE signal is momentary, while the LOR switch is in REMOTE, for connection to and control by the DCS.

5. Throttling Service:
   a. Motor conforms with NEMA MG 1, rated up to 60 starts per hour at a rate not exceeding 600 starts per hour, with embedded thermostats.
   b. Electro-mechanical reversing motor controller.
   c. Local Indication and Control:
      1) Integral valve POSITION indication, 0 to 100 percent OPENED.
      2) Integral OPENED and CLOSED indication lights; red/OPEN, green/CLOSED.
      3) Integral LOCAL-OFF-REMOTE (LOR) lockable maintained switch. OFF disables all other switches and prevents the valve from stroking.
      4) Integral OPEN momentary switch which causes the valve to stroke towards OPENED, as long as the OPEN switch is held, while the LOR switch is in LOCAL.
      5) Integral CLOSE momentary switch which causes the valve to stroke towards CLOSED, as long as the CLOSED switch is held, while the LOR switch is in LOCAL.
   d. Remote Indication and Control:
      1) Monitor relay that closes when the valve is capable of being controlled remotely (LOR switch in REMOTE, etc.) for connection to and monitoring by the DCS.
      2) Limit switch that closes when the valve is fully OPENED for connection to and monitoring by the DCS.
      3) Limit switch that closes when the valve is fully CLOSED for connection to and monitoring by the DCS.
      4) OPEN terminal which causes the valve to stroke towards OPENED, as long as the OPEN signal is true, while the LOR

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switch is in REMOTE, for connection to and control by the DCS.

5) CLOSE terminal which causes the valve to stroke towards CLOSED, as long as the CLOSE signal is true, while the LOR switch is in REMOTE, for connection to and control by the DCS.

6) Current Position Transmitter, 4 to 20 mA dc signal in proportion to 0 to 100 percent OPENED, with 0.5 percent accuracy and 0.5 percent repeatability, capable of driving a 750-ohm load, for connection to and monitoring by the DCS.

6. Modulating Service:
   a. Motor rated up to 1,200 starts per hour, with embedded thermostats.
   b. Solid-state reversing motor controller.
   c. Dynamic braking to limit overrun.
   d. Local Indication and Control:
      1) Integral valve POSITION indication, 0 to 100 percent OPENED.
      2) Integral OPENED and CLOSED indication lights; red/OPEN, green/CLOSED.
      3) Integral LOCAL-OFF-REMOTE (LOR) lockable maintained switch. OFF disables all other switches and prevents the valve from stroking.
      4) Integral OPEN momentary switch which causes the valve to stroke towards OPENED, as long as the OPEN switch is held, while the LOR switch is in LOCAL.
      5) Integral CLOSE momentary switch which causes the valve to stroke towards CLOSED, as long as the CLOSED switch is held, while the LOR switch is in LOCAL.
   e. Analog Position Controller:
      1) Provides remote control of valve position.
      2) Position valve proportionally to external 4 to 20 mA dc signal while in REMOTE, or from OPEN and CLOSE terminals while in LOCAL.
      3) Configurable to stroke fully OPENED, fully CLOSED or maintain last position upon loss of 4 to 20 mA signal.
      4) Deadband and motion inhibitor to prevent hunting.
      5) Position 0 to 100 percent OPENED proportional to 4 to 20 mA with 0.5 percent accuracy and 0.5 percent repeatability.
   f. Remote Indication and Control:
      1) Monitor relay that closes when the valve is capable of being controlled remotely (LOR switch in REMOTE, etc.) for connection to and monitoring by the DCS.

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2) Limit switch that closes when the valve is fully OPENED for connection to and monitoring by the DCS.
3) Limit switch that closes when the valve is fully CLOSED for connection to and monitoring by the DCS.
4) MANUAL/AUTO terminal, which when true causes the valve to be positioned proportionally to 4 to 20 mA dc signal, for connection to and control by the DCS. When MANUAL/AUTO is not true, the valve is positioned by the OPEN and CLOSE terminals.
5) OPEN terminal which causes the valve to stroke towards OPENED, as long as the OPEN signal is true, while the LOR switch is in REMOTE and while the position controller is in MANUAL, for connection to and control by the DCS.
6) CLOSE terminal which causes the valve to stroke towards CLOSED, as long as the CLOSE signal is true, while the LOR switch is in REMOTE and while the position controller is in MANUAL, for connection to and control by the DCS.
7) Current Position Transmitter, 4 to 20 mA dc signal in proportion to 0 to 100 percent OPENED, with 0.5 percent accuracy and 0.5 percent repeatability, capable of driving a 750-ohm load, for connection to and monitoring by the DCS.
8) Analog terminals which receives the 4 to 20 mA dc signal that the valve is to be positioned proportional to, while the LOR switch is in REMOTE and while the position controller is in AUTO, connected to and controlled by the DCS.

7. Actuator Power Supply:
   a. 480-volt, three-phase, 60-hertz, unless otherwise indicated.
   b. Internal control power transformer with primary and secondary fuses, 120-volt secondary.
   c. Externally operable power disconnect switch.
8. Enclosure:
   a. As defined in NEMA 250, Types 4, 4X, 6.
   b. Thermostat operated 120-volt space heaters.
9. Limit Switch:
   a. Single-pole, double-throw (SPDT) type, field adjustable with contacts rated for 5 amps at 120V ac.
   b. Each valve actuator to have a minimum of two sets of contacts at each end position; one set which opens and another set that closes for valve fully OPENED and one set which opens and another set that closes for valve fully CLOSED.
   c. Housed in actuator control enclosure.

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d. Adjustable with the infra-red IQ or other communicator without opening the actuator's enclosure.

10. Manufacturers:
    a. Limitorque Type MX.

2.02 SOURCE QUALITY CONTROL

A. Tests:

1. Each metallic valve shall have both its shell and seat pressure tested in accordance with applicable manufacturing standard.
2. Hydrostatic seat test for gear operated valves shall be performed on completely assembled valve with seat closed by applicable manual gear or motor operator.
3. Valves manufactured in accordance with API Standards shall be seat tested with high-pressure closure test per API 598.
4. Valves pressure rated in accordance with ASME B16.34 shall meet seat leakage requirements of MSS SP-61.
5. Hydrostatic seat closure test is required for carbon steel, stainless steel, and chrome-moly valves.
6. If bypass is required to be furnished, then bypass shall be welded to main valve and hydrostatically tested to prove that piping and bypass valve will withstand pressure not less than 150 percent of main valve's 100 degrees F pressure rating.
7. Each completed electric motor operated valve assembly shall be cycled from full open to full closed and back to full open for verification of limit and torque switch function and setting, and ability of motor operator to open and close valve after seat leakage test has been performed.

B. Inspection: BUYER shall have right to inspect at any stage of fabrication equipment, materials, and associated QA/QC documentation covered by this specification including Suborder(s). Supplier shall include this notation on any Suborder(s).

C. Repair and Restoration:

1. Repair defects in body of cast or forged carbon, alloy, and stainless steel valves by applicable manufacturing standard.
2. Retest repaired valves.
3. Repair of body defects in cast iron, bronze, and nonmetallic valves is not permitted.
4. BUYER reserves right to reject any valve with weld repairs.

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PART 3 - EXECUTION

3.01 INSTALLATION

A. General:

1. All valves shall be installed in strict accordance with manufacturer's instructions.
1. Orient handwheels as shown on BUYER's Drawings.
2. If handwheel orientation is not shown on Drawings, valve stems shall be in vertical position.

B. Butterfly Valves:

1. Separate mating flanges for resilient seat butterfly valves sufficiently so valves do not have to be wedged or forced into position.
2. Set discs in open position prior to tightening mating flange bolting.
3. Operate valve through entire open/ close cycle after tightening of bolts. Verify that disc or seat has not been jammed or damaged.

C. Check Valves

1. Tag to indicate whether internals have been removed, jacked open, or left unaltered.
2. Bag internal parts that have been removed, tag with valve number, and securely attach bag to appropriate valve.

D. Lubricated Plug Valves: Lubricate with sealant appropriate for service.

3.02 SUPPLEMENTS

A. The supplements listed below, following "End of Section," are a part of this Specification:

1. Valve Index.
2. Valve Data Sheets.

END OF SECTION

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VALVE INDEX

Valve Data Sheet	Description	Rev	Date
VB1BCRLC03	Ball, std, CL 300, RF, CS	A	
VB1QLRLP01	Ball, std, 230 psig, RF, PFA lined DI	A	
VB1RBPLB01	Ball, 200 psig, Solder Joint, BZ	A	
VB1RBTLR01	Ball, std, CL 200, TE, BZ	A	
VB1UNRLC01	Ball, 1500 psig, tube fitting, SS	A	
VB2QUGLR01	Ball, full port, 150 psig, Socket, PVC	A	
VB2QVFTR01	Ball, full port, 150 psig, FF, CPVC	A	
VB2QVGTR01	Ball, full port, 230 psig, Socket, CPVC	A	
VB3ACRGC01	Ball, std, CL 150, RF, GO, CS	A	
VB3ACRGC03	Ball, std, CL 150, RF, GO, CS	A	
VB3ACRLC01	Ball, std, CL 150, RF, CS	A	
VB3ACRLC03	Ball, std, CL 150, RF, CS	A	
VB3BCRGC03	Ball, std, CL 300, RF, GO, CS	A	
VB4BNRGC03	Ball, full port, CL 300, RF, GO, SS	A	
VB4BNRLC03	Ball, full port, CL 300, RF, SS	A	
VC1ACBN801	Check, swing, CL 150, BW, CS	A	
VC1ACRN801	Check, swing, CL 150, RF, CS	A	
VC1BCBN801	Check, swing, CL 300, BW, CS	A	
VC1BCBN806	Check, swing, CL 300, BW, CS	A	
VC1BCRN801	Check, swing CL 300, RF, CS	A	
VC1NBPNB01	Check, swing, CL 125, Solder Joint, BZ	A	
VC1NEFNB01	Check, swing, CL 125, FF, CI	A	
VC1NEFNB02	Check, swing, CL 125/175 FF, CI, UL/FM	A	
VC1RBTNB01	Check, swing, CL200, TE, BZ	A	
VC2FCBN505	Check, tilting disc, CL 1500, BW, CS	A	
VC4ANRNR01	Check, wafer, CL 150, SS	A	
VC4NEFNR01	Check, wafer, CL 125, CI	A	
VC5QVRNR01	Check, wafer, 90 psig, RF, CPVC	A	
VC6GCSN501	Check, piston, CL 1690, SW, CS	A	
VC7QLRNR01	Check, ball, 230 psig, RF, PFA lined DI	A	

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Valve Data Sheet	Description	Rev	Date
VC7QUGNR01	Check, ball, 100 psig, Socket, PVC	A	
VC7QVGNR01	Check, ball, 150 psig, Socket, CPVC	A	
VD1QVFHB01	Diaphragm, 90 psig, CL 125, Flg'd, CPVC	A	
VF2ACRH201	Butterfly, Lug, CL 150, CS	A	
VF2ACRL201	Butterfly, Lug, CL 150, CS	A	
VF2AERLD01	Butterfly, Lug, CL 150, DI	A	
VF2ANRH201	Butterfly, Lug, CL 150, SS	A	
VF2ANRL201	Butterfly, Lug, CL 150, SS	A	
VF2BCRH201	Butterfly, Lug, CL 300, CS	A	
VF2BCRL201	Butterfly, Lug, CL 300, CS	A	
VF2NEFHD01	Butterfly, Lug, CL 125/150, GO, DI	A	
VF2NEFLD01	Butterfly, Lug, CL 125/150, DI	A	
VF2QVFLR01	Butterfly, Flanged, 90 psig, FF, CPVC	A	
VF5ACFGC01	Butterfly, Flanged, CL 150, FF, CS	A	
VF5NEFGD01	Butterfly, flanged, CL 125, FF, DI, GO	A	
VL1ABPHS01	Globe, CL 150, Solder Joint, BZ	A	
VL1ACBH801	Globe, CL 150, BW, CS	A	
VL1ACRH801	Globe, CL 150, RF, CS	A	
VL1ANRH301	Globe, CL 150, RF, SS	A	
VL1ANSHS01	Globe, CL 150, SW, SS	A	
VL1BCBH801	Globe, CL 300, BW, CS	A	
VL1BCBH806	Globe, CL 300, BW, CS	A	
VL1BCRH801	Globe, CL 300, RF, CS	A	
VL1NEFGB01	Globe, CL 125, FF, GO, CI	A	
VL1NEFHB01	Globe, CL 125, FF, CI	A	
VL1RBTHB01	Globe, CL 200, TE, BZ	A	
VP5BCRGN01	Plug, lubricated, CL 300 RF, GO, CS, U/G	A	
VP6ACRLN01	Plug, 3-Way, lubricated, CL 150, RF, CS	A	

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SECTION 40 55 00 VALVE DATA SHEET VB1BCRLC03	
Item	**Description**
Type	Ball, Regular Port (Fire Safe) (Note 1).
Rating	Class 300.
Standards	ASME B16.34, ASME B16.10, API 607.
Ends	Flanged, Class 300RF, ASME B16.5.
Body Material	Carbon Steel, ASTM A105/A105M or A216/A216M, Grade WCB.
Bonnet Type & Material	N/A.
Bolting	ASTM A193/A193M, Grade B7.
Ball	Type 316 Stainless Steel.
Seat	Reinforced Teflon.
Stem Type/Material	Type 316 Stainless Steel.
Stem Packing/Seals	Flexible Graphite.
Body Gasket/Seals	N/A.
Operator	Lever.
Size	3" – 4”

Notes:
1. Valve, seat, and stem packing shall incorporate anti-static design, which is suitable for natural gas service.

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SECTION 40 55 00 VALVE DATA SHEET VB1QLRLP01	
Item	**Description**
Type	Ball, Std Port.
Rating	230 psig @ 300 Degrees F.
Standards	Manufacturer's Standard.
Ends	Flanged, Class 150 RF, ASME B16.5.
Body Material	PFA Lined Ductile Iron ASTM A395.
Bonnet Type & Material	N/A.
Bolting	ASTM A193/A193M, Grade B7M.
Ball	PFA Encapsulated Alloy Steel.
Seat	PTFE with PFA Encapsulated Fluor Elastomer O-Ring.
Stem Type/Material	PFA Encapsulated Alloy Steel.
Stem Packing/Seals	PTFE.
Body Gasket/Seals	Silicone/Viton.
Operator	Lever Operator.
Size	1/2" – 6"

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SECTION 40 55 00 VALVE DATA SHEET VB1RBPLB01	
Item	**Description**
Type	Ball, Standard Port.
Rating	200 psig @ 150 Degrees F and 155 psig @ 225 Degrees F.
Standards	Manufacturer's Standard.
Ends	Solder Joint, ASME B16.18.
Body Material	Bronze.
Bonnet Type & Material	N/A.
Bolting	N/A.
Ball	Bronze.
Seat	Buna-N.
Stem Type/Material	Bronze.
Stem Packing/Seals	Buna-N.
Body Gasket/Seals	N/A.
Operator	Lever.
Size	1/4" – 2"

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SECTION 40 55 00 VALVE DATA SHEET VB1RBTLR01	
Item	**Description**
Type	Ball, Standard Port (Port Diameter no Less than One Size Smaller than Nominal Valve Size).
Rating	Class 200, 400 psig @ 100 Degrees F.
Standards	Manufacturer's Standard.
Ends	Female Thread, ASME B1.20.1, NPT.
Body Material	Bronze, ASTM B61 or B62.
Bonnet Type & Material	N/A.
Bolting	Manufacturer's Standard.
Ball	Bronze.
Stem Type/Material	Bronze.
Seat	Teflon.
Stem Packing/Seals	Teflon or Buna-N.
Body Gasket/Seals	N/A.
Operator	Lever.
Size	1/2" – 2"

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SECTION 40 55 00 VALVE DATA SHEET VB2QUGLR01	
Item	**Description**
Type	Ball, Full Port.
Rating	150 psig @ 70 Degrees F.
Standards	Manufacturer's Standard.
Ends	Socket ends with unions between both ends and body, ASTM D2467.
Body Material	PVC, ASTM D1784.
Bonnet Type & Material	N/A.
Bolting	N/A.
Ball	PVC, ASTM D1784.
Seat	Teflon.
Stem Type/Material	PVC, ASTM D1784.
Stem Packing/Seals	Viton.
Body Gasket/Seals	Viton.
Operator	Lever.
Size	1/2" – 4"

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SECTION 40 55 00 VALVE DATA SHEET VB2QVFTR01	
Item	**Description**
Type	Ball, Full Port.
Rating	150 psig @ 70 Degrees F.
Standards	Manufacturer's Standard.
Ends	Socket ends with ANSI CL 150 flanges between both ends and body, ASTM D2467..
Body Material	CPVC, ASTM D1784.
Bonnet Type & Material	N/A.
Bolting	N/A.
Ball	CPVC, ASTM D1784.
Seat	Teflon.
Stem Type/Material	CPVC, ASTM D1784.
Stem Packing/Seals	Viton.
Body Gasket/Seals	Viton.
Operator	T-Handle.
Size	3" – 6"

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SECTION 40 55 00 VALVE DATA SHEET VB2QVGTR01	
Item	**Description**
Type	Ball, Full Port, 3-Piece Union Ends.
Rating	230 psig @ 70 Degrees F.
Standards	Manufacturer's Standard.
Ends	Socket ends with unions between both ends and body, ASTM D2467.
Body Material	CPVC, ASTM D1784.
Bonnet Type & Material	N/A.
Bolting	N/A.
Ball	CPVC, ASTM D1784.
Seat	Teflon.
Stem Type/Material	CPVC, ASTM D1784.
Stem Packing/Seals	Viton.
Body Gasket/Seals	Viton.
Operator	T-Handle.
Size	1/2" – 2"

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SECTION 40 55 00 VALVE DATA SHEET VB3ACRGC01	
Item	**Description**
Type	Ball, Regular Port, Trunnion.
Rating	Class 150.
Standards	ASME B16.34, ASME B16.10, Short Pattern through 16", Long Pattern 18" and Larger, API 607.
Ends	Flanged, Class 150RF, ASME B16.5.
Body Material	Carbon Steel, ASTM A105/A105M or A216/A216M, Grade WCB.
Bonnet Type & Material	N/A.
Bolting	ASTM A193/A193M, Grade B7 or B7M.
Ball	Type 316 Stainless Steel.
Seat	Reinforced Teflon.
Stem Type/Material	Trunnion, Type 316 Stainless Steel.
Stem Packing/Seals	RPTFE, Viton.
Body Gasket/Seals	RPTFE, Viton.
Operator	Enclosed Gear Operator.
Size	6” – 10”

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SECTION 40 55 00 VALVE DATA SHEET VB3ACRGC03	
Item	**Description**
Type	Ball, Regular Port, Trunnion (Fire Safe) (Note 1).
Rating	Class 150.
Standards	ASME B16.34, ASME B16.10, API 607.
Ends	Flanged, Class 150RF, ASME B16.5.
Body Material	Carbon Steel, ASTM A105/A105M or A216/A216M, Grade WCB.
Bonnet Type & Material	N/A.
Bolting	ASTM A193/A193M, Grade B7
Ball	Type 316 Stainless Steel.
Seat	Reinforced Teflon.
Stem Type/Material	Trunnion, Type 316 Stainless Steel.
Stem Packing/Seals	Flexible Graphite.
Body Gasket/Seals	N/A.
Operator	Enclosed Gear Operator.
Size	6” - 10

Notes:
1. Valve, seat, and stem packing shall incorporate anti-static design, which is suitable for natural gas service.

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SECTION 40 55 00 VALVE DATA SHEET VB3ACRLC01	
Item	**Description**
Type	Ball, Regular Port, Trunnion.
Rating	Class 150.
Standards	ASME B16.34, ASME B16.10, Short Pattern through 16", Long Pattern 18" and Larger, API 607.
Ends	Flanged, Class 150RF, ASME B16.5.
Body Material	Carbon Steel, ASTM A105/A105M or A216/A216M, Grade WCB.
Bonnet Type & Material	N/A.
Bolting	ASTM A193/A193M, Grade B7 or B7M.
Ball	Type 316 Stainless Steel.
Seat	Reinforced Teflon.
Stem Type/Material	Trunnion, Type 316 Stainless Steel.
Stem Packing/Seals	RPTFE, Viton.
Body Gasket/Seals	RPTFE, Viton.
Operator	Lever.
Size	3” – 4”

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SECTION 40 55 00 VALVE DATA SHEET VB3ACRLC03	
Item	**Description**
Type	Ball, Regular Port, Trunnion (Fire Safe) (Note 1).
Rating	Class 150.
Standards	ASME B16.34, ASME B16.10, API 607.
Ends	Flanged, Class 150RF, ASME B16.5.
Body Material	Carbon Steel, ASTM A105/A105M or A216/A216M, Grade WCB.
Bonnet Type & Material	N/A.
Bolting	ASTM A193/A193M, Grade B7
Ball	Type 316 Stainless Steel.
Seat	Reinforced Teflon.
Stem Type/Material	Trunnion, Type 316 Stainless Steel.
Stem Packing/Seals	Flexible Graphite.
Body Gasket/Seals	N/A.
Operator	Lever.
Size	3” – 4”

Notes:
1. Valve, seat, and stem packing shall incorporate anti-static design, which is suitable for natural gas service.

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SECTION 40 55 00 VALVE DATA SHEET VB3BCRGC03	
Item	**Description**
Type	Ball, Regular Port, Trunnion (Fire Safe) (Note 1).
Rating	Class 300.
Standards	ASME B16.34, ASME B16.10, Short Pattern, API 607.
Ends	Flanged, Class 300RF, ASME B16.5.
Body Material	Carbon Steel, ASTM A105/A105M or A216/A216M, Grade WCB.
Bonnet Type & Material	N/A.
Bolting	ASTM A193/A193M, Grade B7.
Ball	Type 316 Stainless Steel.
Seat	Reinforced Teflon.
Stem Type/Material	Trunnion, Type 316 Stainless Steel.
Stem Packing/Seals	Flexible Graphite.
Body Gasket/Seals	N/A.
Operator	Enclosed Gear.
Size	6" – 10”

Notes:
1. Valve, seat, and stem packing shall incorporate anti-static design, which is suitable for natural gas service.

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SECTION 40 55 00 VALVE DATA SHEET VB4BNRGC03	
Item	**Description**
Type	Ball, Full Port, Long Pattern (Fire Safe) (Note 1).
Rating	Class 300.
Standards	ASME B16.34, ASME B16.10 long pattern, API 607.
Ends	Flanged, Class 300 RF, ASME B16.5.
Body Material	Type 316 Stainless Steel, ASTM A351/A351M, Grade CF8M.
Bonnet Type & Material	N/A.
Bolting	ASTM A193/A193M, Grade B8M.
Ball	Type 316 Stainless Steel.
Seat	Teflon (TFE).
Stem Type/Material	Type 316 Stainless Steel.
Stem Packing/Seals	Teflon (TFE) or Flexible Graphite.
Body Gasket/Seals	PTFE.
Operator	Gear Operator.
Size	6” – 12”

Notes:
1. Valve, seat, and stem packing shall incorporate anti-static design, which is suitable for natural gas service.

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SECTION 40 55 00 VALVE DATA SHEET VB4BNRLC03	
Item	**Description**
Type	Ball, Full Port, Long Pattern (Fire Safe) (Note 1).
Rating	Class 300.
Standards	ASME B16.34, ASME B16.10 long pattern, API 607.
Ends	Flanged, Class 300 RF, ASME B16.5.
Body Material	Type 316 Stainless Steel, ASTM A351/A351M, Grade CF8M.
Bonnet Type & Material	N/A.
Bolting	ASTM A193/A193M, Grade B8M.
Ball	Type 316 Stainless Steel.
Seat	Teflon (TFE).
Stem Type/Material	Type 316 Stainless Steel.
Stem Packing/Seals	Teflon (TFE) or Flexible Graphite.
Body Gasket/Seals	PTFE.
Operator	Lever.
Size	3” – 4”

Notes:
1. Valve, seat, and stem packing shall incorporate anti-static design, which is suitable for natural gas service.

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SECTION 40 55 00 VALVE DATA SHEET VC1ACBN801	
Item	**Description**
Type	Check, Swing.
Rating	Class 150.
Standards	ASME B16.34, ASME B16.10.
Ends	Butt Weld, ASME B16.25, Standard Weight Bore.
Body Material	Carbon Steel, ASTM A216/A216M, Grade WCB.
Bonnet Type & Material	Bolted, Carbon Steel, ASTM A216/A216M, Grade WCB.
Bolting	ASTM A193/A193M, Grade B7.
Disc	13CR.
Seat	Renewable, Seal Welded, Hardfaced, Stellite or Approved Substitute.
Stem Type/Material	N/A.
Stem Packing/Seals	N/A.
Body Gasket/Seals	Nonasbestos.
Operator	N/A.
Size	3” – 24”

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SECTION 40 55 00 VALVE DATA SHEET VC1ACRN801	
Item	**Description**
Type	Check, Swing.
Rating	Class 150.
Standards	ASME B16.34, ASME B16.10.
Ends	Flanged, Class 150 RF, ASME B16.5.
Body Material	Carbon Steel, ASTM A216/A216M, Grade WCB.
Bonnet Type & Material	Bolted, Carbon Steel, ASTM A216/A216M, Grade WCB.
Bolting	ASTM A193/A193M, Grade B7.
Disc	13CR.
Seat	Renewable, Seal Welded, Hardfaced, Stellite or Approved Substitute.
Stem Type/Material	N/A.
Stem Packing/Seals	N/A.
Body Gasket/Seals	Nonasbestos.
Operator	N/A.
Size	1” – 24”

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SECTION 40 55 00 VALVE DATA SHEET VC1BCBN801	
Item	**Description**
Type	Check, Swing.
Rating	Class 300.
Standards	ASME B16.34, ASME B16.10.
Ends	Butt Weld, ASME B16.25, NPS 3" – 12" Standard Weight Bore, NPS 14" – 24" Schedule 40 Bore.
Body Material	Carbon Steel, ASTM A216/A216M, Grade WCB.
Bonnet Type & Material	Bolted, Carbon Steel, ASTM A216/A216M, Grade WCB.
Bolting	ASTM A193/A193M, Grade B7.
Disc	13CR.
Seat	Renewable, Seal Welded, Hardfaced, Stellite or Approved Substitute.
Stem Type/Material	N/A.
Stem Packing/Seals	N/A.
Body Gasket/Seals	Nonasbestos.
Operator	N/A.
Size	1” – 24”

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SECTION 40 55 00 VALVE DATA SHEET VC1BCBN806	
Item	**Description**
Type	Check, Swing.
Rating	Class 300.
Standards	ASME B16.34, ASME B16.10.
Ends	Butt Weld, ASME B16.25, Schedule 80 Bore.
Body Material	Carbon Steel, ASTM A216/A216M, Grade WCB.
Bonnet Type & Material	Bolted, Carbon Steel, ASTM A216/A216M, Grade WCB.
Bolting	ASTM A193/A193M, Grade B7.
Disc	13CR.
Seat	Renewable, Seal Welded, Hardfaced, Stellite or Approved Substitute.
Stem Type/Material	N/A.
Stem Packing/Seals	N/A.
Body Gasket/Seals	Nonasbestos.
Operator	N/A.
Size	3” – 8”

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SECTION 40 55 00 VALVE DATA SHEET VC1BCRN801	
Item	**Description**
Type	Check, Swing.
Rating	Class 300.
Standards	ASME B16.34, ASME B16.10.
Ends	Flanged, Class 300RF, ASME B16.5.
Body Material	Carbon Steel, ASTM A216/A216M, Grade WCB.
Bonnet Type & Material	Bolted, Carbon Steel, ASTM A216/A216M, Grade WCB.
Bolting	ASTM A193/A193M, Grade B7.
Disc	13CR.
Seat	13CR, Renewable.
Stem Type/Material	N/A.
Stem Packing/Seals	N/A.
Body Gasket/Seals	Nonasbestos.
Operator	N/A.
Size	3” – 24”

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SECTION 40 55 00 VALVE DATA SHEET VC1NBPNB01	
Item	**Description**
Type	Check, Swing.
Rating	Class 125, 200 psig @ 150 Degrees F.
Standards	MSS SP-80.
Ends	Solder Joint, ASME B16.18.
Body Material	Bronze, ASTM B61 or B62.
Bonnet Type & Material	Threaded Cap, Bronze, ASTM B61 or B62.
Bolting	N/A.
Disc	Bronze, Renewable.
Seat	Bronze, Integral.
Stem Type/Material	N/A.
Stem Packing/Seals	N/A.
Body Gasket/Seals	Nonasbestos.
Operator	N/A.
Size	1/4" – 2”

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SECTION 40 55 00 VALVE DATA SHEET VC1NEFNB01	
Item	**Description**
Type	Check, Swing.
Rating	Class 125.
Standards	MSS SP-71, ASME B16.10.
Ends	Flanged, Class 125 FF, ASME B16.1.
Body Material	Cast Iron, ASTM A126/A126M, Class B.
Bonnet Type & Material	Bolted, Cast Iron, ASTM A126/A126M, Class B.
Bolting	ASTM A307, Grade B.
Disc	Bronze, Renewable.
Seat	Bronze, Renewable.
Stem Type/Material	N/A.
Stem Packing/Seals	N/A.
Body Gasket/Seals	Nonasbestos.
Operator	N/A.
Size	2” – 12”

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SECTION 40 55 00 VALVE DATA SHEET VC1NEFNB02	
Item	**Description**
Type	Check, Swing.
Rating	Class 125.
Standards	Underwriters' Listed & Factory Mutual Approved (Note 1), AWWA C508.
Ends	Flanged, Class 125 FF, ASME B16.1.
Body Material	Cast Iron, ASTM A126/A126M, Class B.
Bonnet Type & Material	Bolted, Cast Iron, ASTM A126/A126M, Class B.
Bolting	ASTM A307, Grade B.
Disc	Bronze.
Seat	Bronze.
Stem Type/Material	N/A.
Stem Packing/Seals	N/A.
Body Gasket	Nonasbestos.
Operator	N/A.
Size	4" – 12"

Notes:
1. Face to face dimensions will vary between manufacturers.

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SECTION 40 55 00 VALVE DATA SHEET VC1RBTNB01	
Item	**Description**
Type	Check, Swing (Y-Pattern) (Note 1).
Rating	Class 200, 400 psig @ 100 Degrees F.
Standards	MSS SP-80.
Ends	Threaded, ASME B1.20.1, NPT.
Body Material	Bronze, ASTM B61 or B62.
Bonnet Type & Material	Threaded Cap, Bronze, ASTM B61 or B62.
Bolting	N/A.
Disc	Bronze, Renewable.
Seat	Bronze, Integral.
Stem Type/Material	N/A.
Stem Packing/Seals	N/A.
Body Gasket/Seals	Nonasbestos.
Operator	N/A.
Size	1/2" – 2”

Notes
1. For fire service application, use only Underwriter’s Laboratories listed valves when possible.

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SECTION 40 55 00 VALVE DATA SHEET VC4ANRNR01	
Item	**Description**
Type	Check, Wafer.
Rating	Class 150.
Standards	API Std. 594.
Ends	Serrated Facing to Fit between Class 150 RF, ASME B16.5 Flanges.
Body Material	Type 316 Stainless Steel, ASTM A351/A351M, Grade CF8M.
Spring	Type 316 Stainless Steel.
Disc	Split, Type 316 Stainless Steel.
Seat	Viton (400 Degrees F, Maximum).
Stem Type/Material	N/A.
Stem Packing/Seals	N/A.
Body Gasket/Seals	N/A.
Operator	N/A.
Size	3” – 10”

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SECTION 40 55 00 VALVE DATA SHEET VC4NEFNR01	
Item	**Description**
Type	Check, Wafer.
Rating	Class 125, Maximum 250 Degrees F.
Standards	API Std. 594 (Note 1).
Ends	Installed Between Class 125 FF, ASME B16.1 or Class 150 FF ASME B16.5 Flanges (Note 3).
Body Material	Cast Iron, ASTM A126/A126M, Class B.
Bonnet Type & Material	N/A.
Bolting	ASTM A193/A193M, Grade B7.
Disc	(Split) Ductile Iron-Electroless Nickel Plated (Type 316 Stainless Steel Spring) (Note 2).
Seat	Buna-N.
Stem Type/Material	N/A.
Stem Packing/Seals	N/A.
Body Gasket/Seals	Nonasbestos.
Operator	N/A.
Size	3” – 42”

Notes:
1. Each manufacturer must state (when quoting) that either all valves comply with API Std. 594 dimensions or specifically list those sizes that do not comply.
2. Either stainless steel or aluminum bronze are acceptable alternates.
3. Flange drilling of NPS 16 and larger shall be per AWWA C207, Class D.

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SECTION 40 55 00 VALVE DATA SHEET VC5QVRNR01	
Item	**Description**
Type	Check, Wafer.
Rating	90 psig @ 130 Degrees F.
Standards	API Std. 594.
Ends	Flanged to Fit between Class 150 RF, ASME B16.5 Flanges.
Body Material	CPVC, ASTM D1784.
Spring	Type 316 Stainless Steel.
Disc	CPVC, ASTM D1784.
Seat	Viton (400 Degrees F, Maximum).
Stem Type/Material	N/A.
Stem Packing/Seals	N/A.
Body Gasket/Seals	N/A.
Operator	N/A.
Size	3” – 12”

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SECTION 40 55 00 VALVE DATA SHEET VC7QLRNR01	
Item	**Description**
Type	Check, Ball.
Rating	230 psig @ 300 Degrees F.
Standards	Manufacturer's Standard.
Ends	Flanged, Class 150 RF, ASME B16.5.
Body Material	PFA Lined Ductile Iron ASTM A395.
Bonnet Type & Material	PFA Lined Ductile Iron ASTM A395.
Bolting	ASTM A193/A193M, Grade B7M.
Ball	Solid, PTFE.
Seat	PTFE.
Stem Type/Material	N/A.
Stem Packing/Seals	N/A.
Body Gasket/Seals	Manufacturer's Standard.
Operator	N/A.
Size	1" – 3"

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SECTION 40 55 00 VALVE DATA SHEET VC7QUGNR01	
Item	**Description**
Type	Check, Ball.
Rating	100 psig @ 120 Degrees F.
Standards	Manufacturer's Standard.
Ends	Socket ends with unions between both ends and body, ASTM D2467.
Body Material	PVC, ASTM D1784.
Spring	N/A.
Ball	PVC, ASTM D1784.
Seat	Viton.
Stem Type/Material	N/A.
Stem Packing/Seals	N/A.
Body Gasket/Seals	N/A.
Operator	N/A.
Size	1/2" – 4"

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SECTION 40 55 00 VALVE DATA SHEET VC7QVGNR01	
Item	**Description**
Type	Check, Ball.
Rating	150 psig @ 100 Degrees F.
Standards	Manufacturer's Standard.
Ends	Socket ends with unions between both ends and body, ASTM D2467.
Body Material	CPVC, ASTM D1784.
Bonnet Type & Material	N/A.
Ball	CPVC, ASTM D1784.
Disc	N/A.
Seat	CPVC, ASTM D1784.
Stem Type/Material	N/A.
Stem Packing/Seals	Viton.
Body Gasket/Seals	Viton.
Operator	N/A.
Size	1/2" – 2"

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SECTION 40 55 00 VALVE DATA SHEET VD1QVFHB01	
Item	**Description**
Type	Diaphragm.
Rating	90 psig @ 130 Degrees F.
Standards	Manufacturer's Standard.
Ends	Flanged, Class 125 FF, ASME B16.1.
Body Material	CPVC, ASTM D1784.
Bonnet Type & Material	CPVC, ASTM D1784.
Bolting	ASTM A307, Grade B.
Diaphragm	Molded TFE.
Stem Type/Material	Copper Alloy.
O-Rings	EPDM.
Operator	Handwheel.
Size	1/2" – 4"

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SECTION 40 55 00 VALVE DATA SHEET VF2ACRH201	
Item	**Description**
Type	Butterfly, Tapped Lugs.
Rating	Class 150, (Note 2).
Standards	MSS SP-67, Narrow Body Dimensions (Note 1), Type I Shut-Off.
Ends	Tapped ASME B1.1, UNC, to Fit Class 150 ASME B16.5 Flanges.
Body Material	Carbon Steel, ASTM A216 Grade WCB.
Bonnet Type & Material	N/A.
Bolting	Cap Screws, ASTM A193 Grade B7.
Disc	Type 316 Stainless Steel.
Stem Type & Material	Type 316 or 416 Stainless Steel.
Seat	Inconel.
Stem Packing/Seals	Graphite.
Body Gasket/Seals	N//A.
Operator	Enclosed rotary screw type actuator w/position indicator and Handwheel.
Size	8" – 24”

Notes:
1. Each manufacturer must state (when quoting) that either all valves comply with the narrow body face-to-face dimensions of MSS SP-67 or specifically list those sizes that do not comply.
2. Ratings shall be bubble-tight dead end service rating for both sets of conditions.
3. Deleted.
4. Face-to-face dimension for 10" valve is 2.5", which does not conform to MSS SP-67.

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SECTION 40 55 00 VALVE DATA SHEET VF2ACRL201	
Item	**Description**
Type	Butterfly, Tapped Lugs.
Rating	Class 150, (Note 2).
Standards	MSS SP-67, Narrow Body Dimensions (Note 1), Type I Shut-Off.
Ends	Tapped ASME B1.1, UNC, to Class 150 ASME B16.5 Flanges.
Body Material	Carbon Steel, ASTM A216 Grade WCB.
Bonnet Type & Material	N/A.
Bolting	Cap Screws, ASTM A193 Grade B7.
Disc	Type 316 Stainless Steel.
Stem Type & Material	Type 316 Stainless Steel.
Seat	Inconel.
Stem Packing/Seals	Graphite.
Body Gasket/Seals	N/A.
Operator	Lever w/Throttling Plate.
Size	3" – 6”

Notes:
1. Each manufacturer must state (when quoting) that either all valves comply with the narrow body face-to-face dimensions of MSS SP-67 or specifically list those sizes that do not comply.
2. Ratings shall be bubble-tight dead end service rating for both sets of conditions.

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SECTION 40 55 00 VALVE DATA SHEET VF2AEFLD01	
Item	**Description**
Type	Butterfly, Tapped Lugs.
Rating	Class 150.
Standards	MSS SP-67, Narrow Body Dimensions (Note 1), Type I Shut-Off.
Ends	Tapped ASME B1.1, UNC, to Fit Class 150 ASME B16.5 flanges.
Body	Ductile Iron, ASTM A395/A395M.
Bonnet Type & Material	N/A.
Bolting	Cap Screws, ASTM A193 Grade B7.
Disc	Aluminum Bronze.
Stem	Type 316 Stainless Steel.
Seat	EPDM.
Stem Packing/Seals	Buna-N.
Body Gasket/Seals	N/A.
Operator	Lever w/ Throttling Plate.
Size	3” – 6”

Notes:
1. Each manufacturer must state (when quoting) that either all valves comply with the narrow body face-to-face dimensions of MSS SP-67 or specifically list those sizes that do not comply.
2. Ratings shall be bubble-tight dead end service rating.

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SECTION 40 55 00 VALVE DATA SHEET VF2ANRH201	
Item	**Description**
Type	Butterfly, Tapped Lugs.
Rating	Class 150, (Note 2).
Standards	MSS SP-67, Narrow Body Dimensions (Note 1), Type I Shut-Off.
Ends	Tapped ASME B1.1, UNC, to Fit Class 150 ASME B16.5 Flanges.
Body Material	Stainless Steel, ASME A351 Grade CF8M.
Bonnet Type & Material	N/A.
Bolting	Cap Screws, ASTM A193 Grade B7.
Disc	Type 316 Stainless Steel.
Stem Type & Material	Type 316 or 416 Stainless Steel.
Seat	Inconel.
Stem Packing/Seals	Graphite.
Body Gasket/Seals	N//A.
Operator	Enclosed rotary screw type actuator w/position indicator and Handwheel.
Size	8" – 24”

Notes:
1. Each manufacturer must state (when quoting) that either all valves comply with the narrow body face-to-face dimensions of MSS SP-67 or specifically list those sizes that do not comply.
2. Ratings shall be bubble-tight dead end service rating for both sets of conditions.
3. Face-to-face dimension for 10" valve is 2.5", which does not conform to MSS SP-67.

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SECTION 40 55 00 VALVE DATA SHEET VF2ANRL201	
Item	**Description**
Type	Butterfly, Tapped Lugs.
Rating	Class 150, (Note 2).
Standards	MSS SP-67, Narrow Body Dimensions (Note 1), Type I Shut-Off.
Ends	Tapped ASME B1.1, UNC, to Class 150 ASME B16.5 Flanges.
Body Material	Stainless Steel, ASME A351 Grade CF8M.
Bonnet Type & Material	N/A.
Bolting	Cap Screws, ASTM A193 Grade B7.
Disc	Type 316 Stainless Steel.
Stem Type & Material	Type 316 Stainless Steel.
Seat	Inconel.
Stem Packing/Seals	Graphite.
Body Gasket/Seals	N/A.
Operator	Lever w/Throttling Plate.
Size	3" – 6”

Notes:
1. Each manufacturer must state (when quoting) that either all valves comply with the narrow body face-to-face dimensions of MSS SP-67 or specifically list those sizes that do not comply.
2. Ratings shall be bubble-tight dead end service rating for both sets of conditions.

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SECTION 40 55 00 VALVE DATA SHEET VF2BCRH201	
Item	**Description**
Type	Butterfly, Tapped Lugs.
Rating	Class 300, (Note 2).
Standards	MSS SP-67, Narrow Body Dimensions (Note 1), Type I Shut-Off.
Ends	Tapped ASME B1.1, UNC, to Fit Class 300 ASME B16.5 Flanges.
Body Material	Carbon Steel, ASTM A216 Grade WCB.
Bonnet Type & Material	N/A.
Bolting	Cap Screws, ASTM A193 Grade B7.
Disc	Type 316 Stainless Steel.
Stem Type & Material	Type 316 or 416 Stainless Steel.
Seat	Inconel.
Stem Packing/Seals	Graphite.
Body Gasket/Seals	N//A.
Operator	Enclosed rotary screw type actuator w/position indicator and Handwheel.
Size	8" – 24”

Notes:
1. Each manufacturer must state (when quoting) that either all valves comply with the narrow body face-to-face dimensions of MSS SP-67 or specifically list those sizes that do not comply.
2. Ratings shall be bubble-tight dead end service rating for both sets of conditions.
3. Face-to-face dimension for 10" valve is 2.5", which does not conform to MSS SP-67.

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SECTION 40 55 00 VALVE DATA SHEET VF2BCRL201	
Item	**Description**
Type	Butterfly, Tapped Lugs.
Rating	Class 300, (Note 2).
Standards	MSS SP-67, Narrow Body Dimensions (Note 1), Type I Shut-Off.
Ends	Tapped ASME B1.1, UNC, to Class 300 ASME B16.5 Flanges.
Body Material	Carbon Steel, ASTM A216 Grade WCB.
Bonnet Type & Material	N/A.
Bolting	Cap Screws, ASTM A193 Grade B7.
Disc	Type 316 Stainless Steel.
Stem Type & Material	Type 316 Stainless Steel.
Seat	Inconel.
Stem Packing/Seals	Graphite.
Body Gasket/Seals	N/A.
Operator	Lever w/Throttling Plate.
Size	3" – 6”

Notes:
1. Each manufacturer must state (when quoting) that either all valves comply with the narrow body face-to-face dimensions of MSS SP-67 or specifically list those sizes that do not comply.
2. Ratings shall be bubble-tight dead end service rating for both sets of conditions.

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SECTION 40 55 00 VALVE DATA SHEET VF2NEFHD01	
Item	**Description**
Type	Butterfly, Tapped Lugs.
Rating	150 psig @ 150 Degrees F; 135 psig @ 200 Degrees F, 75 psig @ 220 Degrees F; (Note 2).
Standards	MSS SP-67, Narrow Body Dimensions (Note 1), Type I Shut-Off.
Ends	Tapped ASME B1.1, UNC, to Fit Class 125 ASME B16.1 or Class 150 ASME B16.5 Flanges.
Body Material	Cast or Ductile Iron.
Bonnet Type & Material	N/A.
Bolting	Cap Screws, ASTM A193 Grade B7.
Disc	Aluminum Bronze or Ductile Iron.
Stem Type & Material	Type 316 or 416 Stainless Steel.
Seat	EPDM, Renewable.
Stem Packing/Seals	Buna-N.
Body Gasket/Seals	N//A.
Operator	Enclosed rotary screw type actuator w/position indicator and Handwheel.
Size	8" – 24”

Notes:
1. Each manufacturer must state (when quoting) that either all valves comply with the narrow body face-to-face dimensions of MSS SP-67 or specifically list those sizes that do not comply.
2. Ratings shall be bubble-tight dead end service rating for both sets of conditions.
3. Deleted.
4. Face-to-face dimension for 10" valve is 2.5", which does not conform to MSS SP-67.

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SECTION 40 55 00 VALVE DATA SHEET VF2NEFLD01	
Item	**Description**
Type	Butterfly, Tapped Lugs.
Rating	150 psig @ 150 Degrees F; 135 psig @ 200 Degrees F, 75 psig @ 220 Degrees F; (Note 2).
Standards	MSS SP-67, Narrow Body Dimensions (Note 1), Type I Shut-Off.
Ends	Tapped ASME B1.1, UNC, to Fit Class 125 ASME B16.1 or Class 150 ASME B16.5 Flanges.
Body Material	Cast or Ductile Iron.
Bonnet Type & Material	N/A.
Bolting	Cap Screws, ASTM A193 Grade B7.
Disc	Aluminum Bronze.
Stem Type & Material	Type 316 Stainless Steel.
Seat	EPDM, Renewable.
Stem Packing/Seals	Buna-N.
Body Gasket/Seals	N/A.
Operator	Lever w/Throttling Plate.
Size	3" – 6”

Notes:
1. Each manufacturer must state (when quoting) that either all valves comply with the narrow body face-to-face dimensions of MSS SP-67 or specifically list those sizes that do not comply.
2. Ratings shall be bubble-tight dead end service rating for both sets of conditions.

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SECTION 40 55 00 VALVE DATA SHEET VF2QVFLR01	
Item	**Description**
Type	Butterfly, Lug.
Rating	90 psig @ 130 Degrees F.
Standards	Manufacturer's Standard.
Ends	Flanged, to fit ASME Class 150 Bolt Pattern.
Body Material	CPVC, ASTM D1784.
Bonnet Type & Material	N/A.
Bolting	Cap Screws, ASTM A193 Grade B7.
Disc	CPVC, ASTM D1784.
Seat	Viton.
Stem Packing/Seals	Viton.
Body Gasket/Seals	N/A.
Operator	Lever
Size	1-1/2" – 12"

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SECTION 40 55 00 VALVE DATA SHEET VF5ACFGC01	
Item	**Description**
Type	Butterfly, Short Body.
Rating	Class 150.
Standards	AWWA C504.
Ends	Flanged, Class 150, FF, ASME B16.1 (Note 1).
Body	Carbon Steel, ASTM A216 Grade WCB.
Bonnet Type & Material	N/A.
Bolting	N/A.
Disc	Type 316 Stainless Steel, ASTM A351 CF8M.
Stem Type/Material	Type 316 Stainless Steel.
Seat	Rubber/Stainless Steel Combination (Field Replaceable).
Stem Packing/Seals	Teflon.
Body Gasket/Seals	N/A.
Operator	Handwheel with Enclosed Gear Operator.
Size	26" – 66”

Notes:
1. Flange drilling of NPS 16 and larger shall be per AWWA C207, Class D.

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SECTION 40 55 00 VALVE DATA SHEET VF5NEFGD01	
Item	**Description**
Type	Butterfly, Short Body.
Rating	Class 125.
Standards	AWWA C504.
Ends	Flanged, Class 125, FF, ASME B16.1 (Note 1).
Body	Cast or Ductile Iron.
Bonnet Type & Material	N/A.
Bolting	N/A.
Disc	Aluminum Bronze or Ductile Iron with Stainless Steel Edge.
Stem Type/Material	Stainless Steel.
Seat	Rubber/Stainless Steel Combination (Field Replaceable).
Stem Packing/Seals	Nonasbestos.
Body Gasket/Seals	N/A.
Operator	Handwheel with Enclosed Gear Operator.
Size	30" – 42”

Notes:
1. Flange drilling of NPS 16 and larger shall be per AWWA C207, Class D.

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SECTION 40 55 00 VALVE DATA SHEET VL1ABPHS01	
Item	**Description**
Type	Globe.
Rating	Class 150.
Standards	MSS SP-80.
Ends	Solder Joint, ASME B16.18.
Body Material	Bronze, ASTM B61 or B62.
Bonnet Type & Material	Union, Bronze, ASTM B61 or B62.
Bolting	N/A.
Disc	Composition (Steam), Renewable.
Seat	Bronze, Integral.
Stem Type/Material	Rising, Bronze.
Stem Packing/Seals	Nonasbestos.
Body Gasket/Seals	N/A.
Operator	Handwheel.
Size	1/4" – 2”

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SECTION 40 55 00 VALVE DATA SHEET VL1ACBH801	
Item	**Description**
Type	Globe, Plug Type.
Rating	Class 150.
Standards	ASME B16.34, ASME B16.10.
Ends	Butt Weld, ASME B16.25, Standard Weight Bore.
Body Material	Carbon Steel, ASTM A216/A216M, Grade WCB.
Bonnet Type & Material	Bolted, Carbon Steel, ASTM A216/A216M, Grade WCB.
Disc	13CR.
Bolting	ASTM A193/A193M, Grade B7.
Seat	Renewable, Hardfaced, Stellite or Approved Substitute.
Stem Type/Material	OS&Y, 13CR.
Stem Packing/Seals	Nonasbestos.
Body Gasket/Seals	Nonasbestos.
Operator	Handwheel.
Size	3” – 14”

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SECTION 40 55 00 VALVE DATA SHEET VL1ACRH801	
Item	**Description**
Type	Globe, Plug Type.
Rating	Class 150.
Standards	ASME B16.34, ASME B16.10.
Ends	Flanged, Class 150 RF, ASME B16.5.
Body Material	Carbon Steel, ASTM A216/A216M, Class WCB.
Bonnet Type & Material	Bolted, Carbon Steel, ASTM A216/A216M, Class WCB.
Bolting	ASTM A193/A193M, Grade B7.
Disc	13CR.
Seat	Renewable, Seal Welded, Hardfaced, Stellite or Approved Substitute.
Stem Type/Material	OS&Y, 13CR.
Stem Packing/Seals	Nonasbestos.
Body Gasket/Seals	Nonasbestos.
Operator	Handwheel.
Size	3” – 14”

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SECTION 40 55 00 VALVE DATA SHEET VL1ANRH301	
Item	**Description**
Type	Globe, Plug Type.
Rating	Class 150.
Standards	ASME B16.34, ASME B16.10.
Ends	Flanged, Class 150 RF, ASME B16.5.
Body Material	Type 316 Stainless Steel, ASTM A351/A351M, Grade CF8M.
Bonnet Type & Material	Bolted, Type 316 Stainless Steel, ASTM A351/A351M, Grade CF8M.
Bolting	ASTM A193/A193M, Grade B8M.
Disc	Type 316 Stainless Steel, Renewable, Plug Type.
Seat	Type 316 Stainless Steel, Integral.
Stem Type/Material	OS&Y, Type 316 Stainless Steel.
Stem Packing/Seals	Teflon (TFE).
Body Gasket/Seals	PTFE.
Operator	Handwheel.
Size	3” – 10”

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SECTION 40 55 00 VALVE DATA SHEET VL1ANSHS01	
Item	**Description**
Type	Globe.
Rating	Class 150.
Standards	API Std. 603.
Ends	Socket Weld, ASME B16.11.
Body Material	Type 316L Stainless Steel, ASTM A351/A351M, Grade CF3M or A182/A182M, Grade F316L.
Bonnet Type & Material	Bolted, Type 316 Stainless Steel, ASTM A351/A351M, Grade CF3M or A182/A182M, Grade F316.
Bolting	ASTM A193/A193M, Grade B8M (Type 316 Stainless Steel).
Disc	Type 316 Stainless Steel, Renewable (Plug Type).
Seat	Type 316 Stainless Steel, Integral.
Stem Type & Material	OS & Y, Type 316 Stainless Steel with Position Indicator.
Stem Packing/Seals	Graphite.
Body Gasket/Seals	Graphite.
Operator	Handwheel.
Size	1/2" – 2”

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SECTION 40 55 00 VALVE DATA SHEET VL1BCBH801	
Item	**Description**
Type	Globe, Plug Type.
Rating	Class 300.
Standards	ASME B16.34, ASME B16.10.
Ends	Butt Weld, ASME B16.25, NPS 3" – 12" Standard Weight, 14"-24" Schedule 40 Bore.
Body Material	Carbon Steel, ASTM A216/A216M, Grade WCB.
Bonnet Type & Material	Bolted, Carbon Steel, ASTM A216/A216M, Grade WCB.
Bolting	ASTM A193/A193M, Grade B7.
Disc	13CR.
Seat	Renewable, Hardfaced, Stellite or Approved Substitute.
Stem Type/Material	OS&Y, 13CR.
Stem Packing/Seals	Nonasbestos.
Body Gasket/Seals	Nonasbestos.
Operator	Handwheel.
Size	3” – 12”

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SECTION 40 55 00 VALVE DATA SHEET VL1BCBH806	
Item	**Description**
Type	Globe, Plug Type.
Rating	Class 300.
Standards	ASME B16.34, ASME B16.10.
Ends	Butt Weld, ASME B16.25, Schedule 80 Bore.
Body Material	Carbon Steel, ASTM A216/A216M, Grade WCB.
Bonnet Type & Material	Bolted, Carbon Steel, ASTM A216/A216M, Grade WCB.
Bolting	ASTM A193/A193M, Grade B7.
Disc	13CR.
Seat	Renewable, Hardfaced, Stellite or Approved Substitute.
Stem Type/Material	OS&Y, 13CR.
Stem Packing/Seals	Nonasbestos.
Body Gasket/Seals	Nonasbestos.
Operator	Handwheel.
Size	3” – 8”

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SECTION 40 55 00 VALVE DATA SHEET VL1BCRH801	
Item	**Description**
Type	Globe.
Rating	Class 300.
Standards	ASME B16.34, ASME B16.10.
Ends	Flanged, Class 300 RF, ASME B16.5.
Body Material	Carbon Steel, ASTM A216/A216M, Class WCB.
Bonnet Type & Material	Bolted, Carbon Steel, ASTM A216/A216M, Class WCB.
Bolting	ASTM A193/A193M, Grade B7.
Disc	13CR, Renewable.
Seat	13CR, Renewable.
Stem Type/Material	OS&Y, 13CR.
Stem Packing/Seals	Flexible Graphite.
Body Gasket/Seals	Graphite.
Operator	Handwheel.
Size	3” – 10”

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SECTION 40 55 00 VALVE DATA SHEET VL1DCBH801	
Item	**Description**
Type	Globe, Plug Type.
Rating	Class 600.
Standards	ASME B16.34, ASME B16.10.
Ends	Butt Weld, ASME B16.25, NPS 3" – 8" Schedule XS, 10"-24" Schedule 80 Bore.
Body Material	Carbon Steel, ASTM A216/A216M, Grade WCB.
Bonnet Type & Material	Bolted, Carbon Steel, ASTM A216/A216M, Grade WCB.
Bolting	ASTM A193/A193M, Grade B7.
Disc	13CR.
Seat	Renewable, Seal Welded, Hardfaced, Stellite or Approved Substitute.
Stem Type/Material	OS&Y, 13CR.
Stem Packing/Seals	Nonasbestos.
Body Gasket/Seals	Nonasbestos.
Operator	Handwheel.
Size	3” – 24”

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SECTION 40 55 00 VALVE DATA SHEET VL1DCRH801	
Item	**Description**
Type	Globe.
Rating	Class 600.
Standards	ASME B16.34, ASME B16.10.
Ends	Flanged, Class 600 RF, ASME B16.5.
Body Material	Carbon Steel, ASTM A216/A216M, Class WCB.
Bonnet Type & Material	Bolted, Carbon Steel, ASTM A216/A216M, Class WCB.
Bolting	ASTM A193/A193M, Grade B7.
Disc	13CR, Renewable.
Seat	13CR, Renewable.
Stem Type/Material	OS&Y, 13CR.
Stem Packing/Seals	Flexible Graphite.
Body Gasket/Seals	Graphite.
Operator	Handwheel.
Size	3” – 24”

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SECTION 40 55 00 VALVE DATA SHEET VL1NEFGB01	
Item	**Description**
Type	Globe.
Rating	Class 125.
Standards	MSS SP-85, ASME B16.10.
Ends	Flanged, Class 125 FF, ASME B16.1.
Body Material	Cast Iron, ASTM A126/A126M, Class B.
Bonnet Type & Material	Bolted, Cast Iron, ASTM A126/A126M, Class B.
Bolting	ASTM A307, Grade B.
Disc	Bronze, Renewable.
Seat	Bronze, Renewable.
Stem Type/Material	OS&Y, Bronze.
Stem Packing/Seals	Nonasbestos, TFE Impregnated.
Body Gasket/Seals	Nonasbestos.
Operator	Enclosed Gear Operator.
Size	8” – 10”

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SECTION 40 55 00 VALVE DATA SHEET VL1NEFHB01	
Item	**Description**
Type	Globe.
Rating	Class 125.
Standards	MSS SP-85, ASME B16.10.
Ends	Flanged, Class 125 FF, ASME B16.1.
Body Material	Cast Iron, ASTM A126/A126M, Class B.
Bonnet Type & Material	Bolted, Cast Iron, ASTM A126/A126M, Class B.
Bolting	ASTM A307, Grade B.
Disc	Bronze, Renewable.
Seat	Bronze, Renewable.
Stem Type/Material	OS&Y, Bronze.
Stem Packing/Seals	Nonasbestos, TFE Impregnated.
Body Gasket/Seals	Nonasbestos.
Operator	Handwheel.
Size	3” – 6”

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SECTION 40 55 00 VALVE DATA SHEET VL1RBTHB01	
Item	**Description**
Type	Globe.
Rating	Class 200.
Standards	MSS SP-80.
Ends	Threaded, ASME B1.20.1, NPT.
Body Material	Bronze, ASTM B61.
Bonnet Type & Material	Union, Bronze, ASTM B61.
Bolting	N/A.
Disc	Renewable.
Seat	Renewable.
Stem Type/Material	Rising, Bronze.
Stem Packing/Seals	Nonasbestos, TFE Impregnated.
Body Gasket/Seals	N/A.
Operator	Handwheel.
Size	1/2" – 2”

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SECTION 40 55 00 VALVE DATA SHEET VP5BCRGN01	
Item	**Description**
Type	Plug, Lubricated (Short Pattern) (Note 1).
Rating	Class 300, 350 Degrees F, maximum.
Standards	API Std. 599, ASME B16.10.
Ends	Flanged, Class 300 RF, ASME B16.5.
Body Material	Carbon Steel, ASTM A216/A216M, Grade WCB.
Bonnet Type & Material	Bolted, Carbon Steel, ASTM A216/A216M, Grade WCB.
Bolting	ASTM A193/A193M Grade B7.
Plug	Steel, tapered.
Seat	
Stem Type/Material	
Stem Packing/Seals	
Body Gasket/Seals	
Operator	Enclosed Gear, watertight housing for buried service, with 2" square nut, extension stem and extended lubricant pipe.
Size	3" – 8”

Notes:
1. Lubricant shall be suitable for natural gas.

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SECTION 40 55 00 VALVE DATA SHEET VP6ACRLN01	
Item	**Description**
Type	Plug, 3-Way, Lubricated (Regular Pattern) (Note 1).
Rating	Class 150.
Standards	ASME B16.34, Manufacturer's Standard Dimensions.
Ends	Flanged, Class 150 RF, ASME B16.5.
Body Material	Carbon Steel, ASTM A216/A216M, Grade WCB.
Bonnet Type & Material	Bolted, Carbon Steel, ASTM A216/A216M, Grade WCB.
Bolting	ASTM A193/A193M, Grade B7.
Plug	Steel, Tapered.
Seat	
Stem Type/Material	
Stem Packing/Seals	
Body Gasket/Seals	
Operator	Wrench (Furnish with Valve).
Size	1" – 4"

Notes

1. Lubricant shall be suitable for either fuel oil or natural gas. This valve shall be a 3-way, 2-port, 90-degree turn, 2-position valve similar to Nordstrom/Rockwell's Port Arrangement #1.

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PG&E Topock Remediation Project
60% Design

Project No: 435062
Rev: A
Date: April 5, 2013

Specialty Items List

Item Number	Qty	P&ID	Line Number	SIZE	VENDOR	DESCRIPTION	Remarks	Purchase Order No.
EDT-401A/B	2	I-1201	6"-RW-CPCV-120106	3"	Clark-Reliance or Schutte & Koerting	(2)-3" TLA PVC Eductors to complexly (3 turnovers) mix a 21,000 gal tank for 30 minutes. Min. dP of 20 psi. Tank Dimensions are 8' W X 11ft H X 45' L		
EDT-402A/B	2	I-1202	6"-RW-CPCV-120206	3"	Clark-Reliance or Schutte & Koerting	(2)-3" TLA PVC Eductors to complexly (3 turnovers) mix a 21,000 gal tank for 30 minutes. Min. dP of 20 psi. Tank Dimensions are 8' W X 11ft H X 45' L		
EDT-403A/B	2	I-1203	6"-RW-CPCV-120306	3"	Clark-Reliance or Schutte & Koerting	(2)-3" TLA PVC Eductors to complexly (3 turnovers) mix a 21,000 gal tank for 30 minutes. Min. dP of 20 psi. Tank Dimensions are 8' W X 11ft H X 45' L		
EDT-404A/B	2	I-1204	6"-RW-CPCV-120406	3"	Clark-Reliance or Schutte & Koerting	(2)-3" TLA PVC Eductors to complexly (3 turnovers) mix a 21,000 gal tank for 30 minutes. Min. dP of 20 psi. Tank Dimensions are 8' W X 11ft H X 45' L		

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SECTION 40 57 20
POWER PLANT PIPING ENGINEERED SUPPORTS

PART 1 - GENERAL

1.01 SUMMARY

A. This specification, along with the support detail sheets, defines the requirements for design, material selection, fabrication, inspection, shipping, and installation of Engineered Pipe Supports including Supplemental Steel.

1.02 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Society of Mechanical Engineers (ASME):
   a. B31.1, Power Piping.
   b. Section IX Welding and Brazing Qualifications.
2. American Institute of Steel Construction (AISC): Manual of Steel Construction Allowable Stress Design.
3. Manufacturers Standardization Society (MSS):
   a. SP 58, Pipe Hangers and Supports - Materials, Design, and Manufacture.
   b. SP 69, Pipe Hangers and Supports – Selection and Application.
   c. SP 89, Pipe Hangers and Supports – Fabrication, Installation Practices.
4. AWS D1.1 Structural Welding Code.
5. The Society for Protective Coatings (SSPC):

1.03 DEFINITIONS

A. Certificates of Compliance (COC’s):

1. Purchase Order item number and item code number.
2. Specification and Engineered Support Detail Sheets.
3. Certify manufacturing standard that applies to components.
4. A statement certifying compliance with material specification (and compliance with impact test requirements where applicable).
5. Be signed by Manager of pipe support manufacturer’s Quality Control Department.

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B. Material Test Reports (MTR's):

1. Show results of all chemistry and physical tests and shall be signed by Manager of pipe support manufacturer's Quality Control Department. Data on the manufacturer's test reports shall include the following:
   a. Name of Supplier.
   b. Name of prime material manufacturer and plant location.
   c. Purchase Order number.
   d. Purchase Order item number and item code number.
   e. Quantity, size, heat number (or equivalent), and brief description of item(s).
   f. Material specification and grade, class, or type designation.
   g. Actual test results of chemical analysis and mechanical properties in accordance with the material specification.

C. Supplemental Steel: Includes any steel components required in conjunction with pipe support components to transfer pipe loads to BUYER's pipe rack and/or building steel.

1.04 SUBMITTALS

A. Action Submittals:

1. Detailed shop drawings for each support:
   a. Furnish manufacturer's own shop detail drawings.
   b. Shop detail drawings shall show the following information for each support:
      1) Manufacturer's figure number, type, size, arrangement and weight.
      2) Details of integral pipe attachments required for piping.
      3) Dimensions needed for installation (including rod length).
      4) Design loads and movements plus hot and cold load settings.
      5) Complete list of parts referenced on drawings.
      6) Description of each piece of material including cut lengths.
      7) Weld size, type, and location for field welds.
      8) Drawing revision letters with changes identified on the Drawing with the revision number in a triangle.
      9) Plot plan location referencing steel column lines.
      10) Pipe Support tag number.
      11) Sub-contract number.
2. Compensating Struts and Seismic Restraints:
   a. Furnish the following information:

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1) Force displacement characteristic curve for suddenly applied load and for constant load.
2) Amount of free movement or clearance.
3) Backload versus displacement speed.
4) Maximum load-carrying capacity of device (normal and one time).

B. Informational Submittals:

1. Erection and adjustment instructions for each support.
2. Performance data (e.g., characteristic curves, load capacity, displacement speed) for compensating struts, seismic restraints and suppressors.
3. Chrome Moly Clamps: Material Test Reports.
4. Welder certificates signed by SELLER certifying that welders are qualified in accordance with AWS D1.1, Structural Welding Code.
5. Design calculations demonstrating compliance to stress limitations on fabricated assemblies shall be made available for review on request. Appropriate stress intensities and the basis for using particular intensities shall be part of the calculation.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Components comprising each support assembly shall be assembled as a unit, with exception of rod and hex nuts.

B. For shipment, each unit shall be disassembled only to extent necessary to facilitate field handling and to prevent damage during shipment. Loose components shall either be strung on a wire and securely attached to appropriate support or shipped in a box. Each loose supplemental steel component shall be permanently tagged with the support number.

C. Each assembly or component shall be skidded, crated, boxed or otherwise protected against damage or loss during shipment and to facilitate field handling. Boxes shall be identified with support number, purchase order number, and sub-contract number. Securely affix a copy of the completed packing list to each separate shipping package.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Materials, equipment, and accessories specified in this section shall be products of:

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1. Anvil.
2. Lisega.

2.02 COMPONENTS

A. General:

1. Supports shall meet the material, design, fabrication, and inspection criteria of both ASME B31.1 and MSS SP 58.
2. Supports and support assemblies shall, where practical, incorporate commercially available; load rated, and tested component parts. Similar support items to be from the same manufacturer.
3. Supports are furnished for outdoor service and shall be constructed or protected such that elements will not corrode or otherwise interfere with their intended function.
4. Cut to length and thread plain rods.
5. All clamp halves shall be formed from continuous plate.
6. All supports shall be capable of supporting piping hydrostatic test loads.
7. Alloy steel components shall bear a permanent marking identifying the alloy. This identification marking shall not weaken the component.

B. Allowable Stress:

1. Stress on all components shall be within the limits set by applicable codes listed in Section 1.2 of this Specification.
2. Sufficient surface shall be supplied on beam connections so that the welds prescribed can be achieved in accordance with the applicable codes listed in Section 1.2 of this Specification.
3. In the event that there is a conflict between the codes and this Specification, the more conservative stresses shall be used for design.

C. Flexible Pipe Supports:

1. Variable springs and constant support devices weighing in excess of 50 pounds shall be furnished with lifting lugs.
2. Flexible pipe supports shall allow thermal expansion of piping and in no way restrict pipe movement.
3. Hot load for each spring as it appears on Support Detail Sheet does not include weights of lower components. Add weight of lower components to the operating (hot) and cold loads shown on Support Detail Sheets. For springs which are base mounted, add the weight of the sliding component

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(such as a pipe shoe) to the operating (hot) and cold loads shown on the Support Detail Sheets.

4. Variable type spring support units used as part of support assemblies shall be enclosed and include a guided load column. In no case shall eccentric loading of spring be permitted.
5. Provide variable springs with means of adjusting support through full load range.
6. Variable springs shall have at least two position indicators on opposing sides of the spring for ease in observation and adjustment after installation.
7. Each spring assembly shall have hot and cold position indicators permanently installed to ensure proper support loading. Stick-on labels or other impermanent labels or markers are not allowed.
8. Constant support type supports shall have a total travel equal to or greater than calculated actual travel plus 20 percent, but in no case less than actual travel plus 1 inch, and shall have a minimum of plus or minus 10 percent calibrated load adjustment feature.
9. Support force of any constant support shall not deviate more than 6 percent of calibrated load throughout its full working range.
10. Travel Stop:
    a. Unless otherwise specified, provide on variable springs and constant support devices for hydrostatic testing purposes.
    b. Install in cold position.
    c. Variable Spring: Affix to assembly by cable or chain to prevent loss after removal so they may be reengaged in future.
    d. Constant Supports: Type that can be engaged at end points or any points through full working range of support, minimizing field readjustment of supports during future hydrostatic test and maintenance procedures.

D. Pipe Clamps:

1. Carbon Steel Piping: Equivalent to piping material.
2. Stainless Steel Piping: Same stainless material grade as pipe or, as an alternate, lined or coated with material suitable for loading and conditions of service. Use of such alternates shall be subject to approval by BUYER.
3. When design temperature of supported pipe exceeds 750 degrees F, pipe clamps and welded attachments shall be of suitable alloy steel and heavy duty construction.
4. Insulated Piping: Pipe clamps and welded attachments shall be constructed such that support rod attachment bolt(s) will be external to insulation, and pipe clamps will be rigid relative to pipe insulation.

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E. Compensating Struts or Seismic Restraints:

1. Vibration, seismic, or shock suppressing devices shall be of counterforce, energy-absorbing, mechanical type as specified. Bolted or pinned connections for vibration, seismic, or shock suppression devices shall be fitted for close clearance. Normal bolt-to-bolt hole tolerances are not acceptable.
2. Arranged to permit full thermal expansion movement of piping with minimum backload or restraint.

F. Welded Attachments:

1. Welded attachment material to be identical to pipe material.
2. Weld size and design for all welded attachments, including trunnions, stanchions, and lugs, must meet the minimum criteria of AWS D1.1 Structural Code.

G. Hanger Rods:

1. Turnbuckles shall be provided near the center of the rod assemblies for all large bore pipe supports unless the arrangement provides other means of vertical adjustment.
2. Turnbuckles and other threaded adjustment components shall be provided with jam nuts.
3. Minimum hanger rod diameter shall be 3/8 inch for pipe 2 inches and smaller, and, the minimum hanger rod diameter for pipe 2-1/2 inches and greater shall be 1/2 inch.
4. Rod connections at each end shall allow piping to move laterally with swivel type connections, such as welded eye rods.

H. Supplemental Steel:

1. Supplemental steel shall meet the requirements of Section 051200, Supply and Fabrication of Structural and Miscellaneous Steel.
2. Supplemental steel used in the construction of rigid restraints shall be designed such that deflection of the steel does not exceed 1/16” under maximum calculated design loads identified on the Support Detail Sheets.
3. Supplemental steel assemblies shall be shop fabricated to the greatest extent possible to minimize field welding.

I. Pipe Shoes:

1. Shoes to be fabricated of material equivalent to the pipe material.

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2. Pre-insulated shoes are not permitted.
3. Low friction slide plates shall be provided per the Support Detail Sheets. Insulating material shall be provided when needed to protect the low friction material from thermal damage on high temperature systems.
4. Clamp-on type pipe shoes shall be provided with jam nuts and/or other BUYER approved method of locking.

2.03 CORROSION PROTECTION

A. All components, with the exception of the spring coil, nameplates, indicator scales, alloy, stainless steel, or aluminum parts, shall be galvanized in accordance with Section 09 90 01, Protective Coatings.

B. Galvanized spring hanger housings shall not be welded after the coil has been installed. Retainers for the coil shall be of a bolted or split ring type construction to avoid burning the housing.

C. Spring coils shall be neoprene coated with a thickness of 6 mils.

D. Alternate coatings must be submitted by the Manufacturer for review and approval.

E. Shop paint shall be omitted for a distance of approximately 3 inches back from each connection to be field welded and a weldable primer such as Carboline Carbo 11 applied.

F. Protect threads with heavy coating of grease or antirust compound.

2.04 NAMEPLATES

A. Design Requirements:

1. Each support shall have a durable metal nameplate permanently attached.
2. Fully visible when support is in operating condition.
3. Include manufacturer’s name, figure number, hot load, cold load, travel, serial number, and size.
4. Stamp all nameplate information with 3/16 inch high (minimum) characters.

2.05 IDENTIFICATION TAGS

A. Design Requirements:

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1. Furnish each support with permanently attached identification tag of 18 gauge stainless steel, attached with 18 gauge braided monel or stainless steel wire and meter seal, or rivet to support.
2. Tag shall be stamped with applicable support number and Purchase Order number.
3. Characters on stamp shall be 3/16 inch high minimum.
4. Location of tag shall not interfere with installation or operation of support.

2.06 SOURCE QUALITY CONTROL

A. Factory Inspections: BUYER or BUYER's representative shall have the right to inspect equipment, materials, fabrication work, and associated quality assurance and quality control documentation covered by this Specification.

B. Notify BUYER not less than 10 working days prior to conducting all final inspections.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install in accordance with manufacturer's instructions and Drawings.

B. Observe attachment offsets as shown on Support Detail Sheets.

C. All threaded connections shall be installed with a minimum of 3 complete exposed threads beyond the loaded nut or support component.

END OF SECTION

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SECTION 40 90 00
INSTRUMENTATION AND CONTROL FOR PROCESS SYSTEMS

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM):
   a. A182, Standard Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service.
   b. A276, Standard Specification for Stainless and Heat-Resisting Steel Bars and Shapes.
   c. A312, Standard Specification for Seamless and Welded Austenitic Stainless Steel Pipes.
   d. B32, Standard Specification for Solder Metal.
   e. B88, Standard Specification for Seamless Copper Water Tube.
2. International Society of Automation (ISA):
   a. S5.1, Instrumentation Symbols and Identification (NRC ADOPTED).
   b. PR12.6, Installation of Intrinsically Safe Systems for Hazardous (Classified) Locations.
   c. S5.4, Standard Instrument Loop Diagrams.
   d. S20, Specification Forms for Process Measurement and Control Instruments, Primary Elements and Control Valves.
   e. S50.1, Compatibility of Analog Signals for Electronic Industrial Process Instruments.
3. National Electrical Manufacturers Association (NEMA):
   a. 250, Enclosures for Electrical Equipment (1,000 Volts Maximum).
   b. ICS 1, General Standards for Industrial Control and Systems.
4. National Institute of Standards and Technology (NIST).
5. Underwriters Laboratory, Inc. (UL): 508A, Standard for Safety, Industrial Control Panels.

1.02 SUMMARY

A. Work Includes:

1. Engineering, furnishing, installing, calibrating, adjusting, testing, documenting, starting up, and Owner training for complete Process Instrumentation and Control (PIC) for plant.

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2. Major parts are:
    a. Primary elements, transmitters, and control devices.
    b. Two wall-mounted control panels.
    c. Freestanding control panels.
    d. Programmable logic controllers.
    e. Interfaces with existing control systems.

B. Detailed Design: PIC as shown and specified includes functional and performance requirements and component specifications. Complete detailed PIC design.

1.03 DEFINITIONS

A. Abbreviations:

1. LCP: Local Control Panel.
2. MCC: Motor Control Center.
3. PAT: Performance Acceptance Test.
4. PIC: Process Instrumentation and Control.
5. PLC: Programmable Logic Controller.

B. Rising/Falling: Terms used to define actions of discrete devices about their setpoints.

1. Rising: Contacts close when an increasing process variable rises through setpoint.
2. Falling: Contacts close when a decreasing process variable falls through setpoint.

C. Signal Types:

1. Analog Signals, Current Type:
    a. 4 mA to 20 mA dc signals conforming to ISA S50.1.
    b. Unless otherwise indicated for specific PIC Subsystem components, use the following ISA 50.1 options:
        1) Transmitter Type: Number 2, two-wire.
        2) Transmitter Load Resistance Capacity: Class L.
        3) Fully isolated transmitters and receivers.
2. Analog Signals, Voltage Type: 1 to 5 V dc within panels where a common high precision dropping resistor is used.
3. Discrete signals, two-state logic signals using dc or 120V ac sources as indicated.
4. Pulse Frequency Signals:

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a. Direct current pulses whose repetition rate is linearly proportional to process variable.
b. Pulses generated by contact closures or solid state switches as indicated.
c. Power source less than 30V dc.

5. Special Signals: Other types of signals used to transmit analog and digital information between field elements, transmitters, receivers, controllers, and digital devices.

1.04 SUBMITTALS

A. Action Submittals:

1. General:
   a. Shop Drawings, full-scaled details, wiring diagrams, catalog cuts, and descriptive literature.
   b. Identify proposed items and options. Identify installed spares and other provisions for future work (for example, reserved panel space; unused components, wiring, and terminals).
   c. Legends and Abbreviation Lists: Complete definition of symbols and abbreviations used on this Project (for example, engineering units, flow streams, instruments, structures, and other process items used in nameplates, legends, and data sheets).
2. Bill of Materials: List of required equipment.
   a. Group equipment items [as follows:] [by enclosure and field, and within an enclosure, as follows:]
      1) I&C Components: By component identification code.
      2) Other Equipment: By equipment type.
   b. Data Included:
      1) Equipment tag number.
      2) Description.
      3) Manufacturer, complete model number, and all options not defined by model number.
      4) Quantity supplied.
      5) Component identification code where applicable.
3. Catalog Cuts: I&C Components, Electrical Devices, and Mechanical Devices:
   a. Catalog information, mark to identify proposed items and options.
   b. Descriptive literature.
   c. External power and signal connections.
   d. Scaled drawings showing exterior dimensions and locations of electrical and mechanical interfaces.

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4. Component Data Sheets: Data sheets for I&C components.
    a. Format and Level of Detail: In accordance with ISA-S20.
    b. Include component type identification code and tag number on data sheet.
    c. Specific features and configuration data for each component:
        1) Location or service.
        2) Manufacturer and complete model number.
        3) Size and scale range.
        4) Setpoints.
        5) Materials of construction.
        6) Options included.
    d. Name, address, and telephone number of manufacturer's local office, representative, distributor, or service facility.
5. Sizing and Selection Calculations:
    a. Primary Elements: Complete calculations plus process data used. Example, for flow elements, minimum and maximum values, permanent head loss, and assumptions made.
    b. Controlling, Computing and Function Generating Modules: Actual scaling factors with units and how they were computed.
6. Panel Construction Drawings:
    a. Scale Drawings: Show dimensions and location of panel mounted devices, doors, louvers, and subpanels, internal and external.
    b. Panel Legend: List front of panel devices by tag numbers, nameplate inscriptions, service legends, and annunciator inscriptions.
    c. Bill of Materials: List devices mounted within panel that are not listed in panel legend. Include tag number, description, manufacturer, and model number.
    d. Construction Details: NEMA rating, materials, material thickness, structural stiffeners and brackets, lifting lugs, mounting brackets and tabs, door hinges and latches, and welding and other connection callouts and details.
    e. Construction Notes: Finishes, wire color schemes, wire ratings, wire and terminal block, numbering and labeling scheme.
7. Panel Control Diagrams: For discrete control and power circuits.
    a. Diagram Type: Ladder diagrams in format same as shown on Drawings. Include devices, related to discrete functions that are mounted in or on the panel and that require electrical connections. Show unique rung numbers on left side of each rung.
    b. Item Identification: Identify each item with attributes listed.
        1) Wires: Wire number and color. Cable number, if part of multiconductor cable.

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2) Terminals: Location (enclosure number, terminal junction box number, or MCC number), terminal strip number, and terminal block number.
3) Discrete Components:
   a) Tag number, terminal numbers, and location ("FIELD", enclosure number, or MCC number).
   b) Switching action (open or close on rising or falling process variable), setpoint value and units, and process variable description (for example, Sump Level High).
4) Relay Coils:
   a) Tag number and its function.
   b) On right side of run where coil is located, list contact location by ladder number and sheet number. Underline normally closed contacts.
5) Relay Contacts: Coil tag number, function, and coil location (ladder rung number and sheet number).

c. Show each circuit individually. No "typical" diagrams or "typical" wire lists will be permitted.
d. Ground wires, surge protectors, and connections.
e. Circuit Names: Show names corresponding to Circuit and Raceway Schedule for circuits entering and leaving a panel. Refer to Division 26, Electrical.

8. Panel Wiring Diagrams: Show point-to-point and terminal-to-terminal wiring within panel.
9. Panel Plumbing Diagrams: For each panel containing piping and tubing. Show type and size for: Pipes and Tubes: Thickness, pressure rating, and materials.
   a. Components: Valves, regulators, and filters.
   b. Connections to panel mounted devices.
   c. Panel interface connections.
10. Loop Diagrams: Individual wiring diagram for each analog or pulse frequency loop.
   a. Conform to the minimum requirements of ISA S5.4.
   b. Under Paragraph 5.3 of ISA S5.4, include the information listed under subparagraphs 2 and 6.
   c. Drawing Size: Individual 11-inch by 17-inch sheet for each loop.
   d. Divide each loop diagram into areas for panel face, back-of-panel, and field.
   e. Show:
      1) Terminal numbers, location of dc power supply, and location of common dropping resistors.

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2) Switching contacts in analog loops and output contacts of analog devices. Reference specific control diagrams where functions of these contacts are shown.
3) Tabular summary on each diagram:
a) Transmitting Instruments: Output capability.
b) Receiving Instruments: Input impedance.
c) Loop Wiring Impedance: Estimate based on wire sizes and lengths shown.
d) Total loop impedance.
e) Reserve output capacity.
4) Circuit and raceway schedule names.

11. Interconnecting Wiring Diagrams:
a. Diagrams, device designations, and symbols in accordance with NEMA ICS 1.
b. Diagrams shall bear electrical Subcontractor's signature attesting diagrams have been coordinated with Division 26, Electrical.
c. Show:
1) Electrical connections between equipment, consoles, panels, terminal junction boxes, and field mounted components.
2) Component and panel terminal board identification numbers, and external wire and cable numbers.
3) Circuit names matching Circuit and Raceway Schedule.
4) Intermediate terminations between field elements and panels (for example, to terminal junction boxes and pull boxes).
5) Pull boxes.
12. Installation Details: Include modifications or further details required to adequately define installation of I&C components.
13. List of spares, expendables, test equipment and tools.
14. Additional Equipment Recommended: List of, and descriptive literature for, additional spares, expendables, test equipment and tools recommended. Include unit prices and total costs as specified in Section 01 29 00, Payment Procedures.

B. Informational Submittals: For PIC equipment, provide Manufacturer's Certificate of Proper Installation and readiness for operation.

1. Owner Training Plan. Reference Section 01 43 33, Manufacturers' Field Services.
2. Operation and Maintenance (O&M) Manuals: In accordance with Section 01 78 23, Operation and Maintenance Data, unless otherwise specified in this section.
a. Content and Format:

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b. Complete sets O&M manuals.
c. Sufficient detail to allow operation, removal, installation, adjustment, calibration, maintenance and purchasing replacements for each PIC component.
d. Final versions of Legend and Abbreviation Lists.
e. Manual format in accordance with Section 01 78 23, Operation and Maintenance Data.
f. Include:
    1) Process and Instrumentation Diagrams: One reproducible copy of revised P&ID to reflect as-built PIC design.
    2) Refer to paragraph Shop Drawings for the following items:
        a) Bill of Materials.
        b) Catalog Cuts.
        c) Component Data Sheets.
        d) Panel Control Diagrams.
        e) Panel Wiring Diagrams, one reproducible copy.
        f) Panel Plumbing Diagrams, one reproducible copy.
        g) Loop Diagrams, one reproducible copy.
        h) Interconnecting Wiring Diagrams, one reproducible copy.
        i) Application Software Documentation.
    3) Device O&M manuals for components, electrical devices, and mechanical devices include:
        a) Operations procedures.
        b) Installation requirements and procedures.
        c) Maintenance requirements and procedures.
            (1) Troubleshooting procedures.
            (2) Calibration procedures.
            (3) Internal schematic and wiring diagrams.
            (4) Component Calibration Sheets from field quality control calibrations.
    4) List of spares, expendables, test equipment and tools provided.
    5) List of additional spares, expendables, test equipment and tools recommended.

3. Performance Acceptance Tests (PAT) Submittals:
    a. Preliminary Test Procedures: Outlines of proposed tests, forms, and checklists.
    b. Final Test Procedures: Proposed test procedures, forms, and checklists.
    c. Test Documentation: Copy of signed off test procedures when tests are completed.

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1.05 QUALITY ASSURANCE

A. Calibration Instruments: Each instrument used for calibrating PIC equipment shall bear the seal of a reputable laboratory certifying that instrument has been calibrated within the previous 12 months to a standard endorsed by the NIST.

B. Coordination Meetings:

1. In accordance with Section 01 31 13, Project Coordination.
2. Location: Construction Office
3. Attended By: Engineer, Owner, and Contractor.
4. Minimum of four are required. Specific dates will be established in Progress Schedule.
5. First Meeting: Within 45 days after Notice to Proceed.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Provide Site and warehouse storage facilities for PIC equipment.

B. Prior to shipment, include corrosive-inhibitive vapor capsules in shipping containers, and related equipment as recommended by the capsule manufacturer.

C. Prior to installation, store items in dry indoor locations. Provide heating in storage areas for items subject to corrosion under damp conditions.

D. Cover panels and other elements that are exposed to dusty construction environments.

1.07 ENVIRONMENTAL REQUIREMENTS

A. Standard Environmental Requirements: Unless otherwise noted, design equipment for continuous operation in these environments:

1. Freestanding Panel and Consoles:
   a. Inside, Air Conditioned: NEMA 1.
   b. Inside: NEMA 12.
2. Smaller Panels and Assemblies (that are not Freestanding):
   a. Inside, Air Conditioned: NEMA 12.
   b. All Other Locations: NEMA 4X.
3. Field Elements: Outside.

B. Environmental Design Requirements: Following defines the types of environments referred to in the above.

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1. Inside, Air Conditioned:
   a. Temperature:
      1) Normal: 60 to 80 degrees F.
      2) With Up to 4-Hour HVAC System Interruptions: 40 to 105 degrees F.
   b. Relative Humidity:
      1) Normal: 10 percent (winter) to 70 percent (summer).
      2) With Up to 4-Hour HVAC System Interruption: 10 to 100 percent.
   c. NEC Classification: Nonhazardous.
2. Inside:
   a. Temperature: 20 to 104 degrees F.
   b. Relative Humidity: 10 to 95 percent non-condensing.
   c. NEC Classification: Nonhazardous.
3. Inside, Corrosive:
   a. Temperature: Minus 20 to 104 degrees F.
   b. Relative Humidity: 10 to 95 percent non-condensing.
   c. Corrosive Environment: Hydrogen sulfide gas, Chlorine gas
   d. NEC Classification: Nonhazardous.
4. Outside:
   a. Temperature: 10 to 130 degrees F.
   b. Relative Humidity: 10 to 95 percent non-condensing, rain, snow, freezing rain.
   c. NEC Classification: Nonhazardous.
5. Outside, Corrosive:
   a. Temperature: 10 to 130 degrees F.
   b. Relative Humidity: 10 to 95 percent non-condensing, rain, snow, freezing rain
   c. Corrosive Environment: Hydrogen sulfide gas Chlorine gas
   d. NEC Classification: Nonhazardous.

1.08 SEQUENCING AND SCHEDULING

A. Activity Completion: The following is a list of key activities and their completion criteria:

1. Shop Drawings: Reviewed and approved.
2. Quality Control Submittals: Reviewed and accepted.
3. Hardware Delivery: Hardware delivered to Site and inventoried by Construction Manager.
4. PAT: Completed and required test documentation accepted.

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B. PIC Substantial Completion: When Engineer issues Certificate of Substantial Completion.

1. Prerequisites:
   a. All PIC Submittals have been completed.
   b. PIC has successfully completed PAT.
   c. Owner training plan is on schedule.
   d. All spares, expendables, and test equipment have been delivered to Owner.

C. PIC Acceptance: When Engineer issues a written notice of Final Payment and Acceptance.

1. Prerequisites:
   a. Certificate of Substantial Completion issued for PIC.
   b. Punch-list items completed.
   c. Final revisions to O&M manuals accepted.
   d. Maintenance service agreements for PIC accepted by Owner.

D. Prerequisite Activities and Lead Times: Do not start the following key Project activities until the prerequisite activities and lead times listed below have been completed and satisfied:

Activity	**Prerequisites and Lead Times**
Submittal reviews by Engineer	Engineer acceptance of Submittal breakdown and schedule.
Hardware purchasing, fabrication, and assembly	Associated shop drawing Submittals completed.
Shipment	Completion of PIC Shop Drawing Submittals and preliminary O&M manuals.
Owner Training	Owner training plan completed
PAT	Startup, Owner training, and PAT procedures completed; notice [4] [_____] weeks prior to start.

PART 2 - PRODUCTS

2.01 GENERAL

A. PIC functions as shown on Drawings and as required for each loop. Furnish equipment items as required. Furnish all materials, equipment, and software, necessary to effect required system and loop performance.

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B. First Named Manufacturer: PIC design is based on first named manufacturers of equipment and materials.

1. If an item is proposed from other than first named manufacturer, obtain approval from Engineer for such changes in accordance with Article Submittals.
2. If using proposed item requires other changes, provide work and equipment to implement these changes. Changes that may be required include, but are not limited to: different installation, wiring, raceway, enclosures, connections, isolators, intrinsically safe barriers, software, and accessories.

C. Like Equipment Items:

1. Use products of one manufacturer and of the same series or family of models to achieve standardization for appearance, operation, maintenance, spare parts, and manufacturer's services.
2. Implement all same or similar functions in same or similar manner. For example, control logic, sequence controls, and display layouts.

2.02 LOOP SPECIFICATIONS

A. Location: Article Supplements.

B. Organization: By unit process and loop number.

C. Functional Requirements for Control Loops:

1. Shown on Drawings, in Panel Control Diagrams, and Process and Instrumentation Diagrams (P&ID). P&ID format and symbols are in accordance with ISA S5.1, except as specified or shown on Drawings.
2. Supplemented by Loop Specifications.

D. Subheadings for Each Loop:

1. Functions: Clarifies functional performance of loop, including abstract of interlocks
    a. Components: Lists major components for each loop. Information listed include: Tag numbers.
    b. Component Identification Codes: Alphanumeric codes of required components. Refer to Component Specification referenced in Article Supplements.
    c. Component Names and Options: Required to tailor general Component Specifications to specific application. For example,

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special materials, mounting, size, unit range, scale, setpoints, and controller options.

2.03 I&C COMPONENTS

A. Components for Each Loop: Major components for each loop are listed [under Components in Loop Specification on Data Sheets referenced in Article Supplements. Furnish all equipment that is necessary to achieve required loop performance.

B. Component Specifications: Generalized specifications for each type of component are located in Article Supplements.

2.04 NAMEPLATES AND TAGS

A. Panel Nameplates: Enclosure identification located on the enclosure face.

1. Location and Inscription: As shown.
2. Materials: Laminated plastic attached to panel with stainless steel screws.
3. Letters: 1/2-inch white on black background, unless otherwise noted.

B. Component Nameplates—Panel Face: Component identification located on panel face under or near component.

1. Location and Inscription: As shown.
2. Materials: Laminated plastic attached to panel with stainless steel screws.
3. Letters: 3/16-inch white on black background, unless otherwise noted.

C. Component Nameplates—Back of Panel: Component identification located on or near component inside of enclosure.

1. Inscription: Component tag number.
2. Materials: Adhesive-backed laminated plastic.
3. Letters: 3/16-inch white on black background, unless otherwise noted.

D. Legend Plates for Panel Mounted Pushbuttons, Lights, and Switches.

1. Inscription: Refer to:
   a. Table under paragraph Standard Pushbutton Colors and Inscriptions.
   b. Table under paragraph Standard Light Colors and Inscriptions.
   c. P&IDs in Drawings.
2. Materials: Stainless steel, keyed legend plates. Secured to panel by mounting nut for pushbutton, light, or switch.
3. Letters: Black on gray or white background.

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E. Service Legends: Component identification nameplate located on face of component.

1. Inscription: As shown.
2. Materials: Adhesive backed, laminated plastic.
3. Letters: 3/16-inch white on black background, unless otherwise noted.

F. Nametags: Component identification for field devices.

1. Inscription: Component tag number.
2. Materials: 16-gauge, Type 304 stainless steel.
3. Letters: 3/16-inch imposed.
4. Mounting: Affix to component with 16- or 18-gauge stainless steel wire or stainless steel screws.

2.05 ELECTRICAL REQUIREMENTS

A. In accordance with Division 26, Electrical.

B. I&C and electrical components, terminals, wires, and enclosures: UL recognized or UL listed.

C. Wires within Enclosures:

1. ac Circuits:
   a. Type: 300-volt, Type MTW stranded copper.
   b. Size: For current to be carried, but not less than 18 AWG.
2. Analog Signal Circuits:
   a. Type: 300-volt stranded copper, twisted shielded pairs.
   b. Size: 18 AWG, minimum.
3. Other dc Circuits.
   a. Type: 300-volt, Type MTW stranded copper.
   b. Size: For current carried, but not less than 18 AWG.
4. Special Signal Circuits: Use manufacturer's standard cables.
5. Wire Identification: Numbered and tagged at each termination.
   a. Wire Tags: Machine printed, heat shrink.
   b. Manufacturers:
      1) Brady PermaSleeve.
      2) Tyco Electronics.

D. Wires entering or leaving enclosures, terminate and identify as follows:

1. Analog and discrete signal, terminate at numbered terminal blocks.

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2. Special signals, terminated using manufacturer's standard connectors.
3. Identify wiring in accordance with Section 26 05 05, Conductors.

E. Terminal Blocks for Enclosures:

1. Quantity:
   a. Accommodate present and spare indicated needs.
   b. Wire spare [PLC] [DCS] [RTU] I/O points to terminal blocks.
   c. One wire per terminal for field wires entering enclosures.
   d. Maximum of two wires per terminal for 18-WG wire for internal enclosure wiring.
   e. Spare Terminals: 20 percent of all connected terminals, but not less than 5 per terminal block.
2. General:
   a. Connection Type: Screw compression clamp.
   b. Compression Clamp:
      1) Complies with DIN-VDE 0611.
      2) Hardened steel clamp with transversal groves that penetrate wire strands providing a vibration-proof connection.
      3) Guides strands of wire into terminal.
   c. Screws: Hardened steel, captive and self-locking.
   d. Current Bar: Copper or treated brass.
   e. Insulation:
      1) Thermoplastic rated for minus 55 to plus 110 degree C.
      2) Two funneled shaped inputs to facilitate wire entry.
   f. Mounting:
      1) Standard DIN rail.
      2) Terminal block can be extracted from an assembly without displacing adjacent blocks.
      3) End Stops: Minimum of one at each end of rail.
   g. Wire preparation: Stripping only permitted.
   h. Jumpers: Allow jumper installation without loss of space on terminal or rail.
   i. Marking System:
      1) Terminal number shown on both sides of terminal block.
      2) Allow use of preprinted and field marked tags.
      3) Terminal strip numbers shown on end stops.
      4) Mark terminal block and terminal strip numbers as shown on Panel Control Diagrams and Loop Diagrams.
      5) Fuse Marking for Fused Terminal Blocks: Fuse voltage and amperage rating shown on top of terminal block.
   j. Test Plugs: Soldered connections for 18 AWG wire.

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1) Pin Diameter: 0.079 inch.
2) Quantity: 10
3) Manufacturer and Product: Entrelec; Type FC2.

3. Terminal Block, General-Purpose:
   a. Rated Voltage: 600V ac.
   b. Rated Current: 30 amp.
   c. Wire Size: 22 AWG to 10 AWG.
   d. Rated Wire Size: 10 AWG.
   e. Color: Grey body.
   f. Spacing: 0.25 inch, maximum.
   g. Test Sockets: One screw test socket 0.079-inch diameter.
   h. Manufacturer and Product: Entrelec; Type M4/6.T.
4. Terminal Block, Ground:
   a. Wire Size: 22 AWG to 12 AWG.
   b. Rated Wire Size: 12 AWG.
   c. Color: Green and yellow body.
   d. Spacing: 0.25 inch, maximum.
   e. Grounding: Ground terminal blocks electrically grounded to the mounting rail.
   f. Manufacturer and Product: Entrelec; Type M4/6.P.
5. Terminal Block, Blade Disconnect Switch:
   a. Rated Voltage: 600V ac.
   b. Rated Current: 10-amp.
   c. Wire Size: 22 AWG to 12 AWG.
   d. Rated Wire Size: 12 AWG.
   e. Color: Grey body, orange switch.
   f. Spacing: 0.25 inch, maximum.
   g. Manufacturer and Product: Entrelec; Type M4/6.SN.T.
6. Terminal Block, Fused, 24V dc:
   a. Rated Voltage: 600V dc.
   b. Rated Current: 16-amp.
   c. Wire Size: 22 AWG to 10 AWG.
   d. Rated Wire Size: 10 AWG.
   e. Color: Grey body.
   f. Fuse: 0.25 inch by 1.25 inches.
   g. Indication: LED diode 24V dc.
   h. Spacing: 0.512 inch, maximum.
   i. Manufacturer and Product: Entrelec; Type M10/13T.SFL.
7. Terminal Block, Fused, 120V ac:
   a. Rated Voltage: 600V ac.
   b. Rated Current: 16-amp.

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c. Wire Size: 22 AWG to 10 AWG.
d. Rated Wire Size: 10 AWG.
e. Color: Grey body.
f. Fuse: 0.25 inch by 1.25 inches.
g. Indication: Neon Lamp 110V ac.
h. Leakage Current: 1.8 mA, maximum.
i. Spacing: 0.512 inch, maximum
j. Manufacturer and Product: Entrelec; Type M10/13T.SFL.

8. Terminal Block, Fused, 120V ac, High Current:
   a. Rated Voltage: 600V ac.
   b. Rated Current: 35 amps.
   c. Wire Size: 18 AWG to 8 AWG.
   d. Rated Wire Size: 8 AWG.
   e. Color: Grey.
   f. Fuse: 13/32 inch by 1.5 inches.
   g. Spacing: 0.95 inch, maximum.
   h. Manufacturer and Product: Entrelec; Type MB10/24.SF.

F. Grounding of Enclosures:

1. Furnish isolated copper grounding bus for signal and shield ground connections.
2. Ground bus grounded at a common signal ground point in accordance with National Electrical Code requirements.
3. Single Point Ground for Each Analog Loop:
   a. Locate at dc power supply for loop.
   b. Use to ground wire shields for loop.
   c. Group and connect shields in following locations: Terminal Block
4. Ground terminal block rails to ground bus.

G. Analog Signal Isolators: Furnish signal isolation for analog signals that are sent from one enclosure to another. Do not wire in series instruments on different panels, cabinets, or enclosures.

H. Power Distribution within Panels:

1. Feeder Circuits:
   a. One or more 120V ac, 60-Hz feeder circuits as shown on Drawings.
   b. Make provisions for feeder circuit conduit entry.
   c. Furnish terminal board for termination of wires.
2. Power Panel: Furnish main circuit breaker and a circuit breaker on each individual branch circuit distributed from power panel.

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a. Locate to provide clear view of and access to breakers when door is open.
b. Breaker sizes: Coordinate such that fault in branch circuit will blow only branch breaker but not trip the main breaker.
1) Branch Circuit Breaker: 15 amps at 250V ac.
c. Breaker Manufacturers and Products: [Refer to Division 26, Electrical.] [Square D, Type QO.]

3. Circuit Wiring: P&IDs and Control Diagrams on Drawings show function only. Use following rules for actual circuit wiring:
a. Devices on Single Circuit: 20, maximum.
b. Multiple Units Performing Parallel Operations: To prevent failure of any single branch circuit from shutting down entire operation, do not group all units on same branch circuit.
c. Branch Circuit Loading: 12 amperes continuous, maximum.
d. Panel Lighting and Service Outlets: Put on separate 15-amp, 120V ac branch circuit.
e. Provide 120V ac plug mold for panel components with line cords.

I. Signal Distribution:

1. Within Panels: 4 mA to 20 mA dc signals may be distributed as 1 to 5V dc.
2. Outside Panels: Isolated 4 mA to 20 mA dc only.
3. All signal wiring twisted in shielded pairs.

J. Signal Switching:

1. Use dry circuit type relays or switches.
2. No interruption of 4 mA to 20 mA loops during switching.
3. Switching Transients in Associated Signal Circuit:
a. 4 mA to 20 mA dc Signals: 0.2 mA, maximum.
b. 1 to 5V dc Signals: 0.05V, maximum.

K. Relays:

1. General:
a. Relay Mounting: Plug-in type socket.
b. Relay Enclosure: Furnish dust cover.
c. Socket Type: Screw terminal interface with wiring.
d. Socket Mounting: Rail.
e. Provide holddown clips.
2. Signal Switching Relay:
a. Type: Dry circuit.

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b. Contact Arrangement: 2 Form C contacts.
c. Contact Rating: 0 to 5 amps at 28V dc or 120V ac.
d. Contact Material: Gold or silver.
e. Coil Voltage: As noted or shown.
f. Coil Power: 0.9 watts (dc), 1.2VA (ac).
g. Expected Mechanical Life: 10,000,000 operations.
h. Expected Electrical Life at Rated Load: 100,000 operations.
i. Indication Type: Neon or LED indicator lamp.
j. Seal Type: Hermetically sealed case.
k. Manufacturer and Product: Potter and Brumfield; Series KH/KHA.

3. Control Circuit Switching Relay, Non-latching:
   a. Type: Compact general-purpose plug-in.
   b. Contact Arrangement: 3 Form C contacts.
   c. Contact Rating: 10A at 28V dc or 240V ac.
   d. Contact Material: Silver cadmium oxide alloy.
   e. Coil Voltage: As noted or shown.
   f. Coil Power: 1.8 watts (dc), 2.7VA (ac).
   g. Expected Mechanical Life: 10,000,000 operations.
   h. Expected Electrical Life at Rated Load: 100,000 operations.
   i. Indication Type: Neon or LED indicator lamp.
   j. Push to test button.
   k. Manufacturer and Product: Potter and Brumfield; Series KUP.
4. Control Circuit Switching Relay, Latching:
   a. Type: Dual coil mechanical latching relay.
   b. Contact Arrangement: 2 Form C contacts.
   c. Contact Rating: 10A at 28V dc or 120V ac.
   d. Contact Material: Silver cadmium oxide alloy.
   e. Coil Voltage: As noted or shown.
   f. Coil Power: 2.7 watts (dc), 5.3VA (ac).
   g. Expected Mechanical Life: 500,000 operations.
   h. Expected Electrical Life at Rated Load: 50,000 operations.
   i. Manufacturer and Product: Potter and Brumfield; Series KB/KBP.
5. Control Circuit Switching Relay, Time Delay:
   a. Type: Adjustable time delay relay.
   b. Contact Arrangement: 2 Form C contacts.
   c. Contact Rating: 10A at 240V ac.
      1) Contact Material: Silver cadmium oxide alloy.
   d. Coil Voltage: As noted or shown.
   e. Operating Temperature: Minus 10 to 55 degrees C.
   f. Repeatability: Plus or minus 2 percent.
   g. Delay Time Range: Select range such that time delay setpoint fall between 20 to 80 percent of range.

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h. Time Delay Setpoint: As noted or shown.
i. Mode of Operation: As noted or shown.
j. Adjustment Type: Integral potentiometer with knob external to dust cover.
k. Manufacturer and Products: Potter and Brumfield:
   1) Series CB for 0.1 second to 100 minute delay time ranges.
   2) Series CK for 0.1 to 120 second delay time ranges.

L. Power Supplies:

1. Furnish to power instruments requiring external dc power, including two-wire transmitters and dc relays.
2. Convert 120V ac, 60-Hz power to dc power of appropriate voltage(s) with sufficient voltage regulation and ripple control to assure that instruments being supplied can operate within their required tolerances.
3. Provide output over voltage and over current protective devices to:
   a. Protect instruments from damage due to power supply failure.
   b. Protect power supply from damage due to external failure.
4. Enclosures: NEMA 1 in accordance with NEMA 250.
5. Mount such that dissipated heat does not adversely affect other components.
6. Fuses: For each dc supply line to each individual two-wire transmitter.
   a. Type: Indicating.
   b. Mount so fuses can be easily seen and replaced.

M. Internal Panel Lights for Freestanding Panels:

1. Type: Switched 100-watt incandescent back-of-panel lights.
2. Quantity: One light for every 4 feet of panel width.
3. Mounting: Inside and in the top of back-of-panel area.
4. Protective metal shield for lights.

N. Service Outlets for Freestanding Panels:

1. Type: Three-wire, 120-volt, 15-ampere, GFCI duplex receptacles.
2. Quantity:
   a. For panels 4 feet wide and smaller: One.
   b. For panels wider than 4 feet: One for every 4 feet of panel width, two minimum per panel.
3. Mounting: Evenly spaced along back-of-panel area.

O. Internal Panel Lights and Service Outlets for Smaller Panels:

1. Internal Panel Light: Switched 100-watt incandescent light.

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2. Service Outlet: Breaker protected 120-volt, 15-amp, GFCI duplex receptacle:

P. Standard Pushbutton Colors and Inscriptions: Use following color code and inscriptions for pushbuttons.

Tag Function	Inscription(s)	Color
OO	ON OFF	Red Green
OC	OPEN CLOSE	Red Green
OCA	OPEN CLOSE AUTO	Red Green Black
OOA	ON OFF AUTO	Red Green Black
MA	MANUAL AUTO	Black Black
SS	START STOP	Red Green
RESET	RESET	Black
EMERGENCY STOP	EMERGENCY STOP	Red

1. Lettering Color:
   a. Black on white and yellow buttons.
   b. White on black, red, and green buttons.

Q. Standard Light Colors and Inscriptions: Use following color code and inscriptions for service legends and lens colors for indicating lights, unless otherwise noted in [individual Loop Specifications,] [Instrument List,] Article Supplements.

Tag Function	Inscription(s)	Color
ON	ON	Red
OFF	OFF	Green
OPEN	OPEN	Red
CLOSED	CLOSED	Green

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Tag Function	Inscription(s)	Color
LOW	LOW	Green
FAIL	FAIL	Amber
HIGH	HIGH	Red
AUTO	AUTO	White
MANUAL	MANUAL	Yellow
LOCAL	LOCAL	White
REMOTE	REMOTE	Yellow

1. Lettering Color:
   a. Black on white and amber lenses.
   b. White on red and green lenses.

2.06 MECHANICAL SYSTEMS

A. Manifold, Three-Valve Equalizing:

1. Type: For isolation and equalization of differential pressure transducers.
2. Materials: Stainless steel.
3. Manufacturers and Products:
   a. Anderson, Greenwood and Co.; Type M1.
   b. Evans.

B. Pressure Gauge: For other than process variable measurement.

1. Dial Size: Nominal 2-inch dial size.
2. Accuracy: 2 percent of span.
3. Scale Range: Such that normal operating pressure lies between 50 and 80 percent of scale range.
4. Connection: 1/4-inch NPT through bottom, unless otherwise noted.
5. Manufacturers and Products:
   a. Ashcroft Utility; Gauge Series 1000.
   b. Marsh; Standard Gauge Series.
   c. Ametek U.S.; Gauge Series P500.
   d. Acculite; Series 2000.

C. ON/OFF Valves:

1. Type: Ball valve.
2. Materials: Stainless steel.

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3. Manufacturers and Products:
    a. Whitey; Series 41 through Series 43.
    b. Hoke; Flomite 7100 Series.

D. Regulating Valves:

1. Type: Needle valves, with regulating stems and screwed bonnets.
2. Materials: Stainless steel.
3. Manufacturers and Products:
    a. Whitey; Catalog No. RF or RS.
    b. Hoke; 3100 through 3300 Series.

E. Valve, Three-Way:

1. Type: Ball valve.
2. Materials: Stainless steel with nylon handle.
3. Manufacturers and Products:
    a. Whitey; Series 41 through Series 43.
    b. Hoke; Selecto-Mite Series.

F. Solenoid Valve, Two-Way:

1. Type: Globe valve directly actuated by solenoid and not requiring minimum pressure differential for operation.
2. Materials:
    a. Body: Brassed globe valves.
    b. Valve Seat: Buna-N.
3. Size: As noted and normally closed or opened, as noted.
4. Coil: 115V ac, unless noted otherwise.
5. Solenoid Enclosure: NEMA 4.
6. Manufacturer and Product: ASCO; Red Hat Series 8260.

G. Pressure Regulator, Air:

1. Provide air at reduced pressures, as shown, constant to within plus or minus 10 percent for flows from 0 to 300 scfh with 100 psi supply pressure.
2. Setscrew for outlet pressure adjustment.
3. Integral filter and relief valve.
4. Manufacturers and Products:
    a. Masoneilan; Series 77-4.
    b. Fisher; Series 67FR.

H. Test Tap:

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1. Manufacturers and Products:
    a. Imperial-Eastman; quick-disconnect couplings No. 292-P and caps No. 259-P.
    b. Crawford Fitting Co.; Swagelok quick-connects Series QC4 and caps QC4-DC.
    c. Parker; CPI Series precision quick couplings.

I. Copper Tubing and Fittings:

1. Type K hard copper, ASTM B88, with commercially pure wrought copper solder joint fittings. Make joints with 95-5 wire solder, ASTM B32, Grade 95 TA. Do not use cored solder.
2. Alternatively, Type K, soft temper copper tubing, ASTM B88, with brass compression type fittings may be used where shown on the Drawings.
3. Manufacturers:
    a. Parker-Hannifin.
    b. Swagelok tube fittings.

J. Plastic Tubing and Fittings:

1. Tubing: Polyethylene capable of withstanding 190 psig at 175 degrees F.
    a. Manufacturers and Products:
        1) Dekoron; Type P.
        2) Imperial Eastman; Poly-Flo black instrument tubing.
2. Fittings:
    a. Type: Brass compression.
    b. Manufacturers and Products:
        1) Imperial Eastman; Poly-Flo tube fittings.
        2) Dekoron; E-Z fittings.

K. Stainless Steel Tubing: ASTM A312, Type 316, seamless, soft annealed, as shown on Drawings, 0.065-inch wall.

L. Stainless Steel Fittings:

1. Compression Type:
    a. Materials: Stainless steel, ASTM A182 forged bodies or ASTM A276 barstock bodies, Type 316, flareless.
    b. Manufacturers and Products:
        1) Parker Flodar; BA Series.
        2) Swagelok tube fittings.

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3) Parker CPI tube fittings; Parker A-LOK dual ferrule tube fittings.

2. Socket Weld Type:
   a. Materials: Stainless steel, ASTM A182 forged bodies or ASTM A276 barstock bodies, Type 316 for 3,000 psi maximum working pressure, safety factor 4:1.
   b. Manufacturers:
      1) Cajon.
      2) Swagelok.
      3) Parker WELDLOK.

M. Air Set: Consist of a shutoff valve, pressure regulator, discharge pressure gauge, and interconnecting tubing.

N. Purge Set:

1. Parts: Purge rotameter flow element, pressure regulator, pressure gauge, test tap, shutoff valve, spool valve, and interconnecting tubing as shown on Drawings and as specified.
2. Pressure Gauge Scale Range: 150 percent of the process variable.
3. Mounting: Within consoles, panels, or a separate enclosure as shown. For separate enclosure mounted purge sets, refer to paragraphs Nonfreestanding Panel Construction and Factory Finishing for enclosure requirements.

2.07 FABRICATION

A. General:

1. Panels with external dimensions and instruments arrangement as shown on Drawings.
2. Panel Construction and Interior Wiring: In accordance with the National Electrical Code, state and local codes, NEMA, ANSI, UL, and ICECA.
3. Fabricate panels, install instruments, wire, and plumb, at the PIC factory.
4. Electrical Work: In accordance with Division 26, Electrical.

B. Factory Assembly: Assemble panels at the manufacturer’s factory. No fabrication other than correction of minor defects or minor transit damage shall be done on panels at Site.

C. UL Listing Mark for Enclosures: Mark stating “Listed Enclosed Industrial Control Panel” per UL 508A.

D. Wiring Within PIC Panels:

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1. Restrain by plastic ties or ducts or metal raceways.
2. Hinge Wiring: Secure at each end so that bending or twisting will be around longitudinal axis of wire. Protect bend area with sleeve.
5. Arrange wiring neatly, cut to proper length, and remove surplus wire.
3. Abrasion protection for wire bundles which pass through holes or across edges of sheet metal.
4. Connections to Screw Type Terminals:
    a. Locking-fork-tongue or ring-tongue lugs.
    b. Use manufacturer's recommended tool with required sized anvil to make crimp lug terminations.
    c. Wires terminated in a crimp lug, maximum of one.
    d. Lugs installed on a screw terminal, maximum of two.
5. Connections to Compression Clamp Type Terminals:
    a. Strip, prepare, and install wires in accordance with terminal manufacturer's recommendations.
    b. Wires installed in a compression screw and clamp, maximum of one for field wires entering enclosure, otherwise maximum of two.
6. Splicing and tapping of wires, allowed only at device terminals or terminal blocks.
7. Terminate 24V dc and analog signal circuits on separate terminal block from ac circuit terminal blocks.
8. Separate analog and dc circuits by at least 6 inches from ac power and control wiring, except at unavoidable crossover points and at device terminations.
9. Arrange wiring to allow access for testing, removal, and maintenance of circuits and components.
10. Plastic Wire Ducts Fill: Do not exceed manufacturer's recommendation.

E. Temperature Control:

1. Freestanding Panels:
    a. Nonventilated Panels: Size to adequately dissipate heat from equipment mounted inside panel or on panel.
    b. Ventilated Panels:
        1) Furnish with louvers and forced ventilation as required to prevent temperature buildup from equipment mounted inside panel or on panel.
        2) For panels with backs against wall, furnish louvers on top and bottom of panel sides.
        3) For panels without backs against wall, furnish louvers on top and bottom of panel back.
        4) Louver Construction: Stamped sheet metal.

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5) Ventilation Fans:
   a) Furnish where required to provide adequate cooling.
   b) Create positive internal pressure within panel.
   c) Fan Motor Power: 120V ac, 60-Hz, thermostatically controlled.
6) Air Filters: Washable aluminum, Hoffman Series A-FLT.

2. Refrigerated System: Furnish where heat dissipation cannot be adequately accomplished with natural convection or forced ventilation. Smaller Panels (that are not freestanding): Size to adequately dissipate heat from equipment mounted inside panel or in panel face.
3. Space Heaters: Thermostatically controlled to maintain internal panel temperatures above dew point.

F. Freestanding Panel Construction:

1. Materials: Sheet steel, unless otherwise shown on Drawings with minimum thickness of 10-gauge, unless otherwise noted.
2. Panel Fronts:
   a. Fabricated from a single piece of sheet steel, unless otherwise shown on Drawings.
   b. No seams or bolt heads visible when viewed from front.
   c. Panel Cutouts: Smoothly finished with rounded edges.
   d. Stiffeners: Steel angle or plate stiffeners or both on back of panel face to prevent panel deflection under instrument loading or operation.
3. Internal Framework:
   a. Structural steel for instrument support and panel bracing.
   b. Permit panel lifting without racking or distortion.
4. Lifting rings to allow simple, safe rigging and lifting of panel during installation.
5. Adjacent Panels: Securely bolted together so front faces are parallel.
6. Doors: Full height, fully gasketed access doors where shown on Drawings.
   a. Latches: Three-point, Southco Type 44.
   b. Handles: “D” ring, foldable type.
   c. Hinges: Full length, continuous, piano type, steel hinges with stainless steel pins.
   d. Rear Access Doors: Extend no further than 24 inches beyond panel when opened to 90-degree position.
   e. Front and Side Access Doors: As shown on Drawings.

G. Nonfreestanding Panel Construction:

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1. Based on environmental design requirements required and referenced in Article Environmental Requirements, provide the following:
   a. For panels listed as inside, air conditioned:
      1) Enclosure Type: NEMA 12 in accordance with NEMA 250.
      2) Materials: Steel.
   b. For all other panels:
      1) Enclosure Type: NEMA 4X in accordance with NEMA 250.
      2) Materials: [Type 316 stainless steel.] [Plastic.]
2. Metal Thickness: 14-gauge, minimum.
3. Doors:
   a. Rubber-gasketed with continuous hinge.
   b. Stainless steel lockable quick-release clamps.
4. Manufacturers:
   a. Hoffman Engineering Co.
   b. Rittal.

H. Factory Finishing:

1. Enclosures:
   a. Stainless Steel and Aluminum: Not painted.
   b. Steel Panels:
      1) Sand panel and remove mill scale, rust, grease, and oil.
      2) Fill imperfections and sand smooth.
      3) Paint panel interior and exterior with one coat of epoxy coating metal primer, two finish coats of two-component type epoxy enamel.
      4) Sand surfaces lightly between coats.
      5) Dry Film Thickness: 3 mils, minimum.
      6) Color: ANSI 61 Gray
2. Manufacturer’s standard finish color, except where specific color is indicated. If manufacturer has no standard color, finish equipment with light gray color.

2.08 CORROSION PROTECTION

A. Corrosion-Inhibiting Vapor Capsule Manufacturers:

1. Northern Instruments; Model Zerust VC.
2. Hoffmann Engineering Co; Model A-HCI.

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2.09 SOURCE QUALITY CONTROL

A. Scope: Inspect and test entire PIC to ensure it is ready for shipment, installation, and operation.

B. Location: Manufacturer's factory or Engineer approved staging Site.

C. Test: Exercise and test all functions.

D. Temporary PLC software configuring to allow PLC testing.

PART 3 - EXECUTION

3.01 EXAMINATION

A. For equipment not provided by PIC, but that directly interfaces with the PIC, verify the following conditions:

1. Proper installation.
2. Calibration and adjustment of positioners and I/P transducers.
3. Correct control action.
4. Switch settings and dead bands.
5. Opening and closing speeds and travel stops.
6. Input and output signals.

3.02 INSTALLATION

A. Material and Equipment Installation: Retain a copy of manufacturers' instructions at Site, available for review at all times.

B. Electrical Wiring: As specified in Division 26, Electrical.

C. Mechanical Systems:

1. Drawings for PIC Mechanical Systems are diagrammatic and not intended to specifically define element locations or piping and tubing run lengths. Base materials and installations on field measurements.
2. Copper and Stainless Steel Tubing Support: Continuously supported by an aluminum tubing raceway system.
3. Plastic Tubing Supports: Except as shown on Drawings, provide continuous support in conduits or by aluminum tubing raceway system.
4. Install tubing conduit for plastic tubing and tubing raceways parallel with, or at right angles to, structural members of buildings. Make vertical runs straight and plumb.

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5. Tubing and Conduit Bends:
   a. Tool-formed without flattening, and all of same radius.
   b. Bend Radius: Equal to or larger than conduit and tubing manufacturer's recommended minimum bend radius.
   c. Slope instrument connection tubing in accordance with installation details.
   d. Do not run liquid filled instrument tubing immediately over or within a 3-foot plan view clearance of electrical panels, motor starters, or mechanical mounting panel without additional protection. Where tubing must be located in these zones, shield electrical device to prevent water access to electrical equipment.
   e. Straighten coiled tubing by unrolling on flat surface. Do not pull to straighten.
   f. Cut tubing square with sharp tubing cutter. Deburr cuts and remove chips. Do not gouge or scratch surface of tubing.
   g. Blow debris from inside of tubing.
   h. Make up and install fittings in accordance with manufacturer's recommendations. Verify makeup of tube fittings with manufacturer's inspection gauge.
   i. Use lubricating compound or TFE tape on stainless steel threads to prevent seizing or galling.
   j. Run tubing to allow, for example, clear access to doors, controls, and control panels; and to allow for easy removal of equipment.
   k. Provide separate support for components in tubing runs.
   l. Supply expansion loops and use adapters at pipe, valve, or component connections for proper orientation of fitting.
   m. Keep tubing and conduit runs at least 12 inches from hot pipes.
   n. Locate and install tubing raceways in accordance with manufacturer's recommendations. Locate tubing to prevent spillage, overflow, or dirt from above.
   o. Securely attach tubing raceways to building structural members.
6. Enclosure Lifting Rings: Remove rings following installation and plug holes.

D. Removal or Relocation of Materials and Equipment:

1. Remove from Site materials that were part of the existing facility but are no longer used, unless otherwise directed by Engineer to deliver to Owner.
2. Repair affected surfaces to conform to type, quality, and finish of surrounding surface.

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3.03 FIELD FINISHING

A. Refer to Section 09 90 00, Painting and Coating.

3.04 FIELD QUALITY CONTROL

A. Startup and Testing Team:

1. Thoroughly inspect installation, termination, and adjustment for components and systems.
2. Complete onsite tests.
3. Complete onsite training.
4. Provide startup assistance.

B. Operational Readiness Inspections and Calibrations: Prior to startup, inspect and test to ensure that entire PIC is ready for operation.

1. Loop/Component Inspections and Calibrations:
   a. Check PIC for proper installation, calibration, and adjustment on a loop-by-loop and component-by-component basis.
   b. Prepare component calibration sheet for each active component (except simple hand switches, lights, gauges, and similar items).
      1) Project name.
      2) Loop number.
      3) Component tag number.
      4) Component code number.
      5) Manufacturer for elements.
      6) Model number/serial number.
      7) Summary of functional requirements, for example:
         a) Indicators and recorders, scale and chart ranges.
         b) Transmitters/converters, input and output ranges.
         c) Computing elements' function.
         d) Controllers, action (direct/reverse) and control modes (PID).
         e) Switching elements, unit range, differential (fixed/adjustable), reset (auto/manual).
      8) Calibrations, for example:
         a) Analog Devices: Actual inputs and outputs at 0, 10, 50, and 100 percent of span, rising and falling.
         b) Discrete Devices: Actual trip points and reset points.
         c) Controllers: Mode settings (PID).
      9) Space for comments.

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c. These inspections and calibrations [do not require witnessing.] [will be spot checked by Engineer.]

2. Leak Test: In accordance with Section 40 80 01, Process Piping Leakage Testing.

C. Performance Acceptance Tests (PAT): These are the activities that Section 01 91 14, Equipment Testing and Facility Startup, refers to as Performance Testing.

1. General:
   a. Test all PIC elements to demonstrate that PIC satisfies all requirements.
   b. Test Format: Cause and effect.
      1) Person conducting test initiates an input (cause).
      2) Specific test requirement is satisfied if correct result (effect) occurs.
   c. Procedures, Forms, and Checklists:
      1) Conduct tests in accordance with, and documented on, Engineer accepted procedures, forms, and checklists.
      2) Describe each test item to be performed.
      3) Have space after each test item description for sign off by appropriate party after satisfactory completion.
   d. Required Test Documentation: Test procedures, forms, and checklists. All signed by Engineer and Contractor.
   e. Conducting Tests:
      1) Provide special testing materials, equipment, and software.
      2) Wherever possible, perform tests using actual process variables, equipment, and data.
      3) If it is not practical to test with real process variables, equipment, and data, provide suitable means of simulation.
      4) Define simulation techniques in test procedures.
   f. Coordinate PIC testing with Owner and affected Subcontractors.
      1) Excessive Test Witnessing: Refer to Supplementary Conditions.
2. Test Requirements:
   a. Once facility has been started up and is operating, perform a witnessed PAT on complete PIC to demonstrate that it is operating as required. Demonstrate each required function on a paragraph-by-paragraph and loop-by-loop basis.
   b. Perform local and manual tests for each loop before proceeding to remote and automatic modes.
   c. Where possible, verify test results using visual confirmation of process equipment and actual process variable. Unless otherwise

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directed, exercise and observe devices supplied by others, as needed to verify correct signals to and from such devices and to confirm overall system functionality. Test verification by means of disconnecting wires or measuring signal levels is acceptable only where direct operation of plant equipment is not possible.

d. Make updated versions of documentation required for PAT available to Engineer at Site, both before and during tests.
e. Make one copy of O&M manuals available to Engineer at the Site both before and during testing.
f. Refer to referenced examples of PAT procedures and forms in Article Supplements.

3.05 MANUFACTURER'S SERVICES

A. Specialty Equipment: For following equipment, provide the services of a qualified manufacturer's representative during installation, startup, and demonstration testing and Owner training. Provide original equipment manufacturer's services for two days.

3.06 TRAINING

A. General:

1. Provide an integrated training program to meet specific needs of Owner's personnel.
2. Include training sessions, classroom and field, for managers, engineers, operators, and maintenance personnel.
3. Provide instruction on two working shift(s) as needed to accommodate the Owner's personnel schedule.
4. Owner reserves the right to make and reuse video tapes of training sessions.

B. Operations and Maintenance Training:

1. Include a review of O&M manuals and survey of spares, expendables, and test equipment.
2. Use equipment similar to that provided or currently owned by Owner.
3. Provide training suitable for instrument technicians with at least a 2-year associate engineering or technical degree, or equivalent education and experience in electronics or instrumentation.

C. Operations Training:

1. Training Session Duration: Five 8-hour instructor days.
2. Number of Training Sessions: Two

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3. Location: Site.
4. Content: Conduct training on loop-by-loop basis.
    a. Loop Functions: Understanding of loop functions, including interlocks for each loop.
    b. Loop Operation: For example, adjusting process variable setpoints, AUTO/MANUAL control transfer, AUTO and MANUAL control, annunciator acknowledgement and resetting.
    c. Interfaces with other control systems.

D. Maintenance Training:

E. Training Session Duration: Five 8-hour instructor days.

1. Number of Training Sessions: Two
2. Location: Project Site.
3. Content: Provide training for each type of component and function provided.
    a. Loop Functions: Understanding details of each loop and how they function.
    b. Component calibration.
    c. Adjustments: For example, controller tuning constants, current switch trip points, and similar items.
    d. Troubleshooting and diagnosis for components.
    e. Replacing lamps, chart paper, fuses.
    f. Component removal and replacement.
    g. Periodic maintenance.

3.07 CLEANING/ADJUSTING

B. Repair affected surfaces to conform to type, quality, and finish of surrounding surface.

C. Cleaning:
1. Prior to closing system using tubing, clear tubing of interior moisture and debris.
2. Upon completion of Work, remove materials, scraps, and debris from interior and exterior of equipment.

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3.08 PROTECTION

A. Protect enclosures and other equipment containing electrical, instrumentation and control devices, including spare parts, from corrosion through the use of corrosion-inhibiting vapor capsules.

B. Periodically replace capsules in accordance with capsule manufacturer's recommendations. Replace capsules just prior to Final Payment and Acceptance.

3.09 SUPPLEMENTS

A. Supplements listed below, following "End of Section," are part of this Specification.

1. Component Specifications.
2. Data Sheets.
3. Instrument List.
4. Loop Specifications.
5. PLC Input and Output List.
6. Instrument Calibration Sheet: Provides detailed information on each instrument (except simple hand switches, lights, and similar items).
7. I&C Valve Adjustment Sheet: Each sheet shows detailed information for installation, adjustment, and calibration of a given valve.
8. Performance Acceptance Test Sheet: Describes the PAT for a given loop. The format is mostly free form.
    a. Lists the requirements of the loop.
    b. Briefly describes the test.
    c. Cites expected results.
    d. Provides space for check off by witness.

END OF SECTION

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SUPPLEMENTAL PARAGRAPHS

ELECTRICAL TRANSIENT PROTECTION

A. General:

1. Function: Protect elements of PIC against damage due to electrical transients induced in interconnecting lines by lightning and nearby electrical systems.
2. Implementation: Provide, install, coordinate, and inspect grounding of surge suppressors at:
    a. Connection of ac power to PIC equipment including panels, consoles assembles, and field mounted analog transmitters and receivers.
    b. At the field and panel, console, or assembly connection of signal circuits that have portions of the circuit extending outside of a protective building.
3. Construction: First-stage high energy metal oxide varistor and second-stage bipolar silicon avalanche device separated by series impedance. Includes grounding wire, stud, or terminal.
4. Response: 5 nanoseconds maximum.
5. Recovery: Automatic.
6. Temperature Range: Minus 20 degrees C to plus 85 degrees C.

B. Suppressors on 120V ac Power Supply Connections:

1. Occurrences: Tested and rated for a minimum of 50 occurrences of IEEE 587 Category B test waveform.
2. First-Stage Clamping Voltage: 350 volts or less.
3. Second-Stage Clamping Voltage: 210 volts or less.
4. Continuous Operation: Power supplies for one four-wire transmitter or receiver: 5 amps minimum at 130V ac. All other applications: 30 amps minimum at 130V ac.

C. Suppressors on Analog Signal Lines:

1. Test Waveform: Linear 8 microsecond rise in current form 0 amp to a peak current value followed by an exponential decay of current reaching one half the peak value in 20 microseconds.
2. Surge Rating: Tested and rated for 50 occurrences of 2,000-amp peak test waveform.
    a. dc Clamping Voltage: 20 to 40 percent above operating voltage for circuit.

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b. dc Clamping Voltage Tolerance: Less than plus or minus 10 percent.
a. Maximum Loop Resistance: 18 ohms per conductor.

D. Physical Characteristics:
1. Mounted in Enclosures: Encapsulated inflame retardant epoxy.
2. For Analog Signals Lines: EDCO PC-642 or SRA-64 series.
3. For 120V ac Lines: EDCO HSP-121.
4. Field Mounted at Two-Wire Instruments: Encapsulated in stainless steel pipe nipples. EDCO SS64 series.
5. Field Mounted at Four-Wire Instruments: With 120V ac outlet, ac circuit breaker, and 10-ohm resistors on signal lines, all in enclosure.
a. Enclosure: NEMA 4X fiberglass or Type 316 stainless steel with door.
1) Maximum Size: 12 inches by 12 inches by 8 inches deep.
b. Manufacturer and Product: EDCO; SLAC series.

E. Installation and Grounding of Suppressors: As shown. See Surge Suppressor Installation Details. Grounding equipment, installation of grounding equipment, and terminations for field mounted devices are provided under Division 26, Electrical.

END OF SUPPLEMENTAL PARAGRAPHS
(Example Supplements follow)

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EXAMPLE INSTRUMENT LIST

Tag Number	Comp Code	Component Title	Options	P&ID	Inst. Detail	Mech/Elec	Panel Number
QL-2-51(12)[00]	M49	Selector Switch & Indicator Light Combination	None	17-I-10			FP-4-50
FIT-3-51(2) FE-3-51(2)	F20	Flow Element & Transmitter, Flume or Weir, Ultrasonic	Range: 0 to 60 mgd; Weir Size: 4 feet	17-I-10	717	6-S-4 16-E-24	
LI-3-52(2)	S10	Indicator, Switchboard	Range: 0 to 16.5 feet edgewise	17-I-10			FP-4-90
LSL-3-53(2)	L99	Level Switch, Encapsulated	Setpoint: Elev 425.5	17-I-10		16-E-24	
FIC-3-54(2)	S4	Controller, CAM, Electronic	Range: 0 to 60 mgd	17-I-10			FP-4-90
FIT-3-54(2) FE-3-54(2)	F4	Flow Element & Transmitter, Electromagnetic	Range: 0 to 60 mgd; Pipe Size: 48-inch; Scale: 0 to 60 mgd	17-I-10	701	16-E-34	
LSHH-3-58(2)	L8	Level Switch, Float Type with Integral Switch	Setpoint: Elev 403.0	17-I-10	702	16-E-34	

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EXAMPLE LOOP SPECIFICATION

LOOP 14-5-AERATION BLOWERS FLOW CONTROLS

Functions: Monitor and control the existing blower and provide the following:

1. Compute square root of each flow signal at FP-04-4.
2. Compute sum of square root signals at FP-04-4.
3. Indicate total flow at FP-04-4.
4. Send inlet vane position to FP-14(3).
5. Send blower airflow analog signals to DCU-04.
6. Receive blower airflow setpoint signals from DCU-04
7. Provide PID flow control of blowers based on local setpoint at FP04-4 or remote setpoint from DCU-04.

Provide the following two control modes for blowers M-14-1(3). Allow these control modes to be selected for all blowers at the same time.

Manual: Provide for manual adjustment of blower airflow setpoint. Setpoint Range: 0 to 200 kcfm. Initial Setting: 10 kcfm.

Auto: DO Control:

1. Ratio control for plant influent flow FIT-02-3. Adjustable Ratio Range: 0 to 2 kcfm/mgd; Initial Setting: 0.5 kcfm/mgd.
2. PID control for aeration tank DO. DO Setpoint Range: 0 to 12 mg/L; Initial Setting: 2 mg/L.
3. DO selectable from any of one of the six tanks, AIT-04-4(6)(4), or the average from all six tanks, one per tank.
4. Compute Aeration Tank Airflow demand as the product of the Ration control output and the PIC control output when the PID control is enabled.

Alarm for the following conditions:

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1. Too Many Blowers On: One blower is on and the inlet guide vane position ZT-14-2(3) is more than 98 percent for more than 5 seconds.

2. Too Few Blowers On: Two blowers are on and the inlet guide vane position ZT-14-2(3) is less than 22 percent form more than 5 seconds.

Components

FY-14-5(3)[SQ ROOT]	S3	COMPUTING RELAY, SQUARE ROOT
FY-14-5[SUM]	S1	COMPUTING RELAY, ADD/SUBTRACT Function: Add
FI-14-5	S10	INDICATOR, SWITCHBOARD Scale: Edgewise Scale Range: 0 to 50 kcfm
FIC-14-5	S6	CONTROLLER, ELECTRONIC Control Type: PIC Control Action: Reverse PV Range: 0 to 20 kcfm Setpoint: 10 kcfm

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CH2M HILL INSTRUMENT CALIBRATION SHEET Rev.06.05.92

COMPONENT	MANUFACTURER	PROJECT
Code:	Name:	Number:
Name:	Model:	Name:
	Serial #:	

FUNCTIONS

	RANGE	VALUE	UNITS	COMPUTING FUNCTIONS? Y / N	CONTROL? Y / N
Indicate? Y / N	Chart:			Describe:	Action? direct / reverse Modes? P / I / D
Record? Y / N	Scale:				SWITCH? Y / N Unit Range:
Transmit/	Input:				Differential: fixed/adjustable
Convert? Y / N	Output:				Reset? automatic / manual

ANALOG CALIBRATIONS							DISCRETE CALIBRATIONS					Note
REQUIRED			AS CALIBRATED				REQUIRED			AS CALIBRATED		No.
Input	Indicated	Output	Increasing Input		Decreasing Input		Number	Trip Point	Reset Pt.	Trip Point	Reset Pt.	
			Indicated	Output	Indicated	Output		(note rising or falling)		(note rising or falling)		
							1.					
							2.					
							3.					
							4.					
CONTROL MODE SETTINGS:			P:	I:	D:		5.					

#	NOTES:	Component Calibrated and Ready for Startup
		By:
		Date:

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		Tag No.:

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CH2M HILL **INSTRUMENT CALIBRATION SHEET** Rev.06.05.92
EXAMPLE - ANALYZER/TRANSMITTER

COMPONENT	**MANUFACTURER**	**PROJECT**
Code: *A7*	Name: *Leeds & Northrup*	Number: *WDC30715.B2*
Name: *pH Element & Analyzer/Transmitter*	Model: *12429-3-2-1-7*	Name: *UOSA AWT PHASE 3*
	Serial #: *11553322*	

FUNCTIONS

	RANGE	VALUE	UNITS	COMPUTING FUNCTIONS? N	CONTROL? N
Indicate? Y Record? N	Chart:			Describe:	Action? direct / reverse Modes? P / I / D
	Scale:	*1-14*	*pH units*		SWITCH? N Unit Range:
Transmit/	Input:	*1-14*	*pH units*		Differential: fixed/adjustable
Convert? Y	Output:	*4-20*	*mA dc*		Reset? automatic / manual

ANALOG CALIBRATIONS

REQUIRED			AS CALIBRATED			
Input	Indicated	Output	Increasing Input		Decreasing Input	
			Indicated	Output	Indicated	Output
1.0	*1.0*	*4.0*	*1.0*	*4.0*	*1.0*	*3.9*
2.3	*2.3*	*5.6*	*2.2*	*5.5*	*2.3*	*5.6*
7.5	*7.5*	*12.0*	*7.5*	*11.9*	*7.5*	*12.0*
12.7	*12.7*	*18.4*	*12.7*	*18.3*	*12.6*	*18.3*
14.0	*14.0*	*20.0*	*14.0*	*20.0*	*14.0*	*20.0*
CONTROL MODE SETTINGS:			P: *N.A.*	I:	D:	

DISCRETE CALIBRATIONS

REQUIRED			AS CALIBRATED	
Number	Trip Point	Reset Pt.	Trip Point	Reset Pt.
	(note rising or falling)		(note rising or falling)	
1.	*N.A.*		*N.A.*	
2.				
3.				
4.				
5.				
6.				

Note

No

1.

#	**NOTES:**
	1. Need to recheck low pH calibration solutions.

Component Calibrated and Ready for Startup

By: *J.D. Sewell*

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		Date: *Jun-6-92*
		Tag No.: AIT-12-6[pH]

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CH2M HILL I&C VALVE ADJUSTMENT SHEET Rev.06.05.92

PARTS	Project Name:	Project Number:
Body	Type:	Mfr:
	Size:	Model:
	Line Connection:	Serial #:
Operator	Type:	Mfr:
	Action:	Model:
	Travel:	Serial #:
Positioner	Input Signal:	Mfr:
	Action:	Model:
	Cam:	Serial #:
Pilot	Action:	Mfr:
Solenoid	Rating:	Model:
		Serial #:
I/P	Input:	Mfr:
Converter	Output:	Model:
	Action:	Serial #:
Position	Settings:	Mfr:
Switch	Contacts:	Model:
		Serial #:
Power	Type:	Air Set Mfr:
Supply	Potential:	Model:
		Serial #:

ADJUSTMENTS	Initial	Date	**VERIFICATION**	Initial	Date
Air Set			Valve Action		
Positioner			Installation		
Position Switches			Wire Connection		
I/P Converter			Tube Connection		
Actual Speed					

REMARKS:	**Valve Ready for Startup**
	By:
	Date:
	Tag No.:

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CH2M HILL I&C VALVE ADJUSTMENT SHEET Rev.06.05.92 *EXAMPLE*

PARTS	Project Name: *SFO SEWPCP*	Project Number: *SFO10145.G2*
Body	Type: *Vee-Ball*	Mfr: *Fisher Controls*
	Size: *4-inch*	Model: *1049763-2*
	Line Connection: *159 # ANSI Flanges*	Serial #: *1003220*
Operator	Type: *Pneumatic Diaphragm*	Mfr: *Fisher Controls*
	Action: *Linear - Modulated*	Model: *4060D*
	Travel: *3-inch*	Serial #: *2007330*
Positioner	Input Signal: *3-15 psi*	Mfr: *Fisher Controls*
	Action: *Direct - air to open*	Model: *20472T*
	Cam: *Equal percentage*	Serial #: *102010*
Pilot Solenoid	Action:	Mfr:
	Rating: *None*	Model:
		Serial #:
I/P Converter	Input: *4-20 mA dc*	Mfr: *Taylor*
	Output: *3-15 psi*	Model: *10-T-576-3*
	Action: *Direct*	Serial #: *1057-330*
Position Switch	Settings: *Closed / Open 5 deg, rising*	Mfr: *National Switch*
	Contacts: *Close / Close*	Model: *1049-67-3*
		Serial #: *156 &157*
Power Supply	Type: *Pneumatic*	Air Set Mfr: *Air Products*
	Potential: *40 psi*	Model: *3210D*
		Serial #: *1107063*

ADJUSTMENTS	Initial	Date	**VERIFICATION**	Initial	Date
Air Set	*JDS*	*Jun-06-92*	Valve Action	*JDS*	*Jun-03-92*
Positioner	*JDS*	*Jun-06-92*	Installation	*JDS*	*Jun-03-92*
Position Switches	*JDS*	*Jun-06-92*	Wire Connection	*JDS*	*Jun-04-92*
I/P Converter	*JDS*	*Jun-07-92*	Tube Connection	*JDS*	*Jun-04-92*
Actual Speed	*JDS*	*Jun-07-92*			

REMARKS: *Valve was initially installed backwards.*	**Valve Ready for Startup**
Observed to be correctly installed May-25-92	By: *J.D. Sewell*
	Date: *Jun-07-92*
	Tag No.: *FCV-10-2-1*

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CH2M HILL PERFORMANCE ACCEPTANCE TEST SHEET Rev.06.05.92

Project Name:	Project No.:
Demonstration Test(s): For each functional requirement of the loop: (a) List and number the requirement. (b) Briefly describe the demonstration test. (c) Cite the results that will verify the required performance. (d) Provide space for signoff.	

Forms/Sheets Verified	By	Date	**Loop Accepted By Owner**
Loop Status Report			By:
Instrument Calibration Sheet			Date:
I&C Valve Calibration Sheet			
Performance Acceptance Test	By	Date	
Performed			
Witnessed			Loop No.:

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CH2M HILL PERFORMANCE ACCEPTANCE TEST SHEET **Rev.06.05.92**
EXAMPLE

Project Name: *SFO SEWPCP Plant Expansion*				Project No.: *SFO12345.C1*
Demonstration Test(s): For each functional requirement of the loop: (a) List and number the requirement. (b) Briefly describe the demonstration test. (c) Cite the results that will verify the required performance. (d) Provide space for signoff.				
1. MEASURE EFFLUENT FLOW				
1.a With no flow, water level over weir should be zero and				
FIT indicator should read zero. Jun-20-92 BDG				
2. FLOW INDICATION AND TRANSMISSION TO LP & CCS				
With flow, water level and FIT indicator should be related by expression				
*Q(MGD) = 429*H**(2/3) (H = height in inches of water over weir).*				
Vary H and observe that following.				
2.a Reading of FIT indicator. Jun-6-92 BDG				
2.b Reading is transmitted to FI on LP-521-1. Jun-6-92 BDG				
2.c Reading is transmitted and displayed to CCS. Jun-6-92 BDG				
H(measured)	*0*	*5*	*10*	*15*
Q(computed)	*0*	*47.96*	*135.7*	*251.7*
Q(FIT indicator)	*0*	*48.1*	*137*	*253*
Q(LI on LP-521-1)	*0*	*48.2*	*138*	*254*
Q(display by CCS)	*0*	*48.1*	*136.2*	*252.4*

Forms/Sheets Verified	By	Date	**Loop Accepted By Owner**
Loop Status Report	*J.D. Sewell*	*May-18-92*	By: *J.D. Smith*
Instrument Calibration Sheet	*J.D. Sewell*	*May-18-92*	Date: *Jun-6-92*
I&C Valve Calibration Sheet	*N.A.*		
Performance Acceptance Test	By	Date	
Performed	*J. Blow MPSDC Co.*	*Jun-6-92*	
Witnessed	*B.deGlanville*	*Jun-6-92*	Loop No.: *30-12*

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CONTROL VALVE DATA SHEET

CH2MHILL

PROJECT TOPOCK 60% DEISGN
UNIT FRESHWATER INJECTION
WELL, FW-001
P.O.
ITEM 1
CONTRACT 435062

DATA SHEET 1 OF 1
SPEC
TAG **FCV-014**
DWG CH-I-XXX-0201AD.dwg
SERVICE Freshwater

1 Fluid: Water

SERVICE CONDITIONS

	Units	Max Flow	Norm Flow	Min Flow	Shutoff	
Flow Rate	gpm	**400**		**200**	**0**	
Inlet Pressure	psig	**Note 4**		**Note 4**	**5**	
Outlet Pressure	psig	**119**		**119**	**0**	
Inlet Temperature	°F	**86**		**86**		
Spec Wt/Spec Grav/Mol Wt		**1**		1	--	
Viscosity/Spec Heats Ratio		**1**		1	--	
Vapor Pressure P_v		**.13mmHg**		**.13mmHg**	--	
*Required C_v		**5.46**		**0.22**	--	
*Travel	%	**85**		**20**	**0**	
Allowable/*Predicted SPL	dBA	/	/	/	--	

LINE

Pipe Line Size & Schedule: In **4 inch Sch 80 PVC**; Out **6 inch Sch. 80 PVC**
Pipe Line Insulation None

VALVE BODY/BONNET

*Type **Downhole Flow**
*Size **4 inch** **ANSI Class 150**
Max Press/Temp **150 psig/130 deg F**
*Mfr & Model: **ASR or 3R**
*Body/Bonnet Matl **Stainless Steel**
*Liner Material/ID
End Connection: In **150 lb flange**; Out **150 lb flange**
Fig Face Finish
End Ext/Matl
*Flow Direction Bidirectional
*Type of Bonnet
Lub & ISO Valve Lube
*Packing Material Manufac Standard
Packing Type

TRIM

*Type
*Size Rated Travel
*Characteristic: **Equal Percentage**
*Balanced/Unbalanced
Rated C_V **10.5** F_L X_T
*Plug/Ball/Disk Material: **PVC**
*Seat Material
*Cage/Guide Material
*Stem Material**: SS Shaft**

SPECIALS/ACCESSORIES

1. 4-20 mA position feedback transmitter

ACTUATOR

*Type **Hydraulically Operated**
*Mfr & Model: Food Grade Oil/**GE or equivalent**
*Size Eff Area
On/Off Modulating
Spring Action Open/Close **Fail Closed**
*Max Allowable Pressure
*Min Required Pressure
Available Air Supply Pressure: N/A
Max Min
Material: /
Actuator Action:
Handwheel Type **None**
Air Failure Valve **None** Set at

POSITIONER

Input Signal: **4-20 mA**
*Type
*Mfr & Model **ASR or 3R**
*On **Incr Signal** Output: **Valve Opens**
Gauges Bypass
*Cam Characteristic

SWITCHES

Type Quantity
*Mfr & Model
Contacts/Rating
Actuation Points

AIR SET

*Mfr & Model :
*Set Pressure
Filter: Gauge :

TESTS

*Hydro Pressure
ANSI/FCI Leakage Class

Rev	Date	Revision	Orig	App
A	07/18/2011	IFR		

Notes:
*Information supplied by manufacturer unless already specified.
Note 1: This is a down hole flow and pressure control valve used is ASR wells located in a single pipe with bi-directional flow for injection and recovery.
Note 2: Well ID is 14" and valve will be in inline with a submersible pump.
Note 3: Well is 353' deep and will receive up to 200 gpm (injection) and 400 gpm nominal during recovery during backwashing.
Note 4: Column pressure is from gravity flow into well
Note5: Provide PLC and instrumentation as alternative.

CONTROL VALVE DATA SHEET

CH2MHILL

PROJECT TOPOCK 60% DEISGN
UNIT FRESHWATER INJECTION
WELL, FW-002
P.O.
ITEM 1
CONTRACT 435062

DATA SHEET 1 OF 1
SPEC
TAG **FCV-015**
DWG CH-I-XXX-0201AD.dwg
SERVICE Freshwater

Fluid: Water

SERVICE CONDITIONS

	Units	Max Flow	Norm Flow	Min Flow	Shutoff	
Flow Rate	gpm	**200**		**100**	**0**	
Inlet Pressure	psig	**Note 4**		**Note 4**	**5**	
Outlet Pressure	psig	**88**		**88**	**0**	
Inlet Temperature	°F	**86**		**86**		
Spec Wt/Spec Grav/Mol Wt		**1**		1	--	
Viscosity/Spec Heats Ratio		**1**		1	--	
Vapor Pressure P_v		**.13mmHg**		**.13mmHg**	--	
*Required C_v		**5.46**		**0.22**	--	
*Travel	%	**85**		**20**	**0**	
Allowable/*Predicted SPL	dBA	/	/	/	--	

LINE

Pipe Line Size & Schedule: In **2 inch Sch 80 PVC**; Out **2 inch Sch. 80 PVC**
Pipe Line Insulation None

VALVE BODY/BONNET

*Type **Downhole Flow**
*Size ***** inch** **ANSI Class 150**
Max Press/Temp **150 psig/130 deg F**
*Mfr & Model: **ASR or 3R**
*Body/Bonnet Matl **Stainless Steel**
*Liner Material/ID
End Connection: In **150 lb flange**; Out **150 lb flange**
Fig Face Finish
End Ext/Matl
*Flow Direction Bidirectional
*Type of Bonnet
Lub & ISO Valve Lube
*Packing Material Manufac Standard
Packing Type

TRIM

*Type
*Size Rated Travel
*Characteristic: **Equal Percentage**
*Balanced/Unbalanced
Rated C_V **10.5** F_L X_T
*Plug/Ball/Disk Material: **PVC**
*Seat Material
*Cage/Guide Material
*Stem Material**: SS Shaft**

SPECIALS/ACCESSORIES

1. 4-20 mA position feedback transmitter

ACTUATOR

*Type **Hydraulically Operated**
*Mfr & Model: Food Grade Oil/**GE or equivalent**
*Size Eff Area
On/Off Modulating
Spring Action Open/Close **Fail Closed**
*Max Allowable Pressure
*Min Required Pressure
Available Air Supply Pressure: N/A
Max Min
Material: /
Actuator Action:
Handwheel Type **None**
Air Failure Valve **None** Set at

POSITIONER

Input Signal: **4-20 mA**
*Type
*Mfr & Model **ASR or 3R**
*On **Incr Signal** Output: **Valve Opens**
Gauges Bypass
*Cam Characteristic

SWITCHES

Type Quantity
*Mfr & Model
Contacts/Rating
Actuation Points

AIR SET

*Mfr & Model :
*Set Pressure
Filter: Gauge :

TESTS

*Hydro Pressure
ANSI/FCI Leakage Class

Rev	Date	Revision	Orig	App
A	07/18/2011	IFR		

Notes:
*Information supplied by manufacturer unless already specified.
Note 1: This is a down hole flow and pressure control valve used is ASR wells located in a single pipe with bi-directional flow for injection and recovery.
Note 2: Well is 139’ deep and ID is 14” and valve will be in inline with a submersible pump.
Note 3: Provide PLC and instrumentation as alternative.
Note 4: Column pressure is from gravity flow into well
.

SECTION 40 91 02.01
I&C (PART 2) ANALYTICAL MEASUREMENT SAMPLE COMPONENTS

PART 1 - GENERAL

1.01 COMPONENT SPECIFICATIONS

A. A103 Conductivity Analyzer, Hot Tap Sensor:

1. General:
   a. Function: Measure, indicate, and transmit conductivity of noted process liquid.
   b. Sensor Type: Electrode that is line-mounted and is retractable under line pressure.
   c. Transmitter Type: Four-wire.
   d. Parts: Element, ball valve, transmitter, interconnecting cable, junction box (if specified), ancillaries and expendables.
2. Performance:
   a. Process Liquid: As noted.
   b. Process Range: As noted.
   c. Accuracy: Plus or minus 0.5 percent of measured range.
   d. Maximum Operating Pressure: 200 psig.
   e. Maximum Retraction Pressure: 64 psig.
   f. Process Temperature Range: 0 degrees C to 100 degrees C.
   g. Transmitter Temperature Range: 0 degrees C to 50 degrees C (32 degrees F to 122 degrees F).
3. Features: Temperature Compensation: Automatic thermo compensator for process liquid temperatures 0 degrees C to 200 degrees C.
4. Element:
   a. Type: Retractable Electrode.
   b. Electrode Material: Titanium, unless otherwise noted.
   c. Type 316 stainless steel sensor tube.
   d. Other Wetted Parts: PEEK, EPDM, Graphite, Neoprene; manufacturer to confirm compatibility with process liquid.
   e. Probe Constant: As noted.
   f. Insertion Length: Compatible with main process pipe.
   g. Process Connection: Fits within a 1-1/4-inch NTP full port Type 316 stainless steel valve.
   h. Accessories: 1-1/4-inch NPT full port Type 316 stainless steel ball valve and ancillaries.

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i. Mounting Hardware: As recommended by manufacturer for specific application and/or as shown on Drawings.

5. Transmitter:
   a. Type: Four-wire, unless otherwise noted.
   b. Features:
      1) Indicator: LCD digital display.
      2) Scale Range: As noted.
      3) Contact Setpoint: Setpoint adjustable from 0 percent to 100 percent of full range, initial setting as noted.
   c. Signal Interface:
      1) Output: Isolated 4 to 20 mA dc for load impedance 0 ohms to 500 ohms minimum for 24V dc supply without load adjustments.
      2) Digital communications: As noted.
      3) Contacts:
         a) When noted, SPST rated 3A continuous at 120V ac, minimum.
         b) Setpoint, as noted.
   d. Enclosure:
      1) Type: NEMA 4X.
      2) Mounting:
         a) Wall, unless otherwise noted.
         b) Provide applicable accessories and kits to support specified mounting.
   e. Power: Four-wire: 115V ac, unless otherwise noted.
6. Cable: Length as required to accommodate device locations.
7. Junction Box (weather proof): If noted.
8. Expendables (for each unit provided): One 16-ounce bottle of 2,000 microS/cm conductivity standardizing solution if appropriate for noted range.
9. Manufacturer: Rosemount Analytical: Model 402 sensor and Model 54eC transmitter.

B. A116 Turbidity Element and Transmitter:

1. General:
   a. Function: Continuously measure, indicate and transmit a signal proportional to turbidity of a sample stream of process fluid.
   b. Type: Light scatter detection measurement using a 90-degree scatter photocell detector.
   c. Parts: Element, transmitter, power supply, interconnecting cable, mounting hardware, and expendables.

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2. Performance:
   a. Range: 0 to 100 NTU.
   b. Resolution: 0.0001 NTU.
   c. Repeatability: Plus or minus 1.0 percent or plus or minus 0.002 NTU, whichever is greater.
   d. Response Time:
      1) Initial Response: Within 75 seconds with internal bubble trap.
      2) Varies with flow rate.
   e. Required Flow: 250 to 750 ml per minute.
   f. Sample Fluid Temperature: 0 to 50 degrees C.
   g. Operating Temperature: 0 to 40 degrees C.
   h. Operating Humidity: 5 to 95 percent, noncondensing.
   i. Accuracy:
      1) From 0 to 40 NTU: Plus or minus 2 percent of reading or plus or minus 0.02 NTU, whichever is greater.
      2) From 40 to 100 NTU, plus or minus 5 percent of reading.
3. Element:
   a. General: Flow-through body using focused light and photodetector cell to measure 90-degree scattered light within the fluid.
   b. Internal bubble trap and vent.
   c. Dimensions: 10 by 13 by 18 inches, nominal.
   d. Fittings:
      1) Sample Inlet: 1/4-inch NPT female compression fitting.
      2) Drain: 1/2-inch NPT female hose barb.
4. Transmitter:
   a. Features:
      1) Indicating Range: 0 to 100 NTU.
      2) Four-digit LCD display.
   b. Enclosure:
      1) NEMA 4X.
      2) Dimensions, Nominal: 9 by 9 by 7 inches.
      3) Mounting: Wall, pole, panel, and floor stand.
   c. Signal Interface:
      1) Analog Output:
         a) 4 to 20 mA dc suitable for load impedance of up to 500 ohms.
         b) Span configurable over any portion of the 0 to 100 NTU range.
      2) Alarm Contacts: Two independent alarm setpoints, each SPDT and rated 5A continuous at 115V ac, minimum. Each setpoint adjustable over full range.

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5. Power Supply:
   a. Input: 95 to 240V ac, 50 to 60 Hz, auto selecting, 40 VA.
   b. Enclosure:
      1) NEMA 4X.
      2) Dimensions, Nominal: 9 by 9 by 7 inches.
   c. Mounting: Wall, pole, panel, and floor stand.
6. Cabling: As required.
7. Expendables:
   a. Calibration Kits:
      1) Stablcal, Foremazin, including two calibration cylinders.
      2) Quantity: One for each unit provided.
   b. Manufacturer and Product: Hach Company; 1720D Turbidimeter with Aqua Trend Interface with Signal Output Module (SOM) and PS1201 Power Supply.

C. A307 pH Element and Transmitter:

1. General:
   a. Function: Measure, indicate, and transmit pH of process fluid.
   b. Type:
      1) Differential electrode measurement using three electrodes.
      2) Digital sensor (element).
   c. Parts: Element, analyzer/transmitter, interconnecting cable, and expendables and noted accessories.
   d. Element:
      1) Body Material: PEEK (plastic), unless otherwise noted.
      2) Body Style: Convertible with 1-inch NPT on both ends, unless otherwise noted.
   e. Electrode Material: Glass, general purpose, unless otherwise noted.
   f. Measuring Range: Minus 2 pH to plus 14 pH.
   g. Sensitivity: Plus or minus 0.01 pH.
   h. Stability: 0.03 pH per 24 hours, noncumulative.
   i. Flow Rate: 10 feet per second, maximum.
   j. Operating Pressure: 100 psig at 158 degrees F.
   k. Built-in temperature element.
   l. Integral Preamplifier: Allows signal transmission up to 300 feet with standard cabling and up to 1,000 feet with a termination box.
   m. Operating Temperature: 23 degrees F to 158 degrees F, unless otherwise noted.
      1) Mounting/Process Connections: As shown on Drawings, or as noted from among the following:
         a) Immersion Mount, Standard:

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(1) 1-inch diameter by 4-foot long pipe and 1-inch by 1-inch coupling in respective material.
(2) CPVC.

2) Flow-through Mount:
a) 1-inch tee: CPVC.
b) Insertion Mount:
(1) 1-1/2-inch ball valve with ancillaries.
(2) CPVC.

3) Analyzer/Transmitter:
a) Features and Performance:
(1) Accommodates two sensors (of same or different types).
(2) Display: Graphic dot matrix, LCD, with LED back lighting.
(3) Operating Temperature: Minus 4 degrees F to plus 104 degrees F.
(4) Operating Humidity: 0 to 95 percent relative humidity, noncondensing.
(5) Control Functions:
b) PID (two independent loops), high/low phasing, setpoint, deadband, overfeed timer, off delay, and on delay.
(1) Menu driven software.

4) Alarms: Low and high pH alarms, and others as noted.
5) Built-in data logger, with capacity to store data at 15-minute intervals for 6 months.

n. Signal Interface:
1) Analog Output: Two isolated 4 to 20 mA dc for load impedance 0 ohms to 500 ohms, unless otherwise noted.
2) Discrete Contacts: Three SPDT rated 5 amp continuous at 120V ac.
3) Digital Communications:
a) RS-232 (MODBUS), suitable for communication with IBM-compatible PC, if noted.
b) RS-485 (MODBUS), suitable for networking, if noted.

o. Enclosure:
1) Type: NEMA 4X.
2) Dimensions: 6 inches by 6 inches by 6 inches, nominal.
3) Mounting: Wall, panel, or pipe (horizontal and vertical).

p. Power: 105V ac to 230V ac, 50/60-Hz.

2. Cable: 33 feet (10 m) standard; Length as required to accommodate device location.

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3. Expendables (for Each Unit Provided):
    a. Chemicals: 1 pint each of buffer solution for pH 4, pH 7, and pH 10.
    b. Salt Bridge: One double junction salt bridge, containing ceramic inner junction, binary fill solution, and O-ring.
    c. Standard Cell Replacement Solution: One container, 500 milliliters pH.
4. Accessories: Sun shield for controller, if noted.
5. Manufacturer and Product: Hach Digital Differential pH Sensor and sc100 Controller.

D. A316 Turbidity Element and Transmitter:

1. General:
    a. Function: Continuously measure, indicate and transmit a signal proportional to turbidity of process fluid sample stream.
    b. Type: Light scatter detection measurement using a 90-degree scatter photocell detector.
    c. Parts: Integral sensor/transmitter, accessories, and expendables.
2. Performance:
    a. Complies with US EPA Method 180.1.
    b. Range:
        1) Process Range: As noted.
        2) Permissible Scale Range: 0 NTU to 100 NTU.
    c. Displayed Resolution: 0.0001 NTU.
    d. Accuracy:
        1) 2 percent of reading or plus or minus 0.015 below 40 NTU.
        2) 5 percent of reading above 40 NTU.
    e. Repeatability: Plus or minus 1 percent of reading.
    f. Response Time: Adjustable, 5 seconds to 500 seconds over 0 NTU to 1,000 NTU.
    g. Required Sample Flow: 0.1 gpm to 1.5 gpm.
    h. Operating Temperature: 32 degrees F to 122 degrees F.
3. Element:
    a. General: Rotational flow through assembly using a cuvette.
    b. Bubble rejection system eliminates need for a bubble trap.
    c. Light Source: White light, 10-year life.
    d. Sample Inlet Pressure: 1 psig to 200 psig; typical operating pressure, 60 psig; built in regulator set at 15 psig.
    e. Fittings:
        1) Sample Inlet: 3/16-inch ID tubing.
        2) Drain: 3/16-inch ID tubing.
4. Transmitter:

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a. Features:
   1) Display: Multi-line custom back-light LCD.
   2) Built-in diagnostics.
   3) Security Code: Prevents unauthorized access.
b. Enclosure:
   1) NEMA 4X/IP66, outdoors.
   2) Mounting: Wall or surface.
c. Signal Interface:
   1) Analog Output: 4 to 20 mA dc galvanic isolated.
      a) Span configurable over any portion of 0 NTU to 100 NTU range.
      b) Output Span: As noted.
   2) Alarm Contacts:
      a) Two high and two low alarms.
      b) Form C, 2 amps at 250V ac.
   3) Digital Communications: RS485; Modbus, HF Simplebus, HF Online Interface.

5. Power Supply: 120V ac/240V ac.
6. Overall Dimensions: 14 inches high by 12 inches wide by 12 inches deep.
7. Accessories and Expendables:
   a. Primary calibration kit.
   b. Desiccant tray-refill.
   c. Automatic Ultrasonic Cleaning System: Required.
8. Manufacturer and Product: HF Scientific; Microtol OnLine Turbidimeter.

E. A407 pH Element and Transmitter:

1. General.
   a. Function: Measure, indicate, and transmit pH of process fluid.
   b. Parts: Element, analyzer/transmitter, interconnecting cable, and noted ancillaries.
2. Performance.
   a. Element:
      1) Range: 0 pH to 14 pH.
      2) Operating Temperature: 32 degrees F to 185 degrees F.
      3) Operating Pressure: 100 psig max at 149 degrees F.
   b. Analyzer/Transmitter:
      1) Range: 0 pH to 14 pH units.
      2) Accuracy: Plus or minus 0.01 pH units.
      3) Repeatability: Plus or minus 0.01 pH units.
      4) Stability: Plus or minus 0.01 pH units per month, noncumulative.

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5) Operating Temperature: Minus 4 degrees F to plus 140 degrees F.
6) Operating Humidity: 0 to 95 percent relative humidity, noncondensing.

3. Element:
   a. Process Connection: 1-inch MNPT.
   b. Connector Cable: Watertight sensor-to-cable connector that eliminates rewiring and cable twisting.
   c. Process Fluid: As noted.
   d. Wetted Materials: Compatible with process fluid.
   e. No field-replaceable parts, unless otherwise noted.
   f. Minimum Conductivity: 100 micro S/cm nominal.
   g. Integral Preamplifier: Required, unless otherwise noted.
   h. Mounting/Process Connections: As shown on Drawings or as noted from among the following:
      1) Submersion:
         a) Sensor handrail assembly.
         b) Handrail mounting kit.
      2) Flow-through:
         a) 3/4-inch NPT tee.
         b) 1-inch NPT tee.
         c) 1-1/2-inch NPT tee.
      3) Low-flow cell assembly.
      4) Insertion.
      5) Hot-tap Retractable:
         a) Suitable for 64-psig line pressure.
         b) 1-inch ball valve kit.
         c) Titanium Tube: 21 inches, 12-inch insertion.
4. Analyzer/Transmitter:
   a. Display: Graphic dot matrix, LCD, with back lighting.
   b. Signal Interface:
      1) Analog Outputs: Two isolated 4 to 20 mA dc outputs (pH and temperature).
      2) Discrete Outputs:
         a) Process Alarms: Three SPST, normally open.
         b) Sensor/Analyzer and Process Fault Alarm: SPDT.
         c) Contact Rating: 120 volts, 5 amps, resistive.
   c. Enclosure.
      1) Type: NEMA 4X.
      2) Dimensions: 6 inches by 6 inches by 6 inches, nominal.
      3) Suitable for panel, 2-inch pipe, or wall mounting.

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4) Suitable for use in Class 1, Div 2, Groups A, B, C, and D environment.

d. Power: 115V ac, 50/60 Hz, unless otherwise noted.

5. Interconnecting Cable: Length as required.
6. Expendables (for each unit provided):
   a. Chemicals: 1 pint each of buffer solution for pH 4, pH 7, and pH 9.
7. Accessories:
   a. Junction Box: If noted.
      1) NEMA 4X box for cable extension.
8. Manufacturer and Product: Rosemount Analytical, Model 399VP (water), Model 396PVP (wastewater), or Model 390RVP (retractable) sensor and Model 54e pH analyzer.

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SECTION 40 91 02.05
I&C LEVEL MEASUREMENT SAMPLE COMPONENTS

PART 1 - GENERAL

1.01 COMPONENT SPECIFICATIONS (CONT'D.)

A. L005PC Level Element and Controller, Ultrasonic, Type P:

1. General:
   a. Functions:
      1) Continuous, noncontacting level measurement.
      2) Pump control.
      3) Others such as volume, differential level, open channel flow measurement, and bar screen control.
   b. Type: Ultrasonic.
   c. Parts: Element, transmitter, interconnecting cable, and accessories as noted.
2. Service:
   a. Application: If and as noted.
   b. Vapor Space Pressure: Atmospheric, unless otherwise noted.
   c. Operating Temperature Range:
      1) Element: Minus 40 degrees F to plus 194 degrees F.
      2) Transmitter: Minus 4 degrees to 120 degrees F.
3. Performance:
   a. Range: As noted.
   b. Zero Reference: As noted.
   c. Accuracy: Plus or minus 0.25 percent of maximum range or 6 mm, whichever is greater.
   d. Resolution: 0.1 percent of range or 2 mm, whichever is greater.
   e. Blanking Distance:
      1) Sensor dependent.
      2) 1 foot for 33 feet of range sensor, typical.
4. Element:
   a. Quantity: One, unless otherwise noted.
   b. NEMA 6P waterproof.
   c. Housing: PBT or PVDF, unless otherwise noted.
   d. Blind Flanges: If and as noted.
   e. Facing: None, unless otherwise noted
   f. Integral Flange: If noted.
      1) Face: PTFE, unless otherwise noted.

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2) Size: As noted.

g. Process Connection:
   1) 1-inch NPT, unless otherwise noted.
   2) Top mounted.

h. Electrical Hazardous Rating:
   1) Class I, Div 1, Groups A, B, C, and D.
   2) Class II, Div 1, Groups E, F, and G.
   3) Intrinsically Safe Approval: If noted.

i. Beam Angle: 3 degrees.

j. Integral temperature compensation.

k. Transmitter:
   1) Mounting: Wall, unless otherwise noted.
   2) Available mounting options include wall, rack, fascia, and panel.

l. Display:
   1) Integral keypad, unless otherwise noted.
   2) Six digits plus 12-character text, plus bargraph with direction indicators.
   3) Eight digit on-board resettable and nonresettable flow totalizers.

m. Enclosure: NEMA 4X polycarbonate, unless otherwise noted.
   1) Available enclosures include wall (NEMA 4X), fascia (NEMA 12), and panel (NEMA 4X).

n. Power Supply: 115V ac, 50/60-Hz, unless otherwise noted.

o. Analog Output:
   1) Isolated 4 mA to 20 mA dc for load impedance of 0 to 750 ohms.
   2) Quantity: One, unless otherwise noted.

p. Digital Communications:
   1) Modbus RTU: If noted.
   2) Profibus dP: If noted.
   3) Ethernet: If noted.

q. Discrete Outputs:
   1) Minimum, five relay (SPDT) rated for 5 amps continuous at 240V ac.
   2) Assignable and as noted.

r. Features:
   1) Programming Security: Password protected.
   2) Data Integrity: Nonvolatile RAM.
   3) RS232 port suitable for programming connection with personal computer.

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4) Resident configurable software to implement the following functions:
   a) Level.
   b) Volume: Preprogrammed tank shapes for accurate volume measurement for inventory control, plus capability to measure unusual shapes.
   c) Pump Control: Control up to five pumps with assigning pumps as fixed, lead/lag, FOFO, ratio, and pump-by-time.
   d) Differential: Uses two transducers for upstream and downstream level measurement across a bar screen. Initiates bar screen operation when preset level differential is exceeded.
   e) Open-Channel Flow: Calculates flow from the measured level using built-in routines based on many flume and weir shapes.

5. Interconnecting Cable: Weatherproof, UV protected, length as required, and type as recommended by manufacturer.
6. Accessories:
   a. Submergence Shield: If noted.
   b. Remote Programming: Standard on rack and panel mount units via infra red communicator.
   c. On-board Programming: Standard on wall and fascia mount unit; includes integral keypad.
   d. Programming Via Personal Computer: If noted, 1 copy of Ultra PC software per lot of controllers furnished.
   e. Aiming Kit: If noted.
      1) Facilitates aiming transducer in solids.
   f. Transducer Mounting Kit: If noted.
      1) Wall or Floor Mount: As noted.
   g. External Temperature Sensor: If noted.
      1) Transmitter input that allows higher accuracy for fast changing air temperature effects.
   h. Data Logging:
      1) Allows reporting and trending of level/flow.
      2) Furnish Data Logging Module and Ultralog Software: If noted.
   i. Tropicalized Circuit Boards (for protection against H2S): If noted.
      1) Others: As noted.
7. Manufacturer and Product: Pulsar Ultra 5 Series and Sensor.

B. L42D Level Element/Transmitter, Submersible, Wastewater, Type D:

1. General:

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a. Function: Measure and transmit signal proportional to level.
b. Type: Totally submersible pressure sensor (loop powered).
c. Parts: Sensor, interconnecting cable, other parts as noted.

2. Service:
   a. Fluid: Wastewater, unless otherwise noted.
3. Performance:
   a. Process Range:
      1) As noted.
      2) Provide fixed factory range such that noted process range is between 40 percent and 80 percent of fixed factory range.
   b. Accuracy: 0.25 percent of full scale.
   c. Temperature, Operating: Minus 5 degrees F to plus 140 degrees F.
   d. Overpressure:
      1) Proof: At least 4.0 times full scale.
4. Features:
   a. Sensor:
      1) Silicon pressure-sensing element.
      2) Titanium Body: 5-year corrosion warranty; replace sensor if it fails due to corrosion.
      3) Measurement Diaphragm:
         a) Internal: Titanium.
         b) External: PTFE-coated nitrile rubber.
            (1) NEMA 6/IP 68 rating (submersible).
            (2) Temperature compensation.
            (3) Dimensions, Nominal:
         c) Diameter: 1.2 inches maximum.
         d) Length: 6 inches maximum.
      4) Loop powered, 9-30V dc.
   b. Interconnecting Cable:
      1) Length: As required.
      2) Polyurethane sheathed, unless otherwise noted.
      3) Kevlar strain relief cord.
      4) Integral vent tube.
   c. Sensor Termination Enclosure: Required, unless otherwise noted.
      1) Enclosure: NEMA 4X.
      2) Houses such noted items as desiccant vent, filter, microfilter.
      3) 2-Inch Pipe Mounting Kit: Required, unless otherwise noted.
   d. Accessories:
      1) Desiccant module.
      2) Spare Desiccant Modules: If noted.
         a) Quantity: As noted.

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3) Cable Hanger, Kellems Type Grip: Required, unless otherwise noted.
4) Lightning Protection:
a) External (protects 4 mA to 20 mA dc output): Required, unless otherwise noted.
5) Anchor Assembly: Required, unless otherwise noted.
a) Marine anchor, clamps, Type 316 stainless steel cable, length at least 3 feet greater than interconnecting cable.

5. Signal Interface: 4 mA to 20 mA dc output, for load impedance of 0 ohm to 750 ohms, minimum for 24V dc supply without load adjustment.
6. Certification(s):
a. Class I, Div 1, Groups A, B, C, and D.
b. Class II, Groups E, F, and G.
c. Class III.
7. Manufacturer and Product: GE Sensing; Druck PTX 1290.

C. L108 Level Switch, Rises on Stem:

1. General:
a. Function: Actuate contact at preset liquid level.
b. Type: Direct acting; rises on stem.
2. Service: Liquid, water, wastewater, unless otherwise noted.
3. Performance:
a. Setpoint as noted.
b. Switch Actuation Point: Approximately one-half distance from end of stem to mounting.
c. Operating Temperature Range: Minus 40 to plus 300 degrees F.
4. Features:
a. Assembly Material: Stainless steel.
b. Float Size: 2-1/8-inch diameter.
5. Mounting: Stem Mount: 1/4-inch NPT.
6. Signal Interface:
a. Switch Type: Magnetic reed switch.
b. Switch Contacts:
1) Isolated, rated at 100 VA.
2) NO or NC (by inverting float on unit stem).
3) Lead Wires: 18 AWG, 24-inch length.
7. Manufacturer and Product: GEMS; Single Station Liquid Level Switch, Model LS-1950.

D. L115 Point Level Switch, Ultrasonic, Corrosive Liquids:

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1. General:
   a. Function: Activate contact(s) at preset liquid level.
   b. Type:
      1) Ultrasonic.
      2) Horizontal or vertical mounting.
2. Performance:
   a. Setpoint: As noted.
   b. Operating Temperature:
      1) Ambient, unless otherwise noted.
      2) Range: Minus 40 degrees F to 160 degrees F.
   c. Operating Pressure:
      1) Ambient, unless otherwise noted.
      2) Rated up to 50 psi.
   d. Repeatability: 1/16-inch.
   e. Response Time: 2 seconds.
   f. RFI Effect: No effect on operating point from a 5-watt field at 27, 150, or 450 MHz.
3. Mounting:
   a. Insertion Length:
      1) As noted.
      2) Insertion length up to 5 feet available.
   b. Orientation:
      1) As noted.
      2) Horizontal or vertical available.
   c. Process Connection:
      1) 1-inch NPT, unless otherwise noted.
      2) Flange mounts available.
4. Housing:
   a. NEMA 1-4X, 5 and 12.
   b. FM approved explosion proof.
5. Power:
   a. 12V ac, unless otherwise noted.
   b. Available are 240V ac or 28V dc.
6. Area Classification:
   a. Groups A, B, C, D Class 1, Div 1 or 2.
   b. Groups E, F, G, Class II, Div 1 or 2.
7. Signal Interface:
   a. DPDT relay.
   b. Contact Ratings: 5 amps resistive and 4.4 amps inductive at 120V ac.
8. Features:
   a. Process Wetted Parts: PFA.

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b. Operating Point: 3/8-inch from tip.
c. Fail-Safe: High or low (field selectable).

9. Manufacturer and Product: Drexelbrook Model 504-1000-6 Point Level PFA Verigap Switch.

E. L118 Level Switch, Float, Nonmercury, Type 1A:

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SECTION 40 91 02.07
I&C PRESSURE MEASUREMENT SAMPLE COMPONENTS

PART 1 - GENERAL

1.01 COMPONENT SPECIFICATIONS

A. P209 Pressure Transmitter, Type 1R:

1. General:
   a. Function: Measure pressure and transmit signal proportional to pressure.
   b. Type:
      1) Electronic variable capacitance.
      2) Two-wire transmitter.
   c. Parts: Transmitter and accessories.
2. Performance:
   a. Range: As noted.
      1) Select transmitter's factory upper range limit (URL) such that upper boundary of noted range is as close as possible to 80 percent of factory URL, but does not exceed it.
   b. Accuracy:
      1) Plus or minus 0.075 percent of span for most gauge pressure factory ranges.
      2) Plus or minus 0.25 percent of span for absolute pressure gauges.
   c. Ambient Operating Temperature: Minus 40 degrees F to plus 185 degrees F, with integral meter.
   d. Process Operating Temperature: Minus 40 degrees F to plus 220 degrees F.
   e. Humidity: 0 to 100 percent relative humidity.
   f. Hazardous Location Certifications:
      1) FM explosion-proof.
      2) Others: As noted.
3. Features:
   a. Type: Gauge pressure, unless otherwise noted.
   b. Adjustable damping.
   c. LCD indicator, unless otherwise noted.Display in percent.
   d. Wetted Metallic Parts:
      1) Type 316 stainless steel, unless otherwise noted.
      2) Includes drain/vent valves; process flanges and adapters, and process isolating diaphragm.
   e. Wetted O-Rings: Viton, unless otherwise noted.

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f. Bolts and Nuts (if required): Type 316 stainless steel, unless otherwise noted.
g. Fill Fluid: Silicone, unless otherwise noted.

4. Process Connections:
   a. Line Size: 1/2 inch.
   b. Connection Type: FNPT.
   c. Direct/remote Diaphragm Seal: If and as noted.
5. Signal Interface:
   a. 4-20 mA dc output with digital signal based on HART protocol, unless otherwise noted below.
      1) Nominal Maximum Loop resistance with External 24V dc Power Supply: 500 ohms.
   b. 4-20 mA dc, no HART Protocol: If noted.
6. Enclosure:
   a. Type: NEMA 4X.
   b. Materials: Coated aluminum, unless otherwise noted.
   c. Mounting bracket, unless otherwise noted.
      1) Bracket and Accessories: Type 316 stainless steel bolts, suitable for mounting transmitter to 2-inch pipe.
7. Accessories: If and as noted.
8. Manufacturers and Products:
   a. Gauge Pressure Units: Rosemount; Model 1151GP.
   b. Absolute Pressure Units: Rosemount; Model 1151AP.

END OF SECTION

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SECTION 40 95 60
TELEMETRY SYSTEM

PART 1 - GENERAL

1.01 SUMMARY

A. Telemetry Subsystem (TS) is part of the overall PIC. This section specifies TS functional requirements for the interface with the; Computer Subsystem (CS); communication links provided by others; and equipment at remote facilities.

B. Telemetry Subsystem consists of the following:

1. Communication Links:
   a. Between the CS and the RTUs.
   b. Between the CS and the remote peripherals.
2. Remote Telemetry Units (RTU).
3. RTU Test Set(s).

C. Configuration of the Telemetry Subsystem as shown on Drawings.

1.02 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. Alliance for Telecommunications for Industry Solutions (ATIS): O5.1, Specifications and Dimensions (for Wood Poles).
2. American Association of State Highway and Transportation Officials (AASHTO):
   a. T99, Standard Method of Test for the Moisture-Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in.) Drop.
   b. T310, Standard Specification for In-place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth).
3. American Wood Preservers Association (AWPA).
4. ASTM International:
   a. D1556, Standard Test Method for Density and Unit Weight of Soil In Place by the Sand-Cone Method.
   b. D2167, Standard Test Method for Density and Unit Weight of Soil In Place by the Rubber-Balloon Method.
   c. D2937, Standard Test Method for Density of Soil In Place by the Drive-Cylinder Method.

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5. Federal Aviation Administration (FAA).
6. Federal Communications Commission (FCC).
7. Institute of Electrical and Electronics Engineers, Inc. (IEEE): C37.90, Standards for Relays and Relay Systems Associated with Electric Power Apparatus.
8. International Society of Automation (ISA): 50-00.01, Compatibility of Analog Signals for Electronic Industrial Process Instruments.
9. National Electrical Manufacturers Association (NEMA): 250, Enclosures for Electrical Equipment (1,000 Volts Maximum).
10. Rural Utilities Service (RUS): Bulletin 1728F-700, Specification for Wood Poles, Stubs, and Anchor Logs.
11. Telecommunications Industry Association/Electronic Industries Association (TIA/EIA):
    a. 222-G, Structural Standards for Steel Antenna Supporting Structure and Antennas.
    b. 222-G-1, Structural Standards for Steel Antenna Towers and Antenna Supporting Structure.
    c. 232, Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange.
    d. 603, Land Mobile FM or PM – Communication Equipment – Measurement and Performance Standards.

1.03 DEFINITIONS

A. Abbreviations:

1. AI: Analog inputs.
2. AO: Analog outputs.
3. DI: Discrete inputs.
4. DO: Discrete outputs.
5. DTMF: Dual tone multiple frequency.
6. FAA: Federal Aviation Administration.
7. FCC: Federal Communication Commission.
8. I/O: Input/output.
9. LED: Light omitting diode.
10. N.C.: Normally open.
11. N.O.: Normally closed.
12. PIC: Process Instrumentation and Control.
13. RTU: Remote Telemetry Units.
14. SCADA: Supervisory control and data acquisition.

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15. SPDT: Single-pole double-throw.
16. TS: Telemetry Subsystem.

B. Article Definitions in Section 40 90 00, Instrumentation and Control for Process Systems, apply to this section.

1.2 SUBMITTALS

A. Action Submittals:
1. Overview Block Diagram: Show major assemblies and interrelationships of the TS and CS, including CS/RTU and CS/Remote Peripheral communication links. Diagram similar in content and format as shown on Drawings. Identify each major assembly with the same name and tag numbers as on Overview Equipment List.
2. Overview Description: Comprehensively describe function, operations, and interrelationship of the TS and CS. Emphasize explanation of overview block diagram in minimum of five 8-1/2-inch by 11-inch pages.
3. CS/RTU Communication Link Definition:
   a. Protocol definition of the following:
      1) Control.
      2) Functions.
      3) Format.
      4) Message security techniques.
      5) Message sequences.
   b. Timing definition of the following:
      1) Station scan timing.
      2) TS data base update timing.
      3) TS output command timing.
4. Radio Communication Link Design:
   a. General: Introduction describing approach used for detail link design and material in Submittal. Include the following:
      1) Radio system block diagram.
      2) Definition of minimum signal level (as measured at receiver input) at both control and repeater stations required for satisfactory system operation (dBuV).
      3) Definition of prediction model used for calculations (for example, Bullington, Longley, Rice).
   b. Repeater Station Data: Design criteria, including a block diagram and the following:
      1) Actual repeater Effective Radiated Power (ERP) stated in dBw.
      2) Type, length, and loss of transmission cable.

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3) Loss through duplexer and receiver multicoupler for both the transmitter and receiver as appropriate.
4) Gain of the repeater antenna.

c. Radio Link Design Criteria: Calculations and support material defining design criteria for [each] [the listed] radio link(s) in the SCADA system. Support each radio link calculation with a path profile that clearly shows terrain and obstructions (major buildings and trees) between the ends of each link, path length, and antenna heights. Plot profile on 4/3 earth radius profile paper. Include the following minimum parameters for each radio link calculation:
1) Transmitter power.
2) Transmission cable type, length, and losses.
3) All other losses (for example, for duplexers, receiver multicouplers, antenna switches, connectors).
4) Type and gain of antennas.
5) Predicted median path loss; separate the path loss into at least free space loss and diffraction loss categories.
6) Predicted median signal level at repeater receiver input.
7) Repeater receiver fade margin.
8) Predicted median signal level at control receiver input.
9) Remote station fade margin.
10) Predicted median link reliability.

5. CS/Remote Peripheral Communication Links Definition: Comprehensive definition of communication protocol and timing. Include a definition for the following:
a. Link control.
b. Formats message security.
c. Effective communication rates.
6. Overview Equipment List: List all TS major assemblies and elements shown in overview block diagram. Include in the list as a minimum:
a. Reference or tag number.
b. Name.
c. Description.
d. Actual equipment manufacturer and model number.
e. Quantity.
7. Descriptive Information: Provide for each element of the TS:
a. Manufacturer’s part and model number with all options clearly defined.
b. Catalog information.
c. Performance specifications.

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d. Functional description.
e. Block diagram.
f. Input/output definitions.
g. Installation dimensions and requirements.

8. Assembly Information: For all specifically manufactured equipment, (such as, RTUs, RTU test set, and RTU printed circuit cards) provide the following in addition to material under subparagraph Descriptive Information:
   a. Assembly drawings.
   b. Schematic diagrams.
   c. Bill of Materials.
   d. Power consumption for nominal and worst case.
9. Interconnecting Wiring Diagrams: Show all assemblies of the TS and interconnecting cable and wiring terminations including terminations to interfacing elements and systems. Number all terminations. Label the terminations for circuits that extend beyond assemblies of the TS with circuit names corresponding to Circuit and Raceway Schedule in Division 26. Refer to Article Sequencing and Scheduling.
10. Installation Details: All modifications and details adequately showing the installation of the TS elements and assemblies.
11. Input/Output List: For each I/O point, list the type of I/O point, point ID number, tag number of source or final control equipment, equipment description, RTU number, RTU terminal identification, and RTU location. I/O list sorted in two ways by the following parameters:
    a. Point type, point ID number.
    b. RTU number, point type, point ID number.
12. Seismic anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Seismic Anchorage and Bracing.

B. Informational Submittals:

1. Seismic anchorage and bracing calculations as required by Section 01 88 15, Seismic Anchorage and Bracing.
2. Owner training plan.
3. Operation and Maintenance Data: As specified in Section 01 78 23, Operation and Maintenance Data, and the following:
   a. Updated versions of the following items as required under paragraph Shop Drawings.
      1) Overview block diagram.
      2) Overview description.
      3) CS/RTU communication link definition.
      4) Radio communication link design.

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5) CS/remote peripheral communication link definition.
6) Descriptive information.
7) Assembly information.
8) Interconnecting wiring diagrams.
9) Input/output list.
10) RTU list.

b. Assembly O&M Manuals: For each size RTU, RTU Test Set, and transceiver:
1) Definition of model numbers and options.
2) Performance specifications.
3) Functional description including theory of operation, configuration, capabilities, controls, and operations.
4) Bill of Materials.
5) Assembly drawings.
6) Block and schematic diagrams.
7) Installation and safety requirements.
8) Maintenance tests and diagnostic procedures.

c. Maintenance Information: For each type of RTU printed circuit board, provide the information listed under subparagraph Assembly O&M Manuals, including original equipment manufacturer's part numbers for all component and modules.

d. List of required and recommended spares, expendables, and test equipment.

4. Statement of Qualification: Maintenance technician.
5. Maintenance service agreement.

1.04 QUALITY ASSURANCE

A. Maintenance Technician Qualifications: Factory training and a minimum of 2 years of experience in the installation and maintenance of RTUs of the types required for this Project.

1.05 ENVIRONMENTAL REQUIREMENTS

A. Design the following components of the TS for continuous operation in environments listed:

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1.06 SEQUENCING AND SCHEDULING

A. Coordinate the external circuit portion of the Interconnecting Wiring Diagrams required in paragraph Shop Drawings with the electrical requirements of Division 26.

1.07 MAINTENANCE

A. Maintenance Service Agreement: Preventive Maintenance Program: Visit Owner's Site once every 6 months by qualified maintenance technician to verify operation of the RTUs and calibrate all AI and AO. Visits also include verification and calibration of the RTU Test Set.

PART 2 - PRODUCTS

2.01 SYSTEM PERFORMANCE

A. Availability:

1. Subsystem Availability Calculation: Subsystem availability (A) for the TS is defined as average of the individual RTU availabilities (ai) times the nonspecific availability (NA). That is, A = NA*(A1+A2+A3...+An)/n, where n is the number of RTUs. Subsystem availability does not include communication links provided by others.
2. Availability Requirement: TS availability at least 99 percent.
3. Component and Backup Definitions: For purposes of the availability calculations, each RTU and its process I/O is considered an individual component. There are no backup components.

B. Accuracy: The total, worst case, end-to-end, root mean square error for all analog input data handled by TS and CS, not to exceed plus or minus 0.25 percent of full scale under all operational conditions. This requirement excludes errors in transducers, but includes all system data in all forms.

C. CS/RTU Communication Timing: Maximum times allowed for the CS to perform data acquisition and command output functions with RTUs.

1. Station Scan: Maximum time for the CS to request information from a single RTU, receive a reply, and store the information in the data base 3 seconds. This requirement assumes:
   a. Station is a well RTU with maximum I/O count.
   b. No communication errors, i.e., that messages pass all security checks and no retries are required.

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c. No output commands are required.

2.02 CS/RTU COMMUNICATIONS

A. Radio Communication Links:

1. General:
   a. Radio communication links between CS and some of the RTUs at Owner's remote facilities as listed in Article Supplements.
   b. Functions are intended to identify minimum acceptable communication link performance requirements. Furnish functions and equipment necessary to effect completely operational communication links that function compatibly with the CS and the RTUs to form an overall operational SCADA system.
2. Configuration: Configure CS/RTU radio communication links as shown on Drawings and as follows:
   a. CS site has dual radio transceivers with only one active at any time. Active transceiver selected manually.
   b. Each site has a single antenna for both transmission and reception.
3. Remote sites.Performance: CS/RTU radio communication links in accordance with the following minimum performances for communication channel and radio frequency signals:
   a. Radio communication channel suitable 256 kilo baud minimum, half duplex communication between CS and RTU facilities.
   b. Radio communication links in accordance with applicable FCC and FAA regulations. Radio communication link design provides for 99.9 percent reliability for CS to repeater link. 99.9 percent reliability is achieved if the fade margin is at least 30 dB. That is, the median received signal level is at least 30 dB above the minimum signal level required for satisfactory operation.
   c. Radio communication links between repeater and all facilities, other than CS facility, has a minimum of 20 dB fade margin. This is nominally 99.5 percent reliability.
   d. Use the following criteria for design of radio communication links:
      1) Maximum effective radiated power (ERP) 1 watts.
      2) Maximum antenna height above ground level 20 feet.
      3) Nominal antenna gain at all stations except central repeater 10 dBd.
      4) Nominal antenna gain at central repeater site 9 dBd.
      5) Operating frequencies of 900 MHz spread spectrum.

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2.03 EQUIPMENT

A. Radio Communication Equipment:

1. Transceivers and Repeaters: Contains FM transmitter and FM receiver suitable for operation in 900 MHz spread spectrum band. Units in accordance with the following characteristics:
   a. Equipment FCC type accepted for intended application. Equipment capable of operation without significant degradation when subjected to applicable temperature, shock, humidity, and vibration tests in accordance with TIA/EIA 603. Unit, when contained in NEMA 1 housing in accordance with NEMA 250, meet or exceed all EIA performance criteria at an ambient temperature of plus 60 degrees C while subjected to 100 percent duty cycle.
   b. Transceivers operate from power provided by the RTU. Units employ solid state circuitry throughout.
   c. Antenna switches rated for 10 million operations, minimum.
   d. Unit Manufacturers and Products: GE I-NET 900 II.
2. Transmission Line:
   a. Transmission line performance characteristics in accordance with overall system functional requirements.
   b. Provide with a minimum bend radius 10 inches or less and dielectric jacket, and suitable for direct burial and outdoor design environments.
   c. Terminate only in connectors rated for the required service.
   d. Manufacturer and Product: Andrews; LDF4-50-A.
3. Antennas, Masts, and Poles:
   a. Comply with requirements Section 01 61 00, Common Product Requirements for seismic and wind velocity.
   b. Antenna type, mounting elevation and orientation to achieve overall functional requirements of the system. Antennas suitable for outdoor design environments. Antennas shall provide a low resistance, dc path to ground for lightning protection.
      1) Nominal antenna types for each facility are listed in RTU Summary List, refer to Article Supplements.
      2) Antenna Manufacturer and Products: Maxrad.
         a) Omni: Model MFB9157.
         b) Yagi: Model BMOY8905.
   c. Masts and Poles:
      1) In accordance with TIA 222-G and TIA 222-G-1.
      2) Self-supporting (guyless).
      3) Support antenna at elevation and orientation necessary to achieve functional requirements.

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4) Suitable for outdoor environmental conditions.
5) Adequate support and protection for transmission lines.
6) Complete with necessary mounting accessories.

d. Protective Equipment:
1) Such as lightning arrestors to minimize damage due to lightning discharges.
2) Lightning arrestors connected to ground rod by cable.
3) Do not use mast, poles, or structures for ground path.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Transmission Line:

1. Secure transmission line to suitable supports 3 feet on centers with stainless steelties.
2. Steel or galvanized steel cable clamps not permitted.
3. Replace transmission line jackets cut by ties.

B. Direct Embedment of Poles:

1. General:
a. Poles set in sloping soil, increase setting depth to account for the reduced volume of bearing soil at ground line. Additional depth of setting equal to the drop in elevation in 5 feet measured horizontally. On sloping ground, measure setting depth from low side of pole ground line.
b. Set poles in augured holes approximately 8 inches larger in diameter than pole butt.
2. Backfill: Earth backfill around all poles, except in areas designated otherwise on Drawings. Remove all organic materials and trash from excavation before placing backfill. At grade level, banked and tamped earth backfill around the base of each pole. Place earth backfill material in lifts of maximum 6-inch depth and compact each lift to 95 percent of maximum density at optimum moisture content in accordance with AASHTO T99, Method A. Maintain material at optimum moisture content for compaction.
3. Disposal of Excess Excavation: Dispose of all excess excavated materials, not required for backfill or fills, by carefully spreading.
4. Settlement in backfill occurring within the standard 1-year correction period shall be defective.

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5. Pole Grounding: Ground immediately after setting with grounding method as shown on Drawings.

3.02 TRAINING

A. Provide a minimum of 1 instructor week of maintenance training specific to the Telemetry Subsystem hardware. Provide training at the Site of Work [before] [at the start of] [after] RTU installation.

B. Provide formal classroom instruction and practical laboratory work. Training provides the instruction and experience to enable an instrument technician to properly install, startup, test, troubleshoot, and maintain the Telemetry Subsystem equipment. Cover the following areas, as a minimum:

1. Configuration, communication protocol, performance, interfaces, and hardware of the Telemetry Subsystem.
2. Theory, functions, configuration, performance, limitations, and interfaces of RTU and RTU Test Set hardware and software.
3. Present a short operator's course to ensure that the students understand the CS operator functions and man/machine interfaces. Explain displays and printouts so the student will understand how information is derived, and to recognize system problems.
4. Theory, operation, and analysis of data produced by Contractor's diagnostic programs on CS and RTU Test Set to identify and isolate system problems.
5. Techniques for installation, interfacing, and starting up RTUs.
6. Operations and troubleshooting procedures for RTU Test Set and general-purpose test equipment to diagnose RTU problems to the circuit board level.
7. Performance verification using RTU Test Set.

3.03 SUPPLEMENTS

A. The supplements listed below, following "End of Section," are a part of this Specification.

1. RTU List.
2. RTU Input/Output Summary.

END OF SECTION

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SECTION 40 95 80
FIBER OPTIC COMMUNICATION SYSTEM

PART 1 - GENERAL

1.01 REFERENCES AND DEFINITIONS

A. The following is a list of standards that may be referenced in this section:

1. Electronic Components, Assemblies, and Materials Association (ECA): 310-E, Cabinets, Racks, Panels, and Associated Equipment.
2. Institute of Electrical and Electronic Engineers, Inc. (IEEE): 802.3, Telecommunications and Information Exchange Between Systems—Local and Metropolitan Networks.
3. Insulated Cable Engineers Association (ICEA):
   a. S-83-596, Optical Fiber Premises Distribution Cable.
   b. S-87-640, Optical Fiber Outside Plant Communications Cable.
   c. S-104-696, Indoor-Outdoor Optical Fiber Cable.
4. International Organization for Standardization (ISO): 9001, Quality Management Systems—Requirements.
5. International Telecommunication Union (ITU): T G.652, Characteristics of a Single-mode Optical Fibre and Cable.
6. National Fire Protection Association (NFPA): 70, National Electrical Code (NEC).
7. QuEST Forum (QF): TL 9000, Quality Management Systems.
8. Rural Development Utilities Programs (RDUP):
   a. 7 CFR 1755.902, Minimum Performance Specification for Fiber Optic Cables.
   b. 7 CFR 1755.903, Fiber Optic Service Entrance Cables.
9. Telecommunications Industry Association (TIA):
   a. 526-7, OFSTP-7 Measurement of Optical Power Loss of Installed Single-Mode Fiber Cable Plant.
   b. 526-14, OFSTP-14 Optical Power Loss Measurements of Installed Multimode Fiber Cable Plant.
   c. 568-C.1, Commercial Building Telecommunications Cabling Standards.
   d. 568-C.3, Optical Fiber Cabling Components Standard.
   e. 598, Optical Fiber Cable Color Coding.
   f. 606, Administration Standard for Commercial Telecommunications Infrastructure.
10. Telecommunications Industry Association/Electronics Industry Association (TIA/EIA):

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a. 455-78, FOTP-78 - IEC 60793-1-40 Optical Fibres Part 1-40: Measurement Methods and Text Procedures – Attenuation.
b. 455-133, FOTP-133 IEC-60793-1-22 Optical Fibres Part 1-22: Measurement Methods and Test Procedures Length Measurement.
c. 492AAAA, Detail Specification for 62.5-Micrometer Core Diameter/125-Micrometer Cladding Diameter Class Ia Graded-Index Multimode Optical Fibers.
d. 492AAAB, Detail Specification for 50-Micrometer Core Diameter/125-Micrometer Cladding Diameter Class Ia Graded-Index Multimode Optical Fibers.
e. 492AAAC, Detail Specification for 850-nm Laser-Optimized, 50-um Core Diameter/125-um Cladding Diameter Class Ia Graded-Index Multimode Optical Fibers.
f. 492CAAA, Detail Specification for Class IVa Dispersion-Unshifted Single-Mode Optical Fibers.
g. 492CAAB, Detail Specification for Class IVa Dispersion-Unshifted Single-Mode Optical Fibers with Low Water Peak.
h. 604-2, FOCIS-2 Fiber Optic Connector Intermateability Standard, Type ST.
i. 604-3, FOCIS-3 Fiber Optic Connector Intermateability Standard, Type SC and SC-APC.
j. 604-12, FOCIS-12 Fiber Optic Connector Intermateability Standard, Type MT-RJ.
k. 942, Telecommunications Infrastructure Standard for Data Centers.
l. TSB-140, Additional Guidelines for Field-Testing Length, Loss and Polarity of Optical Fiber Cabling Systems-Contains Color.
m. Underwriter Laboratories (UL): 94, Tests for Flammability of Plastic Materials for Parts in Devices and Appliances.

B. DEFINITIONS

1. ATM: Asynchronous Transfer Mode.
2. AUI: Attachment Unit Interface.
3. dB: Decibel.
4. DNI: Desktop Network Interface.
5. EMB: Effective Modal Bandwidth.
6. ETL: Electrical Test Laboratories.
7. FDDI: Fiber Distributed Data Interface.
8. FIM: Facilities Information Management.
9. Flux Budget: Difference between transmitter output power and receiver input power required for signal discrimination when both are expressed in dBm.
10. FOCS: Fiber Optic Communication System.

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11. FOIRL: Fiber Optic Inter Repeater Link.
12. Fusion Splice: Connecting ends of two fibers together by aligning fiber ends and applying electric arc to fuse ends together.
13. Hybrid Cable: Cable containing more than one type of fiber.
14. LAN: Local Area Network.
15. LIMS: Laboratory Information Management System.
16. m: Micrometer.
17. Mbps: Megabits per Second.
18. Mechanical Splice: Connecting ends of two fibers together by means other than fusion.
19. Megahertz (MHz): One million cycles per second.
20. MHz: Megahertz.
21. micro: x 10^{-6}.
22. Micron: Micrometer or one millionth meter.
23. MIS: Management Information System.
24. n, nano: x 10^{-9}.
25. N: Newton.
26. nm: Nanometer—unit of measure equal to one billionth meter.
27. OFL: Over-filled Launch.
28. OFN: Nonconductive Optical Fiber Cable.
29. OFNP: Nonconductive Optical Fiber Plenum Cable.
30. OFNR: Nonconductive Optical Fiber Riser Cable.
31. OLTS: Optical Loss Test Sets.
32. OTDR: Optical Time Domain Reflectometer.
33. OVD: Outside Vapor Deposit.
34. PIC: Process Instrumentation and Control.
35. Plenum: Air return path of central air handling system, such as open space above suspended ceiling.
36. RLM: Restricted Mode Launch.
37. ROL: Reverse Oscillation Lay.
38. SPC: Super Physical Contact.
39. UPC: Ultra Physical Contact.
40. UPS: Uninterruptible Power Supply.
41. V ac: Volts Alternating Current.
42. WAN: Wide Area Network.

1.02 SYSTEM DESCRIPTION

A. Function of FOCS is to transmit digital data between network nodes. Requirements listed identify minimum acceptable system performance.

B. Provide a FOCS based on referenced standards for use in the following local and wide area networks: Fast Ethernet.

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1.03 SUBMITTALS

A. Action Submittals:

1. Site Layout Diagram Showing:
   a. Access holes, with identification.
   b. Abovegrade cable routings, with pole and cable identification.
   c. Belowgrade conduit routings between access holes and buildings, with conduit counts and identification.
   d. Belowgrade innerduct routings through conduits, with innerduct counts and identification.
   e. Cable routings through innerducts and to patch panels, fiber centers, or network nodes, with cable and node identification.
2. Cable Schedule Showing:
   a. Cable identification.
   b. Fiber counts for each cable and identification of used fiber pairs.
   c. Cable length and attenuation, with splice(s), based on TIA 568-C.3, Annex H.
3. Component Data:
   a. Manufacturer and model number.
   b. General data and description.
   c. Engineering specifications and data sheet.
   d. Scaled drawings and mounting arrangements.

B. Informational Submittals:

1. Manufacturer’s statement that installer is certified to perform installation Work.
2. Subcontractor Qualifications:
   a. FOCS Subcontractor: Minimum of 5 years experience providing, integrating, installing, and commissioning of similar systems.
      1) Statement of Experience: List of at least three fiber optic data communications systems comparable to system specified which have been furnished and placed into operation. For each system, provide following information:
         a) Owner’s name, address, telephone number, and name of current operations supervisor or other contact.
         b) Description of system hardware configuration, including major equipment items, number of nodes, and communication standards implemented.
         c) System block diagram.
         d) Dates when contract was signed, equipment was delivered, and system was accepted by OWNER. Also,

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include originally scheduled completion date and if different from actual date, explain why.
e) Approximate value of listed FOCS provided in dollars.
f) Detailed horizontal and riser routing.
g) Distribution frame arrangements.
h) Fiber and termination identification, including spares.

b. FOCS Subcontractor's Site Representative: Minimum of 5 years experience installing similar systems.
c. Qualification of Personnel:
1) Resumes identifying management and technical qualifications of supervisory, local service representative, and key personnel.
2) Qualification data of firm and persons to demonstrate capabilities and experience in the following areas:
a) Fiber optic cable handling and placement techniques.
b) Fiber optic splicing and installation of connections.
c) Attenuation testing procedures.
d. OWNER acceptance of FOCS Subcontractor does not exempt FOCS Subcontractor or Contractor from meeting Contract Document requirements nor does it give prior acceptance of subsystems, equipment, materials, or services.
e. Sample of Network Test Report, 10 page-minimum, generated by Contractor in a previous project.
f. Testing and acceptance plan, 30 days prior to beginning of testing.
g. Fiber test results. Documentation covering fiber facility testing, not later than 2 days after testing, showing:
1) Manufacturer's tag of attenuation per fiber as recorded from OTDR reading before shipment.
2) Attenuation of each fiber upon delivery to Site.
3) Attenuation of each fiber plus connector after installation as recorded from OTDR with tracing.
4) Flux Budget calculations with comparison to measured attenuation for each run verifying adequate optical signal strength.
h. For each maintenance organization, identify location of base of service and how required coverage will be achieved.

3. Manufacturer's Certificate of Compliance, in accordance with Section 01 43 33, Manufacturers' Field Services.
4. Manufacturer's suggested installation practice.
5. Operation and Maintenance Data: As specified in Section 01 78 23, Operation and Maintenance Data.

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1.04 ENVIRONMENTAL REQUIREMENTS

A. Optical Fiber Cable and Cable Splice Centers:

1. Outside, Underground/Submerged: Minus 20 degrees C to 40 degrees C.
2. Outside, Overhead: Minus 40 degrees C to 80 degrees C.
3. Outside, Aboveground in Conduit: Minus 40 degrees C to 80 degrees C.
4. Inside: 0 degree C to 40 degrees C.

B. Equipment:

1. Outside, Aboveground: Minus 40 degrees C to 80 degrees C.
2. Control Rooms, Equipment Rooms, and Telecommunications Closets: 30 percent to 55 percent relative humidity, 18 degrees C to 24 degrees C.
3. Other Interior Areas: 0 percent to 100 percent relative humidity, 5 degrees C to 35 degrees C.

1.05 QUALITY ASSURANCE

A. Manufacturer Qualifications:

1. Cable:
   a. ISO 9001 or QF TL 9000 registered, whichever applies to material.
   b. Minimum of 20 years in manufacturing optical fiber cable in order to demonstrate reliable field performance.
2. Housing: ISO 9001 and QF TL 9000 registered.
3. Connector:
   a. ISO 9001 or QF TL 9000 registered.
   b. Minimum 10-year history of manufacturing and supporting connector technology that does not require epoxy or polishing in field.
4. Jumper Cable: ISO 9001 and QF TL 9000 registered.

B. Installer Qualifications:

1. Individuals with at least 3 years of experience with projects utilizing fiber optic cable in compliance with TIA 568-C.3.
2. Certified by fiber cable manufacturer.

C. Tester Qualifications: Individuals with at least 3 years of experience with projects utilizing fiber optic cable in compliance with TIA 568-C.3.

1. Technician: Successfully attended training program, which includes testing with an OLTS and an OTDR and have obtained a certificate as proof

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thereof. Certificate may have been issued by the following organizations or an equivalent organization:

a. Manufacturer of fiber optic cable and fiber optic connectors.
b. Manufacturer of test equipment used for field certification.
c. Other independent training organizations acceptable to OWNER.

D. Provide connectors/coupling, splicing enclosures, mounting hardware, and miscellaneous accessories for fibers by same manufacturer.

1.06 SPECIAL GUARANTEE

A. Provide manufacturer's extended guarantee or warranty, with OWNER named as beneficiary, in writing, as special guarantee. Special guarantee shall provide for correction, or at option of OWNER, removal and replacement of Work specified in this specification section found defective during a period of 2 years after date of Substantial Completion. Duties and obligations for correction or removal and replacement of defective Work shall be as specified in General Conditions.

PART 2 - PRODUCTS

2.01 FIBER OPTIC CABLE

A. Single-Mode: 8.3/125-micron Class IVa dispersion-unshifted optical fibers for use in the backbone distribution subsystem shall meet or exceed requirements of TIA 568-C.3, including the following specifications:

1. Chromatic Dispersion:
   a. Zero-Dispersion Wavelength: Between 1,302 nm and 1,322 nm.
   b. Maximum value of dispersion slope at zero dispersion wavelength shall be no greater than 0.093 ps per km-nm^2.
2. Mode Field Diameter: Nominal 8.7 microns to 10 microns, with a tolerance of plus or minus 0.5 micron at 1,300 nm.
3. Maximum Attenuation:
   a. Outside and Indoor-Outdoor Optical Fiber Cable:
      1) 0.5 dB per km at 1,310 nm.
      2) 0.5 dB per km at 1,550 nm.
   b. Inside Optical Fiber Cable:
      1) 1 dB per km at 1,310 nm.
      2) 1 dB per km at 1,550 nm.
4. Cutoff Wavelength of Cabled Fiber: Less than 1,260 nm.
5. [TIA 492 CAAB (OS2) low water peak and complies with ITU T G.652 (A to D).] [TIA 492 CAAA (OS1) compliant.]
6. Distance Capacity per IEEE 802.3:
   a. 1 Gbit Ethernet, 1,300 nm Laser Minimum Distance: 5000 m.

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b. 10 Gbit Ethernet: 10 km at 850 nm and 40 km at 1,310 nm.

B. Type 8.3/250, Backbone for Underground Conduit Installation:

1. Individual Fibers: 8.3/125/250 microns.
2. Assembly:
   a. Nonmetallic, gel-free, dry water blocked, loose-tube fiber core with dielectric strength member enclosed by nonmetallic cross-ply sheath; requires buffer tubing.
   b. Cable: Comply with ICEA S-87-640 and RDUP 7 CFR 1755.902 for backbone, feeder and distribution cables [and RDUP 7 CFR 1755.903 for service entrance or drop cable with 12 strands or less used having a distance of 100 m or less (fiber-to-the-home applications)].
3. NEC/UL Listing: None; not approved for general use within building, except when installed in metallic conduit.
4. Protective Covering: Black, antifungus, UV-resistant, polyethylene jacket with rip-cord.
5. Minimum Short Term Pull Strength: 600 lbf.
6. Manufacturers and Products:
   a. Corning Cabling Systems; ALTOS loose-tube dielectric cable.
   b. Mohawk; Outdoor loose-tube cable.

C. Type 8.3/250, Backbone for Underground Conduit and Building Riser Installation:

1. Individual Fibers: 8.3/125/250 microns.
2. Assembly:
   a. Nonmetallic, gel-free, dry water blocked, loose-tube fiber core with dielectric strength member enclosed by nonmetallic cross-ply sheath; requires buffer tubing.
   b. Cable: Comply with ICEA S-104-696.
3. NEC/UL Listing: OFNR.
4. Protective Covering: Black, flame and UV-resistant, thermoplastic jacket with rip-cord.
5. Minimum Short Term Pull Strength: 600 lbf.
6. Manufacturers and Products:
   a. Corning Cabling Systems; FREEDM cable.
   b. Mohawk; RiserLite loose-tube cable.

D. Type 8.3/900, Backbone for Building Installation:

1. Individual Fibers: 8.3/125/250/900 microns.
2. Assembly:

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a. Distribution style with core of individually tight-buffered fibers surrounded by nonmetallic sheath.
b. Cable: Comply with ICEA S-83-596.

3. Protective Covering: Flame retardant outer jacket with pull string.
   a. NEC/UL Listing: [OFNR] [OFNP] [OFNR Low Smoke Zero Halogen].
4. Manufacturers and Products:
   a. Corning Cabling Systems; (MIC) cable.
   b. Mohawk; Distribution Riser cable.

2.02 MULTIMODE FIBER OPTIC CABLE

A. 50/125 and 62.5/125-micron, graded-index for use in backbone and horizontal distribution subsystems, meets or exceeds the requirements of TIA 568-C.3, including the following specifications:

1. Maximum Mean Fiber Loss:
   a. 3.5 dB per km at 850 nm.
   b. 1.5 dB per km at 1,300 nm.
2. Minimum OFL Bandwidth:
   a. [OM1-200 MHz•km minimum at 850 nm; TIA 492AAAA.]
   b. [OM2-500 MHz•km minimum at 850 nm; TIA 492AAAB.]
   c. [OM3-1500 MHz•km minimum at 850 nm; TIA 492AAAC.]
   d. 500 MHz•km minimum at 1,300 nm.
3. Distance Capacity per IEEE 802.3:
   a. 100Mbit Ethernet: [OM1] [OM2] [OM3] 300m at 850 nm and 2000m at 1,310 nm.
   b. 1 Gbit Ethernet:
      1) [OM1: 300m at 850 nm and 550 at 1310 nm.]
      2) [OM2: 600m at 850 nm and 600 at 1310 nm.]
      3) [OM3: 1000m at 850 nm and 600 at 1310 nm.]
   c. 10 Gbit Ethernet—10km at 850 nm and 40km at 1310 nm:
      1) [OM1: 33m at 850 nm and 300 at 1310 nm.]
      2) [OM2: 82m at 850 nm and 600 at 300 nm.]
      3) [OM3: 300m at 850 nm and 300 at 1310 nm.]

B. Type [50/250 [OM2] [OM3] [62.5/250 OM1], Backbone for Underground Conduit Installation:

1. Individual Fibers: [50/125/250] [62.5/125/250] microns.
2. Assembly:

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a. Nonmetallic, gel-free, dry water blocked, loose-tube fiber core with dielectric strength member enclosed by nonmetallic cross-ply sheath; requires buffer tubing.
b. Cable: Comply with ICEA S-87-640.

3. NEC/UL Listing: None; not approved for general use within building except when installed in metallic conduit.
4. Protective Covering: Black, antifungus, UV-resistant, polyethylene jacket with rip-cord.
5. Minimum Short Term Pull Strength: 600 lbf.
6. Manufacturers and Products:
   a. Corning Cabling Systems; ALTOS loose-tube dielectric cable.
   b. Mohawk; Outdoor loose-tube cable.

C. Type [50/250 [OM2] [OM3] [62.5/250 OM1], Backbone for Underground Conduit and Building Riser Installation:

1. Individual Fibers: [50/125/250] [62.5/125/250] microns.
2. Assembly:
   a. Nonmetallic, gel-free, dry water blocked, loose-tube fiber core with dielectric strength member enclosed by nonmetallic cross-ply sheath; requires buffer tubing.
   b. Cable: Comply with ICEA S-104-696.
3. NEC/UL Listing: OFNR.
4. Protective Covering: Black, flame and UV-resistant, thermoplastic jacket with rip-cord.
5. Minimum Short Term Pull Strength: 600 lbf.
6. Manufacturers and Products:
   a. Corning Cabling Systems; FREEDM cable.
   b. Mohawk; RiserLite loose-tube cable.

D. Type [50/900 [OM2] [OM3] [62.5/900 OM1], Indoor/Outdoor Cable:

1. Individual Fibers: [50/125/250/900] [62.5/125/250/900] microns.
2. Assembly:
   a. Distribution Style with core of individually tight-buffered fibers surrounded by nonmetallic sheath.
   b. Cable: Comply with ICEA S-83-596.
3. Protective Covering: Flame retardant outer jacket with pull string.
4. NEC/UL Listing: [OFNR] [OFNP] [OFNR Low Smoke Zero Halogen].
5. Manufacturers and Products:
   a. Corning Cabling Systems; (MIC) cable.
   b. Mohawk; Distribution Riser cable.

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2.03 MULTICELL CONDUIT SYSTEM

A. Nonmetallic, designed for fiber optic cabling and telecommunications.

1. Features:
   a. Outerduct, complete with innerducts preinstalled.
   b. Innerduct identification system.
   c. Gasketing that allows watertight assembly and disassembly of outer and innerducts for direct buried and encased installations.
   d. Couplings, access hole terminators, innerduct seals for both empty and cabled ducts, and fixed and flexible bends.
2. Outerduct (conduit located outside innerduct):
   a. Industry standard, 100-mm duct with integral bell end.
   b. Material: [PVC ‘C’ duct, 3.8-mm wall] [PVC Schedule 40] [Fiberglass, [1.8] [2.3] [6]-mm wall] [Galvanized rigid steel].
   c. Marking: Indicate proper innerduct orientation and alignment.
   d. Length: 6 meters.
3. Innerduct:
   a. Size and Count: [30 mm; 4] [38 mm; 3] [As shown on Drawings] [_____].
   b. Material: Smoothwall PVC.
   c. Lubrication: Prelubricated with atomized silicone lubricant.
4. Manufacturer and Product: Carlon; Multi-Gard.

B. Innerduct:

1. Function: Installs into conduit system provided by others, to provide smooth, low-friction path through conduit, with only one cable per path to facilitate changing individual cables.
2. Features:
   a. Size and Count, in 4-inch Conduit: [19 mm; 4] [25 mm; 3] [32 mm; 3] [As shown on Drawings].
   b. Type: Annular, corrugated innerduct.
   c. Material: HDPE.
   d. Color Code: Orange, blue, green, brown, white, or grey.
   e. Strength: Minimum 600-pound tensile strength, with no more than 5 percent ovalization at 600-pound tension.
   f. Lubrication: Prelubricated.
1. Manufacturers:
   a. Endocor.
   b. Dura-Line.

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2.04 FIBER DISTRIBUTION FRAME

A. Function: Provides industry-standard rack mounting system for interface between fiber optic backbone and equipment cables.

B. Features:

1. Used in either cross-connect or interconnect configuration.
2. 23-inch (584-mm) rack for mounting 19-inch (483-mm) rack mount units.
   a. Accommodates up to 576 fiber terminations per frame.
   b. Accepts connector module housing and splice housing within same rack.
   c. Fiber Optic Connectors: [SC] [and] Optic [ST] [LC] [MT-RJ] [FC].
3. Fiber/Wire Management System:
   a. Vertical: 75-mm by 100-mm supports on 200-mm centers vertically on four sides (front LHS, back LHS, front RHS, back RHS).
   b. Horizontal: Supports on 100-mm centers horizontally above and below each termination frame front and back. Support may serve frames immediately above and below.
4. Mounting Hardware: Accepts standard 19-inch (483-mm) rack for integrated fiber optic system (for example, hubs, routers, patch panels).
5. Splice Trays with Coil Former: Former to wind slack cable around, provides controlled long radius bends.
   a. Doors: Pivot down lockable.
   b. Foot and End Caps: Included in final, assembled unit.
   c. Ancillaries: Jumper troughs and covers, cable tie brackets.

C. Manufacturers:

1. Ortronics.
2. Siecor.

2.05 FIBER CENTERS

A. Function: Provides secure place to terminate fiber optic cables.

B. Features:

1. Compartments: Two; one for fiber optic cable, one for jumpers to individual equipment.
2. Coil Former: Former to wind slack cable around, provides controlled long radius bends.
3. Connectors: Minimum 24 [SC] [and] [ST] [LC] connectors for entry and exit.

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4. Size: Maximum 450 mm by 300 mm by 100 mm.
5. Construction: 1.5-mm steel with corrosion proof finish.
6. Mountings: Suitable for permanent attachment as shown, or provide separate mountings that do not obscure covers and doors.
7. Doors: [Separate doors for cable and jumper terminations] [and] [lockable].

C. Manufacturers:

1. Ortronics.
2. AT&T.
3. Siecor.

2.06 HOUSINGS

A. Termination Housing:

1. Rack mountable connector housing.
2. Mountable in ECA 310-E compatible 465-mm or 592-mm rack.
3. Available in several sizes, including 1U, 2U, 3U, and 4U. One ECA rack space or panel height (denoted as U) is defined as being 44.45 mm in height.
4. In accordance with design requirements of TIA 568-C.3 and polymer compounds flammability requirements of UL 94.
5. Manufactured using 16-gauge aluminum or equivalent for structural integrity.
6. Finished with wrinkled black powder coat for durability.
7. Provide black installation fasteners.
8. Available sizes with their corresponding fiber capacities are noted below:

Termination Housing Sizes and Fiber Capacities

Unit Size	Panel Capacity	Fiber Capacity with 6f Panels	Fiber Capacity with 12f Panels	Fiber Capacity with 24f Panels
1U	2	12	24	48
2U	4	24	48	96
3U	6	36	72	144
4U	12	72	144	288

B. Splice Housing:

1. Mountable in ECA 310-E compatible 465-mm or 592-mm rack.

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2. Available in two rack mount sizes of 3U and 5U. One ECA rack space or panel height (denoted as U) is defined as being 44.45 mm in height.
3. Provide individual tray access with minimal disturbance to neighboring trays and fibers.
4. In accordance with design requirements of TIA 568-C.3 and polymer compounds flammability requirements of UL 94.
5. Manufactured using 16-gauge aluminum or equivalent for structural integrity.
6. Finished with wrinkled black powder coat for durability.
7. Front and rear doors shall be lockable.
8. Brackets shall allow wall mounting of rack-mounted hardware.
2. Provide black installation fasteners.
9. Available sizes with their corresponding fiber capacities are noted below:

Splice Housing Sizes and Splice Capacities			
Unit Size	**Tray Height (inches)**	**Tray Capacity**	**Splice Capacity**
3U	0.2	12	144
3U	0.4	7	84
5U	0.2	22	264
5U	0.4	14	168

C. Combination Termination/Splice Housings:

1. In accordance with design requirements listed in TIA 568-C.3, TIA/EIA-942, and polymer compounds flammability requirements of UL 94.
2. Mountable in ECA 310-E compatible 465-mm rack or 592-mm rack.
3. Available in 1U and 4U sizes.
   a. One ECA rack space or panel height (denoted as U) is defined as being 44.45 mm in height.
   b. 1U shall have removable top lid.
   c. 4U shall have integrated jumper routing guides.
4. Depth: 16 inches deep for extra cable routing.
5. Manufactured using 16-gauge aluminum or equivalent for structural integrity.
6. Finished with rustic gun-metal grey powder coat for durability.
7. Joints shall be welded and finished in a workman-like manner.
8. Provide installation fasteners that match housing color.
9. Provide clamshell-type cable clamping mechanism to provide cable strain relief.

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10. Front and rear doors shall be lockable.
11. Connector housings shall have a labeling scheme that complies with TIA-606.
12. Available with factory-installed connectorized cable stubs in multiple cable and connector types.
13. Able to accommodate fusion splicing with additional hardware.

2.07 PANELS

A. Closet Connector Housing Panel:

1. Manufactured from 16-gauge cold rolled steel or injection-molded polycarbonate for structural integrity.
2. Designed to accommodate applications requiring specified labeling.
3. Offered in 6-fiber, 8-fiber, 12-fiber, 16-fiber, and 24-fiber versions.
    a. 6-fiber panels shall be offered in ST compatible, FC, SC simplex.
    b. 8-fiber and 12-fiber versions shall include ST Compatible Connector, FC, LC duplex, SC duplex and simplex, and MT-RJ multifiber connectors.
    c. For high-density applications, MT-RJ and LC duplex panels shall be available in 16-fiber and 24-fiber versions. When MT-RJ adapters are used, adapter shall be a style that has a polarity adjustment knock-out keyway tab that shall be oriented on inside of panel so that it is not accessible to user once system is installed.
4. Capable of being used with field-installable connectors or in applications where preconnectorized cables are routed directly from equipment to interconnect hardware.
5. Capable of accepting interchangeable connector panel.
6. Panel shall be attached with two push-pull latches to allow quick installation and removal.
7. Blank Connector Panel:
    a. Available to fill unused space within housing.
    b. Attached with at least two push-pull latches to allow quick installation and removal.
    c. Manufactured from injection-molded polycarbonate.

B. Pigtailed Adapter Panels:

1. Manufactured from 16-gauge cold rolled steel or injection-molded polycarbonate for structural integrity.
2. Attached with two push-pull latches to allow quick installation and removal.
3. Use for splicing preterminated pigtails to field cables.
    a. Pigtails shall be bundled in a MIC or Ribbon style subunit.

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b. Pigtail Length: 3 meters.

4. Offered in 6-fiber, 8-fiber, 12-fiber, 16-fiber, and 24-fiber versions.
   a. 6-fiber panels shall be offered in ST compatible, FC, SC simplex.
   b. 8-fiber and 12-fiber versions shall include ST compatible connector, FC, LC duplex, SC duplex and simplex and MT-RJ multifiber connectors.
   c. For high-density applications, MT-RJ and LC duplex panels shall be available in 16-fiber and 24-fiber versions.
      1) When MT-RJ adapters are used, adapter shall be a style that has a polarity adjustment knock-out keyway tab that shall be oriented on inside of panel so that it is not accessible to user once system is installed.
   d. Each individual fiber shall be color coded in accordance with TIA 598.

2.08 SPLICE TRAY

A. General:

1. Compatible with hardware connector/splice housings.
2. Securely organize and provide physical protection without stress on fibers for both single-mode and multimode individual and ribbonized fiber splices.
3. Splice enclosures to include various lengths and depths for a variety of splicing methods.

B. Features:

1. Shall not induce attenuation of signal at operational wavelengths up to 1,550 nm.
2. Consist of rugged aluminum base and aluminum cover with crimpable metal tabs that provide buffer tube strain-relief on both ends of tray.
3. Hold up to 24 single-fiber splices and up to six mass fusion splices.
4. Splice Organizer:
   a. Accommodate fusion splice, fusion splice with heat-shrink sleeve or mechanical sleeve, and mechanical splice part.
   b. High-precision molded construction that holds and protects actual splice thus eliminating need for extra splice protection parts.
   c. Provide positive holding action for maximum splice protection during installation and operation.
5. Strain-relief Points: Tie-wrap buffer tubes or pigtails to metal tray.
6. Finish: Black powder coating for ease of fiber identification and protection.

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2.09 SPLICE CLOSURES, AERIAL AND UNDERGROUND

A. Function: Enclose branch and inline splices in aerial and underground applications.

B. Available in canister (butt) and in-line styles to fit most applications.

C. Sizes:

1. Small: Accommodate up to 72 single-fiber splices or 144 ribbon-fiber splices using 12-fiber ribbons.
2. Medium: Accommodate up to 288 single-fiber splices or 432 ribbon-fiber splices.
3. Large: Accommodate up to 480 single-fiber splices or 864 ribbon-fiber splices.

D. Housing:

1. Nonmetallic, resistant to solvents, stress cracking, and creep.
2. Material shall be compatible with chemicals and other materials to which they might be exposed in normal applications.

E. End Caps:

1. Feature two express ports for uncut feeder cables.
2. Capable of accepting additional cables without removal of sheath retention or strength-member-clamping hardware on previously installed cables or disturbing existing splices.

F. Quick-seal mechanical seal drop ports.

G. Optical Fiber Closure:

1. Capable of accepting optical fiber cable commonly used in interoffice, outside plant, and building entrance facilities.
2. Provide clamping mechanism to prevent pistoning of central member or strength members, and to prevent cable sheath slip or pullout.
3. Ability to double cable capacity of installed canister splice closure by use of a kit. Such a conversion shall not disturb existing cables or splices.

H. Encapsulation shall not be required to resist water penetration.

I. Re-enterable.

J. Bonding:

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1. Provide hardware to facilitate bonding and grounding of metal components in closure and armored cable sheath.
2. Cable bonding hardware shall be able to accommodate a copper conductor equal to or larger than 6 AWG.

K. Aerial Splice Closures:

1. Provide hardware to attach and secure closure to aerial strand.
2. Accommodate splice trays suitable for single fiber, single-fiber heat-shrink, and mechanical or ribbon heat-shrink splices.

L. Installation shall not require specialized tools or equipment other than those normally carried by installation crews.

2.10 CONNECTORS

A. General:

1. Comply with TIA/EIA 604-2, TIA/EIA 604-3, TIA/EIA 604-12, and TIA 568-C.3.
2. LCconnectors.
3. Pull Strength: 0.2 N minimum.
4. Durability: Sustain minimum 500 mating cycles without violating other requirements.
   a. Ferrules: Free-floating low loss ceramic.
   b. Polarizing key on duplex connector systems.
5. Attenuation:
   a. In accordance with TIA 568-C.3.
   b. Maximum of 0.75 dB per connector pair.
6. Manufacturer: AMP.

2.11 PATCHCORDS

A. General:

1. In accordance with TIA 568-C.3.
2. Function: Connect fiber centers to network nodes, such as computer workstations.
3. Fiber Characteristics: In accordance with requirements for fiber optic cable.
4. Cable Configuration:
   a. Individual tight-buffer thermoplastic, fibers single or multimode, to match fibers being jumpered on.
   b. Protected with kevlar strength members and enclosed in thermoplastic jacket.

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5. Length: Standard, to meet requirements shown, plus minimum 3 meters at workstations.
6. Connectors:
   a. As required by Article Connectors.
   b. On-axial Pull Strength: 33 N.
   c. Normal-to-Axial Pull Strength: 22 N.
7. Cable Rating: OFNR or OFNP.
8. Color: Per standards or as indicated.
9. Measured for insertion loss with the following values for each connector:
   a. Typical of 0.3 dB and maximum of 0.5 dB (LC typical of 0.1 dB and maximum of 0.3 dB).
   b. OM3 fiber shall be measured for insertion loss with the following values for each connector pair: Typical of 0.15 dB and maximum of 0.25 dB.

2.12 CONDUIT

A. In accordance with Section 26 05 33, Raceway and Boxes.

2.13 ACCESSORIES

A. Hardware: Provide cable clamps, strain reliefs, blocking and grommet kits, closures, and fan outs for complete installation.

PART 3 - EXECUTION

3.01 PREPARATION

A. Conduit:

1. Ensure installed conduit system conforms to fiber optic system requirements, including:
   a. Conduits and Innerducts: Size and number.
   b. Access Holes, Handholes, and Pull Boxes: Location and size, to ensure cables and innerducts may be installed without exceeding manufacturer’s limitations.
   c. Outlet Boxes: Size to coordinate with outlet cover plates for adequate volume and bend radius.
2. Spare Conduit:
   a. No cables shall be pulled into spare conduit.
   b. 100 percent spare conduit capacity required for buried conduit only. For example, for every conduit with one or more cables in it, there shall be one spare equal-size conduit with no cables.
   c. [Spare conduit need not have innerduct installed.]

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3. Expansion Plugs: Seal conduit to stop ingress of water and grit with fabricated expansion plugs.
4. Ensure duct bank, conduit, and other confined routing is free and clear of debris before cable placement.

B. Multicell Conduit System:

1. Cabled Innerducts: Seal cables into innerducts to stop ingress of water and grit with fabricated expansion seals that have separate seals for each cable.
2. Empty Innerducts: Seal empty innerducts immediately after installation to stop ingress of water and grit with fabricated expansion plugs. Remove plugs as required to install cables.

C. Innerduct:

1. In accordance with manufacturer's recommendations.
2. Install no more than one innerduct of each color in single conduit.
3. Terminate innerducts in conduit with fabricated termination kits.
4. Identify innerducts at both ends by methods such as color-coding or waterproof tags wired through innerduct wall.
5. Sealing:
   a. Cabled Innerducts: Seal cables into innerducts to stop ingress of water and grit with fabricated expansion seals that have separate seals for each cable.
   b. Innerduct to Conduit: Seal gaps between innerducts and conduit with sealing compound such as 3M Ductseal.
   c. Empty Innerducts: After installation, seal with fabricated expansion plugs to stop ingress of water and grit. Remove plugs as required to install cables.

3.02 INSTALLATION

A. Fiber Optic Cable:

1. Specified fiber counts, routing, origination, and terminating points are indicated on Drawings.
2. Installation by manufacturer's certified installer.
3. Install cables in accordance with manufacturer's requirements.
4. Install cable directly from shipping reels. Ensure that cable is:
   a. Not dented, nicked, or kinked.
   b. Not subjected to pull stress greater than manufacturer's specification.
   c. Not bent to a radius below manufacturer's minimum bend radius.
   d. Not subjected to treatment that may damage fiber strands during installation.

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5. Cables per Conduit or Innerduct: [One cable maximum.] [In accordance with NFPA 70 NEC conduit fill limitations.]
6. If calculation indicates cable will attenuate signals more than 8 dB, reroute may be allowed if approved by ENGINEER.
7. Splices:
    a. Install fiber optic cables [in unspliced lengths from fiber centers to switches or hubs] [with splices above grade in buildings, protected by splice housings as shown] [and] [outside splices either in access holes or on aerial cabling, protected by splice closures].
    b. Fusion-splice fibers using apparatus applicable to type and size of fiber being spliced. Insert loss of splicing unit shall not exceed 0.2 dB on single-mode fibers and 0.25 dB on multimode fibers.]
8. Connector: Insertion loss on multimode connections exceeding 0.5 dB and 0.4 dB on single-mode connections not permitted.
9. Identification:
    a. Identify cable on both ends, in access holes, and pull points.
    b. In accordance with TIA 606.
10. Arrange cable, equipment, and hardware to provide neat appearance and accessibility for servicing.
11. Access Holes:
    a. Provide supports for cables in access and handholes [as shown on Drawings] [at minimum] [600 mm] [_____ mm centers along sides].
    b. While maintaining minimum bend radius, lace cables neatly to supports to keep them out of way of personnel.

B. Fiber Center, Fiber Distribution Frame, Housing, Panel, Splice Tray: Install securely in field panels or enclosures as shown on Drawings.

C. Cable Terminations:

1. In accordance with TIA 568-C.3.
2. Fan out fiber cable to allow direct connectorization of connectors.
    a. Sleeve over individual fibers with transparent furcation tubes.
    b. At point of convergence of furcation tubes, provide strain relief with metal or high density plastic fan-out collar.
3. Break-out Kits:
    a. Terminate cables using manufacturer-supplied break-out kits.
    b. Terminate in accordance with manufacturer’s recommendations.
4. Slack:
    a. Fiber Centers, Hubs, and Switches: Minimum, 3-meter slack fiber at each end, coiled neatly in cable management equipment.

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b. Communications Management Outlets: Minimum, 1-meter slack fiber, coiled neatly in outlet box.

5. Connectors:
   a. Terminate [minimum 12] [100 percent] [_____] fibers in each cable to specified connector.
   b. Connect into fiber management system.

D. Ethernet Fiber Optic Repeaters:

1. Install repeaters in accordance with manufacturer's instructions.
2. Location: Install transceivers securely in enclosures as shown on Drawings.
3. Power: As indicated on Drawings.

E. Ethernet Fiber-to-Copper Transceivers:

1. Install transceivers in accordance with manufacturer's instructions.
2. Location: Install transceivers securely in field panels, close to network nodes and fiber centers.
3. Power: Energize each transceiver from its field panel's UPS, if applicable.
4. Connections:
   a. Connect transceiver to fiber optics and network node.
   b. Lace fiber optics neatly in place, routed through wireways.

F. Conduit: Install in accordance with Section 26 05 33, Raceway and Boxes.

3.03 LABELING CONVENTIONS

A. Conform to TIA 606 or to requirements specified by OWNER or OWNER's representative.

B. Backbone (Riser) Cables:

1. Multiconductor cables connecting main distribution field to an intermediate distribution field, usually a wiring closet or cabinet, and are labeled at each terminating end. Label name identifies each endpoint, cable medium, and number of conductors as follows:
   a. Copper: IDF-MDF-C-PPP-N.
   b. Fiber: IDF-MDF-F-MMM, SSS-N.

Where:

IDF Is the 3-5 position IDF/wiring closet/building code
MDF Is the 3-5 position MDF (or IDF) code
F Fiber

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PPP Is pair count of a copper cable
MMM Is multimode strand count
SSS Is single-mode strand count
N Is a sequential number

C. Horizontal (Station) Cables:

1. Connect jack stations to wiring closets or cabinets and are labeled at each end to identify wiring closet they connect to and sequential jack station number as follows:
   a. Data: IDF-D-NNN-A/B.
   b. Voice: IDF-V-NNN-A/B.

Where:

IDF Is the 3-5 position IDF/wiring closet/building code
D Data cable (green)
V Voice cable (gray)
NNN Is the sequence number
A/B Indicates left or right port in faceplate

3.04 FIELD QUALITY CONTROL

A. General:

1. Advise ENGINEER at least 48 hours in advance of each test. ENGINEER shall have the option to witness and participate actively in tests.
2. In accordance with Section 01 91 14, Equipment Testing and Facility Startup.
3. Provide equipment, instrumentation, supplies, and skilled staff necessary to perform testing.
4. Outlets, cables, patch panels, and associated components shall be fully assembled and labeled prior to field testing.
5. Testing performed on incomplete systems shall be redone on completion of the Work.
6. Document Test Results: Confirm each cable has at least specified number of fibers that meet standards, in accordance with As-Built Fiber Optic Cable Installation form included as Supplement to this section.
7. Confirm quantities and sizes of conduit and innerduct, in accordance with As-Built Conduit/Innerduct Installation form included as Supplement to this section.

B. Test Equipment:

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1. Field test instruments shall have latest software and firmware installed.
2. Optical Fiber Cable Testers:
    a. Field test instrument shall be within calibration period recommended by manufacturer.
    b. Optical Loss Test Set (OLTS):
        1) Single-mode Optical Fiber Light Source:
            a) Provide dual laser light sources with central wavelengths of 1,310 nm (plus or minus 20 nm) and 1,550 nm (plus or minus 20 nm).
            b) Output Power: Minus 10 dBm, minimum.
            c) Manufacturer: Fluke Networks.
        2) Multimode Optical Fiber Light Source:
            a) Provide dual LED light sources with central wavelengths of 850 nm (plus or minus 30 nm) and 1,300 nm (plus or minus 20 nm).
            b) Output Power: Minus 20 dBm minimum.
            c) Meet launch requirements of TIA/EIA 455-78. This launch condition can be achieved either within the field test equipment or by use of an external mandrel wrap, as described in Clause 11 of TIA 568-C.3, with Category 1 light source.
            d) Manufacturer: Fluke Networks.
        3) Power Meter:
            a) Provide 850 nm, 1,300/1,310 nm, and 1,550 nm wavelength test capability.
            b) Power Measurement Uncertainty: Plus or minus 0.25 dB.
            c) Store reference power measurement.
            d) Save at least 100 results in internal memory.
            e) PC interface (serial or USB).
            f) Manufacturer: Fluke Networks.
        4) Optional Length Measurement: Capable of measuring optical length of fiber using time-of-flight techniques.
3. Optical Time Domain Reflectometer (OTDR):
    a. Bright, color transmissive LCD display with backlight.
    b. Rechargeable for 8 hours of normal operation.
    c. Weight with battery and module of not more than 4.5 pounds and volume of not more 200 cubic inches.
    d. Internal nonvolatile memory and removable memory device with at least 16 MB capacity for results storage.
    e. Serial and USB ports to transfer data to PC.
    f. Single-mode OTDR:
        1) Wavelengths: 1,310 nm (plus or minus 20 nm) and 1,550 nm (plus or minus 20 nm).

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2) Event Dead Zone: 2 meters maximum at 1,310 nm and 2 meters maximum at 1,550 nm.
3) Attenuation Dead Zone: 15 meters maximum at 1,310 nm and 15 meters maximum at 1,550 nm.
4) Distance Range: Minimum 10,000 meters.
5) Dynamic Range: Minimum 10 dB at 1,310 nm and 1,550 nm.

g. Multimode OTDR:
1) Wavelengths: 850 nm (plus or minus 20 nm) and 1,300 nm (plus or minus 20 nm).
2) Event Dead Zone: 1 meter maximum at 850 nm and 2 meters maximum at 1,300 nm.
3) Attenuation Dead Zone: 6 meters maximum at 850 nm and 15 meters maximum at 1,300 nm.
4) Distance Range: 2,000 meters minimum.
5) Dynamic Range: Minimum 10 dB at 850 nm and 1,300 nm.

h. Manufacturer: Fluke Networks.

4. Fiber Microscope:
a. Magnification: 250X or 400X for end-face inspection.
b. Manufacturer: Fluke Networks.

5. Integrated OLTS, OTDR, and Fiber Microscope:
a. Test equipment that combines into one instrument such as OLTS, OTDR, and fiber microscope may be used.
b. Manufacturer: Fluke Networks.

C. Conduit Test:

1. Test and seal spare conduits.
2. Conduit and Innerduct Testing:
a. Blow full-diameter mouse through each spare conduit and innerduct to verify they are unrestricted over full length.
b. If conduit is restricted over full length, advise ENGINEER.
3. Documentation: Confirm conduit test As-Built Conduit/Innerduct Installation form documentation includes details of innerducts.

D. Cable Testing:

1. Test procedures and field test instruments shall comply with applicable requirements of:
a. LIA Z136.2.
b. TIA/EIA 455-78.
c. TIA/EAI 455-133.
d. TIA 526-7.
e. TIA 526-14.

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f. TIA 568-C.1.
g. TIA 568-C.3.
h. TIA TSB 140.

2. Test attenuation and polarity of installed cable plant with OLTS and installed condition of cabling system and its components with OTDR.
3. Verify condition of fiber end face.
4. Perform on each cabling link (connector to connector).
5. Perform on each cabling channel (equipment to equipment).
6. Do not include active devices or passive devices within link or channel other than cable, connectors, and splices. For example, link attenuation does not include such devices as optical bypass switches, couplers, repeaters, or optical amplifiers.
7. Document Tests:
   a. OLTS dual wavelength attenuation measurements for single-mode and multimode links and channels.
   b. OTDR traces and event tables for single-mode and multimode links and channels.

E. Fiber Testing Parameters:

1. Each cabling link shall be in compliance with the following test limits:
   a. Optical Loss Testing:
      1) Backbone (single-mode and multimode) Link:
         a) Calculate link attenuation by the formulas specified in TIA 568-C.1.
         b) Values for Attenuation Coefficient (dB/km) are listed in the table below:

Attenuation Coefficient				
Type of Optical Fiber	**Wave-length (nm)**	**Attenuation Coefficient (dB/km)**	**Wave-length (nm)**	**Attenuation Coefficient (dB/km)**
Single-mode (Inside plant)	1310	1.0	1550	1.0
Single-mode (Outside plant)	1310	0.5	1550	0.5
Multimode 62.5/125 µm	850	3.5	1300	1.5
Multimode 50/125 µm	850	3.5	1300	1.5

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b. OTDR Testing:
   1) Reflective Events: Maximum 0.75 dB.
   2) Nonreflective Events: Maximum 0.3 dB.
c. Magnified Endface Inspection:
   1) Visually inspect fiber connections for end-face quality.
   2) Scratched, pitted, or dirty connectors shall be diagnosed and corrected.

F. Diagnosis and Correction:

1. Installed cabling links and channels shall be field tested and pass test requirements and analysis as described herein.
2. Link or channel that fails these requirements shall be diagnosed and corrected.
3. Document corrective action and follow with new test to prove corrected link or channel meets performance requirements.
4. Provide final and passing result of tests for links and channels.

G. Acceptance: Acceptance of test results shall be given in writing after Project is tested and completed in accordance with Contract Documents and satisfaction of OWNER.

H. Test Execution:

1. Optical Fiber Cable Testing:
   a. Tests performed that use laser or LED in test set shall be carried out with safety precautions in accordance with LIA Z136.2.
   b. Link and channel test results from OLTS and OTDR shall be recorded in test instrument upon completion of each test for subsequent uploading to a PC in which administrative documentation may be generated. Record end-face images in memory of test instrument for subsequent uploading to a PC and reporting.
   c. Perform Testing:
      1) On each cabling segment (connector to connector).
      2) On each cabling channel (equipment to equipment).
      3) Using high-quality test cords of same fiber type as cabling under test.
         a) Test cords for OLTS testing shall be between 1 meter and 5 meters in length.
         b) Test cords for OTDR testing shall be approximately 100 meter for launch cable and at least 25 meters for receive cable.
2. Optical Loss Testing (OLTS):

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a. Backbone Link:
    1) Test single-mode at 1,310 nm and 1,550 nm in accordance with TIA 526-7, Method A.1, One Reference Jumper or equivalent method.
    2) Test multimode at 850 nm and 1,300 nm in accordance with TIA 526-14A, Method B, One Reference Jumper or equivalent method.
    3) Perform tests in both directions.

3. OTDR Testing:
    a. Test backbone, horizontal, and centralized links at appropriate operating wavelengths for anomalies and to ensure uniformity of cable attenuation and connector insertion loss.
        1) Single-mode: 1,310 nm and 1,550 nm.
        2) Multimode: 850 nm and 1,300 nm.
    b. Test each fiber link and channel in one direction.
    c. Install launch cable between OTDR and first link connection.
    d. Install receive cable after last link connection.
4. Magnified Endface Inspection:
    a. Inspect fibers at 250X or 400X magnification.
        1) 250X magnification is suitable for inspecting multimode and single-mode fibers.
        2) 400X magnification may be used for detailed examination of single-mode fibers.
5. Length Measurement:
    a. Record length of each fiber.
    b. Measure optical length using OLTS or OTDR.
6. Polarity Testing:
    a. Test paired duplex fibers in multifiber cables to verify polarity in accordance with subclause 10.3 of TIA/EIA 568-C.1.
    b. Verify polarity of paired duplex fibers using OLTS.
7. Test Results Documentation:
    a. Test results saved within field-test instrument shall be transferred into Windows-based database utility that allows for maintenance, inspection, and archiving of test records. These test records shall be uploaded to the PC unaltered. For example, “as saved in the field-test instrument.” The file format, CSV (comma separated value), does not provide adequate protection of these records and shall not be used.
    b. Available for inspection by OWNER or OWNER’s representative during installation period. Submit within 5 working days of completion of tests on cabling served by a telecommunications room or of backbone cabling.
    c. Database for project, including twisted-pair copper cabling links, if applicable, shall be stored and delivered on CD-ROM prior to

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OWNER acceptance of building. CD-ROM shall include software tools required to view, inspect, and print test reports.

d. Circuit IDs reported by test instrument shall match specified label identification.

e. Provide in electronic database for each tested optical fiber with the following information:
   1) Identification of Site.
   2) Name of test limit selected to execute stored test results.
   3) Name of personnel performing test.
   4) Date and time test results were saved in memory of tester.
   5) Manufacturer, model, and serial number of field test instrument.
   6) Version of test software and version of test limit database held within test instrument.
   7) Fiber identification number.
   8) Length for Each Optical Fiber: Optionally the index of refraction used for length calculation when using a length capable OLTS.
   9) Test results to include OLTS attenuation link and channel measurements at appropriate wavelength and margin; difference between measured attenuation and test limit value.
   10) Test results to include OTDR link and channel traces, and event tables at appropriate wavelength.
   11) Length for each optical fiber as calculated by the OTDR.
   12) Overall pass/fail evaluation of link-under-test for OLTS and OTDR measurements.
   13) [Magnified Endface Inspection:
      a) Picture or image of each fiber end-face.
      b) Pass/fail status of end-face based upon visual inspection.]

I. Drawings:

1. Record Copy: Provide at end of Project on CD-ROM.
   a. CAD format and include notations reflecting as-built conditions of additions and variations from Drawings provided, such as to cable path and termination point.
   b. CAD drawings shall incorporate test data imported from test instruments.
2. As-built Drawings:
   a. Include, but not limited to block diagrams, frame and cable labeling, cable termination points, equipment room layouts, and frame installation details.
   b. Include field changes made up to construction completion:
      1) Field directed changes to pull schedule.

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2) Field directed changes to cross connect and patching schedule.
3) Horizontal cable routing changes.
4) Backbone cable routing or location changes.
5) Associated detail drawings.

3.05 TRAINING

A. Train OWNER's staff in the following skills:

1. Connectorizing fibers.
2. Splicing optical fiber cables, including fiber splices.
3. Testing quality of connectors, splices and fibers.

B. Schedule: Provide two 8-hour training sessions on consecutive weekdays, to suit OWNER's schedule.

C. Materials: Provide hardware for training, including fibers, connectors, and splice kits.

D. Tools: [Provide _____ sets of tool kits for trainees' use.] [Trainees will use specified Contractor-supplied tool kits. Ensure kits are available prior to start of training.]

3.06 SUPPLEMENTS

A. Supplements listed below, following "End of Section," are part of this Specification.

1. As-Built Fiber Optic Cable Installation Form.
2. As-Built Conduit/Innerduct Installation Form.

END OF SECTION

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Contractor: _____
Signed by: _____

AS-BUILT FIBER OPTIC CABLE INSTALLATION

Sheet 1 of 2

Cable Identification: _____
Routing: From: _____ In: _____
(Identify field panel, control room, etc. in building)

Through: 1
(Identify access hole, building, gallery, etc.)
Through: 2 Through: 5
Through: 3 Through: 6
Through: 4 Through: 7
To: In:
See As-Built Conduit/Innerduct Installation forms for identification of conduits/innerducts cable is routed through.

Acceptable Attenuation:
Multimode Fibers

cable length*

850 nm: 3.5 dB/km x km + 1.5 dB = dB
1300 nm: 1.0 dB/km x km + 1.5 dB = dB

*Contractor to provide actual length installed, within ±0.1 km.

Fiber ID	Use/Spare	Measured Attenuation (dB)			
		Hub-to-Node		Node-to-Hub	
		850 nm	1,300 nm	850 nm	1,300 nm

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Single-mode Fibers

	cable length*		
1310 nm:	[1.0] [0.5] dB/km x	km + 1.5 dB =	dB
1550 nm:	[1.0] [0.5] dB/km x	km + 1.5 dB =	dB

*Contractor to provide actual length installed, within ±0.1 km.

Fiber ID	Use/Spare	Measured Attenuation (dB)			
		Hub-to-Node		Node-to-Hub	
		1,310 nm	1,550 nm	1,310 nm	1,550 nm

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Contractor: _____

Signed by: _____

AS-BUILT CONDUIT/INNERDUCT INSTALLATION

From: _____ To: _____
(Identify building, access hole, field panel, etc.) Sheet 1 of 1

Conduits:
Used: 4 inches; 2 inches
Spare: 4 inches; 2 inches Confirm all spares unrestricted: Yes/No
(Provide number of conduits in each category)

Innerducts:

Conduit ID*	Innerduct ID	Cable ID / Spare
(Continued overleaf delete if not applicable) *Provide conduit ID if required to identify innerduct uniquely in the access hole, if for example, color-coded innerduct is used in more than one conduit. If innerducts are tagged uniquely, leave this column blank.		

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SECTION 43 40 02
HIGH DENISTY POLYETHYLENE TANK

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Society of Mechanical Engineers (ASME):
2. ASTM International (ASTM):

1.02 DEFINITIONS

A. HDPE: High Density Polyethylene

1.03 DESIGN REQUIREMENTS

A. Design Loads: See Datasheet

1.04 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. Fabricators catalog information, descriptive literature, specifications, and identification of materials of construction, including complete resin system information.
   b. Letter from resin manufacturer stating that selected resin is suitable for intended service.
   c. Detailed fabrication drawings.
   d. Tank data indicating equipment number, pressure rating, diameter, straight shell lengths, overall lengths, wall thickness, corrosion barrier thickness, and details of nozzle designs.
   e. Tank capacity chart indicating gallons (cubic feet of volume) for each inches of depth and cumulative total from bottom
   f. Fabricator’s detailed requirements for tank foundations.

B. Informational Submittals:

1. Complete design calculations for tanks, supports and appropriate accessories.
2. Fabricator’s Certificate of Compliance with fabrication requirements.
3. Quality Assurance Inspection:.

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4. Certification that supports and access nozzles have been coordinated with actual equipment being furnished.
5. Component and attachment testing seismic certificate of compliance as required Special shipping, storage and protection, and handling instructions.
6. Fabricator's printed installation and tank support instructions.
7. Manufacturer's Certificate of Proper Installation.

1.05 QUALITY ASSURANCE

A. Fabricator's Quality Assurance Supervisor: Minimum of 5 years' experience in producing substantially similar equipment, and shall be able to show evidence of at least five installations in satisfactory operation for at least five years.

B. Designer: Registered professional engineer licensed in California.

C. Independent HDPE Quality Assurance Inspector:

1. Minimum 5 years' experience as HDPE tank inspector.
2. Representing a corporately and financially independent organization that can function as an unbiased inspection authority.
3. Professionally independent of manufacturers, suppliers, and installers of systems being inspected.

1.06 DELIVERY, STORAGE, AND HANDLING

A. In accordance with Section 01 61 00, Common Product Requirements. In addition, prepare and protect tank for shipment as follows:

1. Mount tank on padded cradles if shipped horizontally or on a suitable skid if shipped vertically.
2. Protect flanged nozzles with wooden blinds bolted to flange and having a diameter of 2 inches greater than outside diameter of flange.
3. Provide either rigid plugs inside ends to prevent deflection or wooden boxes for unflanged components. Brace open end of tank with suitable stiffening member to prevent deflection.
4. Do not ship components or other pieces loose inside tank.
5. Load tank with at least 2 inches of clearance between tank (including fittings) and bulkheads, or bed of vehicle.
6. Regardless of mode of transportation, firmly fasten and pad components to prevent shifting of load or flexing of components while in transit.

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1.07 SEQUENCING AND SCHEDULING

A. Do not ship tank from factory until Engineer's review of Certification of Factory Testing is completed.

PART 2 - PRODUCTS

2.01 SUPPLEMENTS

A. Some specific requirements relative to this section are attached as supplements at the end of section.

2.02 SERVICE CONDITIONS

A. Operating Pressure: Atmospheric.

2.03 MATERIALS

A. Resin: Suitable for intended service.

1. Premium grade and corrosion resistant.
2. Post-cure tank and appurtenances in accordance with resin manufacturer's recommendation for time and temperature. Post-curing should be completed with warm-to-hot dry air, free of combustion products. Hot spots shall be avoided.
3. For hypochlorite service, no MEKP cobalt catalyst system shall be allowed in liner. Cure liner with benzoyl peroxide-dimethyl aniline. Structural layer may be cured with either catalyst system.
4. Apply a white color coat after inspection of laminate has been completed.

B. Marking:

1. Identify each tank with fabricator's name, capacity in gallons, maximum temperature, design pressure/vacuum, specific gravity, pH, resin, minimum thickness, tank number, tank name, and date of manufacture.
2. Provide permanent marking. Seal decals, labels, etc., into laminate exterior with clear resin.
3. Calibration Strips:
   a. Translucent, 6 inches wide.
   b. Calibration: Multiples of 50 gallons or less.
   c. Stencil gallonage in 2-inch-high numerals.

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C. Nozzles:

1. Gusset 4-inch or smaller nozzles with conical or plate type gussets. Larger nozzles shall be gusseted, if noted.
2. Finish flush with inside surface of tank, unless otherwise indicated.
3. Gaskets:
   a. Provide two per nozzle, 1/8-inch-thick, full-face elastomeric material having a hardness of Shore A60 plus or minus 5.
   b. Material shall be suitable for intended service.
4. Flanged Nozzles: Rated at 100 psi, with other dimensions and bolting corresponding to ASME B16.5 for 150-pound steel flanges.
5. Back face of flanges shall be spot-faced, flat and parallel to flange face of sufficient diameter to accept SAE metal washer under bolthead or nut.

D. Dip-Pipes:

1. Provide inside and outside surfaces of dip-pipes with corrosion barrier.
2. Surfacing veil for this corrosion barrier shall be same as specified for tank.
3. Corrosion barrier shall consist of appropriate surfacing veil, backed by two layers of fiberglass mat.
4. If "ready-made" pipe is used, it shall have an equivalent internal corrosion barrier and shall have specified corrosion barrier applied to outside surface.

2.04 APPURTENANCES

A. Supports:

1. Pipe Supports:
   a. Provide for tank overflow pipes, loading pipes and recirculation pipes.
   b. Spacing of supports shall be as recommended by fabricator, but shall not be greater than 4 feet on center.

B. Lifting Lugs: Provide suitably attached for tank weighing over 100 pounds.

C. Anchor Bolts: Type 316 stainless steel bolts.

D. Manway Bolts: Type 316 stainless steel bolts

E. Heat Tracing

2.05 SOURCE QUALITY CONTROL

A. Factory Test Reports: Certify results, by signature, of the following:

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1. Inspections.
   a. Results of hydrostatic testing.
   b. Test reports of physical properties of standard laminates.

PART 3 - EXECUTION

3.01 INSTALLATION

A. In accordance with fabricator's written instructions.

B. Accurately place anchor bolts using templates furnished by fabricator.

3.02 FIELD QUALITY CONTROL

A. Functional Test:

1. Conduct on each tank.
2. Hydrostatic leak test with tank full of clean water. Allow water to stand for 24 hours to verify no leakage.

3.03 MANUFACTURER'S FIELD SERVICES

A. Provide fabricator's representative at Site for installation assistance, inspection and certification of proper installation for equipment.

3.04 SUPPLEMENTS

A. The supplements listed below, following "End of Section," are part of this specification.

1. HDPE Tank Schedule.
2. Equipment Data Sheet

END OF SECTION

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HDPE Tank Schedule						
Name of Tank*	**25% Caustic Storage Tank**	**Coagulant Storage Tank**	**19% HCl Acid Tank**	**MW-20 Well Maint. Reagent Day Tank**	**TW Bench Well Maint. Reagent Day Tank**	**TW Bench Purge Water Return Tank**
Equipment Numbers	TNK-421	TNK-431	TNK-441	*T719	*T903	*T904
Filament-wound or Contact-molded						
Maximum Capacity Measured to High Solution Level (gallons)	500	500 (Note 1)	500	1,000 gal	500 gal	1,000 gal
Installation (Vertical/Horizontal)	Vertical - Note 3	Vertical - Note 3	Vertical - Note 3	Vertical	Vertical	Vertical
Diameter (feet)	*	*	*	*	*	*
Straight Shell Height (feet)	*	*	*	*	*	*
Support (saddles, flat pad, legs)	*	*	*	*	*	*
Type of Bottom Head	Flat	Flat	Flat	Flat	Flat	Flat
Type of Top Head	Dished	Dished	Dished	Dished	Dished	Dished
Ladder Required (Yes/No)	No	No	No	No	No	No
Tank Location (indoor/outdoor)	Indoor	Indoor	Indoor	Indoor	Indoor	Indoor

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HDPE Tank Schedule						
Name of Tank*	**25% Caustic Storage Tank**	**Coagulant Storage Tank**	**19% HCl Acid Tank**	**MW-20 Well Maint. Reagent Day Tank**	**TW Bench Well Maint. Reagent Day Tank**	**TW Bench Purge Water Return Tank**
Ambient Temperature Range (degrees F)	60-110°F	60-110°F	60-110°F	60-110°F	60-110°F	60-110°F
Exterior Loading (psf):						
Personnel Roof Loads	*	*	*	*	*	*
Platforms	*			*	*	*
Mixers	N/A	N/A	N/A	N/A	N/A	N/A
Pipe Supports	*	*	*	*	*	*
Operating Contents:						
Temperature (degrees F, not to exceed 180)	75°F	75°F	75°F	75°F	75°F	75°F
Chemical Composition	25% Caustic	Note 2	19% HCl	Note 2	Note 2	Note 2
Specific Gravity	1.28	Note 2	1.09	Note 2	Note 2	Note 2
Concentration	25%	Note 2	19%	Note 2	Note 2	Note 2
pH Range	14	Note 2	7	Note 2	Note 2	Note 2

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HDPE Tank Schedule						
Name of Tank*	**25% Caustic Storage Tank**	**Coagulant Storage Tank**	**19% HCl Acid Tank**	**MW-20 Well Maint. Reagent Day Tank**	**TW Bench Well Maint. Reagent Day Tank**	**TW Bench Purge Water Return Tank**
Sight Glass Type (1 or 2)						
Sight Glass Tube Length						
Insulation/Heat Tracing (Yes/No)	Yes, Tracing	Yes, Tracing	Yes, Tracing	No	No	No
*Specify feed/mix tanks as such.						

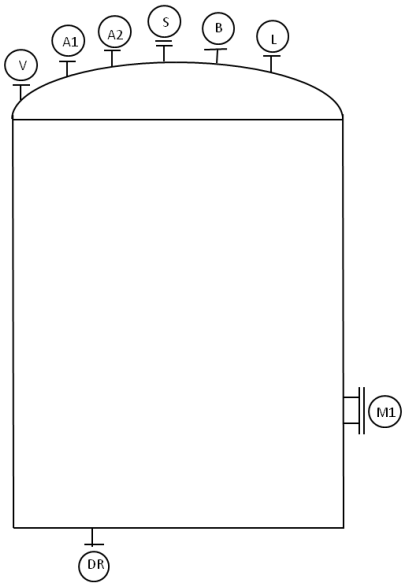
NOTES:

*- Manufacturer to Specify
1. Capacity to be determined.
2. Tank contents to be determined.
3. Tank to be double wall and heat traced.

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Project No.: 435062	CH2MHILL	By: Rolana Harris
Owner: PG&E		Date: 07-18-2012
		Equipment No.: TNK-421421, TNK-431431, TNK-441441
	EQUIPMENT DATA SHEET	Equipment Name: Influent Storage Tank # 1, 2, 3, 4



Nozzle Table

* - Manufacturer to provide information

Mark	Req'd	Size	Rating	Type	Face	Service
A1	1	2″	150#	RF	WN	Chemical Inlet
A2	1	2″	150#	RF	WN	Recirculation
B	1	2″	150#	RF	WN	Outlet
DR	1	2″	150#	RF	WN	Drain
L	1	3″	150#	RF	WN	Level Element
M	1	18″	150#	RF	WN	Manway
S	1	2″	150#	RF	WN	Spare
V	1	3″	150#	RF	WN	Vent

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SECTION 43 40 13
STEEL STORAGE TANK

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Society of Mechanical Engineers (ASME):
2. ASTM International (ASTM):

1.02 DESIGN REQUIREMENTS

A. Design Loads: See Datasheet

1.03 SUBMITTALS

A. Action Submittals: Submit the following:

1. Shop Drawings:
   a. Layout and all critical dimensions.
   b. Materials.
   c. Fitting locations and details.
   d. Accessories.
   e. Anchors and holddowns, as required.
   f. Internal floating roof and appurtenances.
   g. Foam fire suppression system design, layout and certification.
2. Product Data:
   a. Manufacturer's literature, illustrations, calibration charts, specifications, engineering data and installation instructions.

B. Informational Submittals: Submit the following:

1. Certificates:
   a. Certification of Design.
   b. Certificate of Compliance for Lightning Protection Systems.
2. Source Quality Control Submittals:
   a. Shop test reports.
3. Site Quality Control Submittals:
   a. Field inspection reports as specified in Part 3 of this specification.

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1.04 QUALITY ASSURANCE

A. Fabricator's Quality Assurance Supervisor: Minimum of 5 years' experience in producing substantially similar equipment, and shall be able to show evidence of at least five installations in satisfactory operation for at least five years.

B. Designer: Registered professional engineer licensed in California.

C. Independent Quality Assurance Inspector:

1. Minimum 5 years' experience as steel tank inspector.
2. Representing a corporately and financially independent organization that can function as an unbiased inspection authority.
3. Professionally independent of manufacturers, suppliers, and installers of systems being inspected.

1.05 DELIVERY, STORAGE, AND HANDLING

A. In accordance with Section 01 61 00, Common Product Requirements. In addition, prepare and protect tank for shipment as follows:

1. Mount tank on padded cradles if shipped horizontally or on a suitable skid if shipped vertically.
2. Protect flanged nozzles with wooden blinds bolted to flange and having a diameter of 2 inches greater than outside diameter of flange.
3. Provide either rigid plugs inside ends to prevent deflection or wooden boxes for unflanged components. Brace open end of tank with suitable stiffening member to prevent deflection.
4. Do not ship components or other pieces loose inside tank.
5. Load tank with at least 2 inches of clearance between tank (including fittings) and bulkheads, or bed of vehicle.
6. Regardless of mode of transportation, firmly fasten and pad components to prevent shifting of load or flexing of components while in transit.

1.06 SEQUENCING AND SCHEDULING

A. Do not ship tank from factory until Engineer's review of Certification of Factory Testing is completed.

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PART 2 - PRODUCTS

2.01 SUPPLEMENTS

A. Some specific requirements relative to this section are attached as supplements at the end of section.

2.02 SERVICE CONDITIONS

A. Operating Pressure: Atmospheric.

2.03 MATERIALS

A. Construction

1. Tanks shall be fabricated in accordance with API Standard 650, Welded Steel Tanks for Oil Storage (Shop Fabricated).
2. Steel shall conform to ASTM A 36.
3. Minimum thickness for any part of the storage tank, wall, floor or roof shall be a minimum thickness, as determined in API-650 or as specified, whichever is greater.
4. All tanks shall be fabricated using a minimum number of joints.
5. All welds shall be non-porous and free from pinholes, cracking and under-cutting. Sharp edges and high spots shall be ground smooth. Corners shall be ground to a minimum radius of 1/8-inch. All weld flux, spatter and foreign matter shall be removed. All welds shall be continuous and smooth and by ASME Code qualified welders.
6. Interior and exterior surfaces and appurtenances shall be painted in accordance with Section 09 91 00, Painting.
7. The tanks shall be sealed air tight at all openings prior to shipment and installation.
8. Tanks shall be double walled with a 6-inch thick lightweight insulating concrete.

B. Nozzles:

1. Gusset 4-inch or smaller nozzles with conical or plate type gussets. Larger nozzles shall be gusseted, if noted.
2. Finish flush with inside surface of tank, unless otherwise indicated.
3. Gaskets:
   a. Provide two per nozzle, 1/8-inch-thick, full-face elastomeric material having a hardness of Shore A60 plus or minus 5.
   b. Material shall be suitable for intended service.
4. Flanged Nozzles: Rated at 100 psi, with other dimensions and bolting corresponding to ASME B16.5 for 150-pound steel flanges.

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5. Back face of flanges shall be spot-faced, flat and parallel to flange face of sufficient diameter to accept SAE metal washer under bolthead or nut.

C. Dip-Pipes:

1. Provide inside and outside surfaces of dip-pipes with corrosion barrier.
2. Surfacing veil for this corrosion barrier shall be same as specified for tank.
3. Corrosion barrier shall consist of appropriate surfacing veil, backed by two layers of fiberglass mat.
4. If "ready-made" pipe is used, it shall have an equivalent internal corrosion barrier and shall have specified corrosion barrier applied to outside surface.

2.04 APPURTENANCES

A. Supports:

1. Pipe Supports:
   a. Provide for tank overflow pipes, loading pipes and recirculation pipes.
   b. Spacing of supports shall be as recommended by fabricator, but shall not be greater than 4 feet on center.

B. Lifting Lugs: Provide suitably attached for tank weighing over 100 pounds.

C. Anchor Bolts: Type 316 stainless steel bolts.

D. Manway Bolts: Type 316 stainless steel bolts

2.05 SOURCE QUALITY CONTROL

A. Factory Test Reports: Certify results, by signature, of the following:

1. Inspections.
2. Results of hydrostatic testing.
3. Test reports of physical properties of standard laminates.

PART 3 - EXECUTION

3.01 INSTALLATION

A. In accordance with fabricator's written instructions.

B. Accurately place anchor bolts using templates furnished by fabricator.

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3.02 FIELD QUALITY CONTROL

A. Functional Test:

1. Conduct on each tank.
2. Hydrostatic leak test with tank full of clean water. Allow water to stand for 24 hours to verify no leakage.

3.03 MANUFACTURER'S FIELD SERVICES

A. Provide fabricator's representative at Site for installation assistance, inspection and certification of proper installation for equipment.

3.04 SUPPLEMENTS

A. The supplements listed below, following "End of Section," are part of this specification.

1. Steel Tank Schedule.

END OF SECTION

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Steel Tank Schedule	
Name of Tank*	**MW-20 Carbon Substrate Tank**
Equipment Numbers	*T701
Filament-wound or Contact-molded	
Maximum Capacity Measured to High Solution Level (gallons)	15,000 gal
Installation (Vertical/Horizontal)	Horizontal
Diameter (feet)	*
Straight Shell Height (feet)	*
Support (saddles, flat pad, legs)	*
Type of Ends	Flat
Ladder Required (Yes/No)	No
Tank Location (indoor/outdoor)	Outdoor
Ambient Temperature Range (degrees F)	60-110°F
Exterior Loading (psf):	
Personnel Roof Loads	*
Platforms	*
Mixers	N/A
Pipe Supports	*
Operating Contents:	
Temperature (degrees F, not to exceed 180)	75°F
Chemical Composition	Note 2
Specific Gravity	Note 2
Concentration	Note 2
pH Range	Note 2
Sight Glass Type (1 or 2)	
Sight Glass Tube Length	
Insulation/Heat Tracing (Yes/No)	No
*Specify feed/mix tanks as such.	
NOTES: *- Manufacturer to Specify 1. Capacity to be determined. 2. Tank contents to be determined. 3. Tank to be double wall and heat traced	

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SECTION 44 44 13.01
CHEMICAL METERING PUMPS

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. Institute of Electrical and Electronics Engineers (IEEE): 112, Standard Test Procedure for Polyphase Induction Motors and Generators.
2. Hydraulic Institute Standards.
3. National Electrical Manufacturer's Association (NEMA): MG 1, Motors and Generators.

1.02 DEFINITIONS

A. Terminology pertaining to pumping unit performance and construction shall conform to the ratings and nomenclature of the Hydraulic Institute Standards.

1.03 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. Make, model, weight, and horsepower of each equipment assembly.
   b. Complete catalog information, descriptive literature, specifications, and identification of materials of construction.
   c. Performance data on pumps, including curves showing flow rate verses pump stroke setting (in percent) at specified maximum speed in strokes per minute [and at minimum pump speed].
   d. Pump data sheet confirming pump capacity in gallons per hour and pressure in psig, required backpressure valve setting, pumped chemical characteristics, pipe connection sizes, stroke rate, materials, testing requirements, intermediate fluid type, and appurtenances to be provided with pumps.
   e. Detailed dimensional drawings for pump and driver, including mounting requirements and piping connection sizes and locations.
   f. Power and control wiring diagrams, including terminals and numbers.
   g. Complete motor nameplate data, as defined by NEMA, motor manufacturer, and including any motor modifications.
   h. Manufacturer's materials compatibility information, confirming compatibility of wetted parts with specified pumped chemicals.

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i. Factory finish system.

B. Informational Submittals:

1. Factory Functional Test Reports.
2. Special shipping, storage and protection, and handling instructions.
3. Manufacturer's printed installation instructions.
4. Suggested spare parts list to maintain the equipment in service for a period of 1 year and 5 years. Include a list of special tools required for checking, testing, parts replacement, and maintenance with current price information.
5. List special tools, materials, and supplies furnished with equipment for use prior to and during startup and for future maintenance.
6. Operation and Maintenance Data

1.04 EXTRA MATERIALS

A. Furnish for each pump:

1. One complete pump, drive motor, and gear box.
2. One variable speed drive controller.
3. One diaphragm back pressure control valve.
4. One printed circuit board of each type.
5. One complete set of any special tools required to dismantle pump.

PART 2 - PRODUCTS

2.01 GENERAL

A. Coordinate pump requirements with drive manufacturer and be responsible for pump and drive requirements.

B. Where adjustable speed drives are required, furnish a coordinated operating system complete with pump, drive, and speed controller.

2.02 PUMP

A. Positive displacement self-compensating hydraulically activated diaphragm type consisting of simplex pumping heads, with internal automatic pressure relief valve, external manually adjustable stroke positioner from 0 percent to 100 percent, and with maximum stroke rate as specified in attached Pump Data Sheet.

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B. Alternatively, pump shall be simplex, motor-driven, reciprocating, mechanically-actuated diaphragm type. Pump shall include an integral motor, oil-lubricated gear reducer and a cam-spring drive mounted in aluminum housing. Maximum stroke rate shall be as specified in attached Pump Data Sheet.

C. Lubricant, nontoxic-food grade quality.

D. Pump leakage shall be prevented through diaphragm design.

E. Pump shall include adjustable, spring-loaded internal pressure relief valve to protect pump against excessive hydraulic pressure.

2.03 PULSATION DAMPENERS

A. Single diaphragm type mounted on discharge piping as shown for pneumatic-hydraulic pulsation dampening. Size for pump-stroke volume.

B. Air charging valve and pressure gauge.

2.04 VALVES

A. Adjustable diaphragm backpressure sustaining type installed on pump discharge and set at **[___]** psig as recommended by pump manufacturer

B. Adjustable pressure relief type installed on pump discharge as shown on Drawings and set at **[___]** psig as recommended by pump manufacturer.

2.05 ACCESSORIES

A. Equipment Identification Plate: 16-gauge stainless steel with 1/4-inch die-stamped equipment tag number securely mounted in a readily visible location.

B. Lifting Lugs: Equipment weighing over 100 pounds.

C. Anchor Bolts**:** [Galvanized,] [Type 316 stainless steel,] [sized by equipment manufacturer,] [1/2-inch minimum diameter,] and as specified in Section 05 50 00, Metal Fabrications. [Coat in accordance with Section 09 90 00, Painting and Coating.]

D. Gauge Connections: Tapped and plugged suction and discharge gauge connections on piping headers adjacent to pumps.

E. Screens or Guards: Mesh size of less than 0.5 inch, exposed rotating shafts, rotors, couplings, pulley, wheel, bolts, chains, or similar components. Where

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guards/screens are over grease fittings, couplings, or other items requiring maintenance, provide a means for ready access.

F. Calibrated Cylinder: Graduated in 50-ml increments, constructed of clear polypropylene and PVC with ball type shutoff valve. Provide calibration column.

2.06 FACTORY FINISHING

A. Manufacturer's standard finish.

2.07 SOURCE QUALITY CONTROL

A. Factory Test Report:

B. Functional Test: Perform manufacturer's standard.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install in accordance with manufacturer's printed instructions.

3.02 FIELD QUALITY CONTROL

A. Conduct tests on each pump.

B. Functional Test:

1. Alignment: Test complete assemblies for correct rotation, proper alignment and connection, and quiet operation.

C. Performance Test:

1. Perform under actual or approved simulated operating conditions.
2. Test for a continuous 3-hour period without malfunction.

3.03 MANUFACTURER'S SERVICES

A. Manufacturer's Representative: Present at Site or classroom designated by Owner for minimum person-days listed below, travel time excluded:

1. 1-person-days for installation assistance and inspection.

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3.04 SUPPLEMENTS

A. Supplement listed below, following "End of Section," are part of this Specification.

1. Data Sheet: Pump and motor.

END OF SECTION

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CHEMICAL METERING PUMP DATA SHEET, 44 44 13.01

Tag Numbers: PMP-421A/B

Pump Name: Caustic Feed Pump 1 & 2

Manufacturer and Model Number: (1) LMI Milton Roy – C78

(2) Pulsafeeder

SERVICE CONDITIONS

Liquid Pumped (Material and Percent): 25% NaOH

Pumping Temperature (Fahrenheit): Normal: 75 Max 110 Min 60

Liquid pH: 14

Abrasive (Y/N) N (Highly Corrosive) Possible Scale Buildup (Y/N): N

Suction Pressure (psig): Minimum 0

Altitude (ft msl): 625 Area Classification: Not classified Location (indoor/outdoor): Indoor

PERFORMANCE REQUIREMENTS

Capacity (US gpm): Maximum: 35 Minimum: 20

Maximum Discharge Pressure (psig): 30 psi

Internal Bypass Valve Setting (psig): *

Relief Valve Setting (psig/as recommended): *

Back Pressure Valve Setting (psig/as recommended): *

Max. Stroke Rate (spm): Mfr. (1) 100 Mfr. (2)

DESIGN AND MATERIALS

Pump Type: Single Diaphragm (Y/N) Y

Tubular (double) Diaphragm (Y/N) N Other

Wet End Material: Teflon Tubular Diaphragm Housing Material: N/A

Check Valve Material: Configuration(Single/Double):

Diaphragm Material: Primary: Tubular: N/A

Calibration Cylinder: Quantity: 2 Material: Units: Capacity:

Diaphragm Actuation Type: Mechanical Hydraulic

Stroke Position Adjustment: Manual Automatic X

Pump Speed Control: Constant Variable X

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CHEMICAL METERING PUMP DATA SHEET, 44 44 13.01

Tag Numbers: PMP-421A/B

DRIVE MOTOR (See Section 26 20 00, Low-Voltage AC Induction Motors)

Horsepower: * Voltage: 120 Phase: 3

Synchronous Speed (rpm)_____ Service Factor: 1.15

Motor nameplate horsepower shall not be exceeded at any head-capacity point on pump curve.

Enclosure: DIP _____ EXP ____ ODP ____ TEFC X____

CISD-TEFC ___TENV ____ WPI ____ WPII _____

SUBM ____

TESTING

Pump Tests: Factory Functional (Y/N) Y_____ Factory Performance (Y/N) __Y__

Field Functional (Y/N) Y_____ Field Performance (Y/N) Y_____

Motor Test: Short Commercial (Y/N) _____ Other _____

REMARKS:

* Vendor Supplied Information

1. Vendor to provide motor and horsepower requirements
2. Unless, otherwise stated, vendor to provide, backpressure protection, integral bypass, pressure relief valve, and pulsation damper.

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CHEMICAL METERING PUMP DATA SHEET, 44 44 13.01

Tag Numbers: PMP-431A/B

Pump Name: Coagulant Feed Pump 1& 2

Manufacturer and Model Number: (1) LMI Milton Roy – C78

(2) Pulsafeeder

SERVICE CONDITIONS

Liquid Pumped (Material and Percent): TBD

Pumping Temperature (Fahrenheit): Normal: 75 Max 110 Min 60

Liquid pH: 14

Abrasive (Y/N) TBD Possible Scale Buildup (Y/N): N

Suction Pressure (psig): Minimum 0

Altitude (ft msl): 890 Area Classification: Not classified Location (indoor/outdoor): Indoor

PERFORMANCE REQUIREMENTS

Capacity (US gpm): Maximum: 35 Minimum: 20

Maximum Discharge Pressure (psig): 30 psi

Internal Bypass Valve Setting (psig): *

Relief Valve Setting (psig/as recommended): *

Back Pressure Valve Setting (psig/as recommended): *

Max. Stroke Rate (spm): Mfr. (1) 100 Mfr. (2) _____

DESIGN AND MATERIALS

Pump Type: Single Diaphragm (Y/N) Y

Tubular (double) Diaphragm (Y/N) N Other _____

Wet End Material: Teflon Tubular Diaphragm Housing Material: N/A

Check Valve Material: _____ Configuration(Single/Double): _____

Diaphragm Material: _____ Primary: _____ Tubular: N/A

Calibration Cylinder: Quantity: 2 Material: ____ Units: ____ Capacity: _____

Diaphragm Actuation Type: Mechanical _____ Hydraulic _____

Stroke Position Adjustment: Manual _____ Automatic X

Pump Speed Control: Constant _____ Variable X

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CHEMICAL METERING PUMP DATA SHEET, 44 44 13.01

Tag Numbers: PMP-431A/B

DRIVE MOTOR (See Section 26 20 00, Low-Voltage AC Induction Motors)

Horsepower: * Voltage: 120 Phase: 3

Synchronous Speed (rpm)

Service Factor: 1.15

Motor nameplate horsepower shall not be exceeded at any head-capacity point on pump curve.

Enclosure: DIP ____ EXP ____ ODP ____
TEFC X CISD-TEFC ____ TENV ____
WPI ____ WPII ____ SUBM ____

TESTING

Pump Tests: Factory Functional (Y/N) Y Factory Performance (Y/N) Y
Field Functional (Y/N) Y Field Performance (Y/N) Y
Motor Test: Short Commercial (Y/N) ____ Other ____

REMARKS

* Vendor Supplied Information

1. Vendor to provide motor and horsepower requirements
2. Unless, otherwise stated, vendor to provide, backpressure protection, integral bypass, pressure relief valve, and pulsation damper.

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CHEMICAL METERING PUMP DATA SHEET, 44 44 13.01

Tag Numbers: PMP-441A/B

Pump Name: Acid Feed Pump 1 & 2

Manufacturer and Model Number: (1) LMI Milton Roy – C78

(2) Pulsafeeder

SERVICE CONDITIONS

Liquid Pumped (Material and Percent): 19% Hydrochloric Acid

Pumping Temperature (Fahrenheit): Normal: 75 Max 110 Min 60

Liquid pH: 14

Abrasive (Y/N) N (Highly Corrosive) Possible Scale Buildup (Y/N): N

Suction Pressure (psig): Minimum 0

Altitude (ft msl): 890 Area Classification: Not classified Location (indoor/outdoor): Indoor

PERFORMANCE REQUIREMENTS

Capacity (US gpm): Maximum: 35 Minimum: 20

Maximum Discharge Pressure (psig): 30 psi

Internal Bypass Valve Setting (psig): *

Relief Valve Setting (psig/as recommended): *

Back Pressure Valve Setting (psig/as recommended): *

Max. Stroke Rate (spm): Mfr. (1) 100 Mfr. (2) _____

DESIGN AND MATERIALS

Pump Type: Single Diaphragm (Y/N) Y

Tubular (double) Diaphragm (Y/N) N Other _____

Wet End Material: Teflon Tubular Diaphragm Housing Material: N/A

Check Valve Material: _____ Configuration(Single/Double): _____

Diaphragm Material: _____ Primary: _____ Tubular: N/A

Calibration Cylinder: Quantity: 2 Material: _____ Units: _____ Capacity: _____

Diaphragm Actuation Type:

Mechanical _____ Hydraulic _____

Stroke Position Adjustment:

Manual _____ Automatic X

Pump Speed Control: Constant _____ Variable X

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CHEMICAL METERING PUMP DATA SHEET, 44 44 13.01

Tag Numbers: PMP-441A/B

DRIVE MOTOR (See Section 26 20 00, Low-Voltage AC Induction Motors)

Horsepower: * Voltage: 120 Phase: 3

Synchronous Speed (rpm)____ Service Factor: 1.15

Motor nameplate horsepower shall not be exceeded at any head-capacity point on pump curve.

Enclosure: DIP ____ EXP ____ ODP ____ TEFC X CISD-TEFC ____

TENV ____WPI ____ WPII ____ SUBM ____

TESTING

Pump Tests: Factory Functional (Y/N) Y Factory Performance (Y/N) Y

Field Functional (Y/N) Y Field Performance (Y/N) Y

Motor Test: Short Commercial (Y/N) ____ Other _____

REMARKS

* Vendor Supplied Information

1. Vendor to provide motor and horsepower requirements
2. Unless, otherwise stated, vendor to provide, backpressure protection, integral bypass, pressure relief valve, and pulsation damper.

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SECTION 44 42 56.04
SUBMERSIBLE PUMPS

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards that may be referenced in this section:

1. American Society of Mechanical Engineers (ASME):
2. ASTM International (ASTM):
3. Hydraulic Institute Standards (HIS):
4. National Electrical Manufacturers Association (NEMA).
5. National Fire Protection Association (NFPA): 70, National Electrical Code.
6. Underwriters Laboratories Inc. (UL).

1.02 DEFINITIONS

A. Terminology pertaining to pumping unit performance and construction shall conform to ratings and nomenclature of Hydraulic Institute Standards.

1.03 SUBMITTALS

A. Action Submittals:

1. Make, model, weight, and horsepower of each equipment assembly.
2. Complete catalog information, descriptive literature, specifications, and identification of materials of construction, including cable seal details.
3. Performance data curves showing head, capacity, horsepower demand, and pump efficiency over entire operating range of pump, from shutoff to maximum capacity. Indicate separately head, capacity, horsepower demand, overall efficiency, and minimum submergence required at guarantee point.
4. Power and control wiring diagrams, including terminals, and numbers.
5. Motor data, in accordance with the requirements of Section 26 20 00, Low-Voltage AC Induction Motors.
6. Factory-finish system.

B. Informational Submittals:

1. Seismic anchorage and bracing calculations as required by Section 01 88 15, Seismic Anchorage and Bracing.
2. Special shipping, storage and protection, and handling instructions.

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3. Manufacturer's printed installation instructions.
4. Suggested spare parts list to maintain equipment in service for period of 1 year. Include list of special tools required for checking, testing, parts replacement, and maintenance with current price information.
5. List special tools, materials, and supplies furnished with equipment for use prior to and during startup and for future maintenance.
6. Operation and Maintenance Data.

PART 2 - PRODUCTS

2.01 GENERAL

A. Submersible pump for pumping wastewater.

B. Designed for intermittent operation under submerged conditions.

2.02 COMPONENTS

A. Equipment consists of pump complete with motor, control system, guide rail, anchoring brackets, base elbow, power cable, and pump lifting cable and control panel and level switches.

B. Motor nameplate horsepower not to be exceeded at head-capacity point on pump curve.

C. Pump motor and sensor cables shall be suitable for submersible pump application and cable sizing shall conform to NEC specifications for pump motors. Cables shall be of sufficient length to reach junction boxes without strain or splicing.

D. Pumps to be designed, manufactured, and tested in accordance with all applicable ANSI/HI 2000 Standards

2.03 ACCESSORIES

A. Equipment Identification Plate: 16-gauge stainless steel with 1/4-inch die-stamped equipment tag number securely mounted in readily visible location.

2.04 SOURCE QUALITY CONTROL

A. Submersible Motor Functional Test: In accordance with HIS 11.6.

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PART 3 - EXECUTION

3.01 MANUFACTURER'S SERVICES

A. Manufacturer's Representative: Present at Site or classroom designated by OWNER for minimum person-days listed below, travel time excluded:

1. 1 person-days for installation assistance, inspection, and functional performance testing.

3.02 SUPPLEMENTS

A. The supplements listed below, following "End of Section," are part of this Specification.

1. Data Sheets: Pump including Motor Information.

END OF SECTION

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SUBMERSIBLE WELL PUMP DATA SHEET, 44_42-56.04A

Equipment Tag Numbers: PMP-001

Service: Freshwater Injection well, FW-001, Backwash Pump	
Pump Manufacturer **1. Grundfos** **2.** **3.**	**Model 385S400-5**
No .Pumps Required: 1	Drive Type: Constant (Note 1)
LIQUID	**OPERATING/SERVICE CONDITIONS**
Liquid Pumped: Freshwater/Backwash	**Capacity: (US gpm): Rated: 400**
Pumping Temperature (°F):	TDH at Submersible Pump Outlet (ft): 276
Normal 86 Max 130 Min 20	Suction Pressure Minimum Submergence: 5 ft
Specific Gravity at 60°F: 1	NPSH Available@ rated Capacity: XX at min. pump submergence
Vapor Pressure at 60°F: 0.256 psia	Min. Pump Bowl Efficiency @ rated Capacity: *
Viscosity (cP): 1	**Location: Topock, Needles, CA**
pH: 6.5-8.5	Seismic Information: Site Class D Seismic Design category: D Ss = 0.434, S1=0.135
Corrosion/Erosion caused by: Corrosives /chlorides in water	Elevation: Ground Surface: 488 Depth to Water: 36 Depth to Pump Screen: 113
PERFORMANCE REQUIREMENTS:	
Pump Speed Range (rpm) - *	
Max Pump Speed @ Rated Capacity (rpm): 3450	
Notes: *- Manufacturer to Specify 1. Backwash Pump operates intermittently on a daily backwash cycle	

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COMPONENTS	
IMPELLER	**PUMP COLUMN**
Impeller Type: *	Column Material: Schedule 80 PVC
Impeller Material: Type 304 stainless steel	Size: Well has 14”-inch diameter. Pump Submergence is 80’. Well is 353’ deep
Impeller Wear Ring: Manufacturer to Specify	Connections: Manufacturer to Specify
BOWL AND BELL	**MOTOR**
Bowl and Suction Case Material: Type 304 stainless steel	Type: Grunfos
Bowl and Suction Case Bearings: Manufacturer to Specify	Material: Type 304 stainless steel
Suction Bell: Type 304 stainless steel	
Strainer: Pump Screen Type 304 stainless steel	**FACTORY TESTING**
	X Required: Field Performance Testing/Startup Assistance
	MECHANICAL SEAL
	Manufacturer: Manufacturer to Specify
	Model: Manufacturer to Specify
	Material: Manufacturer to Specify
	API Class Code: N/A
	Rotating Face: Manufacturer to Specify
	Stationary Face: Manufacturer to Specify
	O-Rings: Manufacturer to Specify
Notes:	

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ELECTRIC MOTOR DATA	
Type: Grunfos Submersible Manufacturer: For multiple units of this same type of equipment, furnish motors and accessories of a single manufacturer. Service Factor (rated @ maximum ambient temperature): 1.15 at 50°C ambient	
General:	Driven Speed:
Motor Horsepower: Manufacturer to Specify	Constant Speed: 3,600 rpm, synchronous
Voltage: 460	
Phase: 3	
Frequency: 60-Hz	
Torque: Variable	
Additional Requirements:	

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SUBMERSIBLE WELL PUMP DATA SHEET, 44_42-56.04A

Equipment Tag Numbers: PMP-002

Service: Freshwater Injection well, FW-002, Backwash Pump	
Pump Manufacturer **1. Grundfos** **2.** **3.**	**Model 230S150-5B**
No .Pumps Required: 1	Drive Type: Constant (Note 1)
LIQUID	**OPERATING/SERVICE CONDITIONS**
Liquid Pumped: Freshwater/Backwash	**Capacity: (US gpm): Rated: 200**
Pumping Temperature (°F):	TDH at Submersible Pump Outlet (ft): 204
Normal 86 Max 130 Min 20	Suction Pressure Minimum Submergence: 5 ft
Specific Gravity at 60°F: 1	NPSH Available@ rated Capacity: XX at min. pump submergence
Vapor Pressure at 60°F: 0.256 psia	Min. Pump Bowl Efficiency @ rated Capacity: *
Viscosity (cP): 1	**Location: Topock, Needles, CA**
pH: 6.5-8.5	Seismic Information: Site Class D Seismic Design category: D Ss = 0.434, S1=0.135
Corrosion/Erosion caused by: Corrosives /chlorides in water	Elevation: Ground Surface: 565 Depth to Water: 110 Depth to Pump Screen: 187
PERFORMANCE REQUIREMENTS:	
Pump Speed Range (rpm) - *	
Max Pump Speed @ Rated Capacity (rpm): 3450	
Notes: *- Manufacturer to Specify 1. Backwash Pump operates intermittently on a daily backwash cycle	

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COMPONENTS	
IMPELLER	**PUMP COLUMN**
Impeller Type: *	Column Material: Schedule 80 PVC
Impeller Material: Type 304 stainless steel	Size: Well has 14”-inch diameter. Pump Submergence is 80’. Well is 139’ deep
Impeller Wear Ring: Manufacturer to Specify	Connections: Manufacturer to Specify
BOWL AND BELL	**MOTOR**
Bowl and Suction Case Material: Type 304 stainless steel	Type: Grunfos
Bowl and Suction Case Bearings: Manufacturer to Specify	Material: Type 304 stainless steel
Suction Bell: Type 304 stainless steel	
Strainer: Pump Screen Type 304 stainless steel	**FACTORY TESTING**
	X Required: Field Performance Testing/Startup Assistance
	MECHANICAL SEAL
	Manufacturer: Manufacturer to Specify
	Model: Manufacturer to Specify
	Material: Manufacturer to Specify
	API Class Code: N/A
	Rotating Face: Manufacturer to Specify
	Stationary Face: Manufacturer to Specify
	O-Rings: Manufacturer to Specify
Notes:	

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ELECTRIC MOTOR DATA	
Type: Grunfos Submersible Manufacturer: For multiple units of this same type of equipment, furnish motors and accessories of a single manufacturer. Service Factor (rated @ maximum ambient temperature): 1.15 at 50°C ambient	
General:	Driven Speed:
Motor Horsepower: Manufacturer to Specify	Constant Speed: 3,600 rpm, synchronous
Voltage: 460	
Phase: 3	
Frequency: 60-Hz	
Torque: Variable	
Additional Requirements:	

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SECTION 44 42 56.10
HORIZONTAL END SUCTION CENTRIFUGAL PUMPS

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Bearing Manufacturers' Association (ABMA).
2. Hydraulic Institute Standards.
3. National Electrical Manufacturer's Association (NEMA): MG 1, Motors and Generators.
4. Occupational Safety and Health Administration (OSHA).

1.02 DEFINITIONS

A. Terminology pertaining to pumping unit performance and construction shall conform to the ratings and nomenclature of the Hydraulic Institute Standards.

1.03 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. Make, model, weight, and horsepower of each equipment assembly.
   b. Complete catalog information, descriptive literature, specifications, and identification of materials of construction.
   c. Performance data curves showing head, capacity, horsepower demand, and pump efficiency over entire operating range of pump from shutoff to maximum capacity. Indicate separately the head, capacity, horsepower demand, overall efficiency, and minimum submergence required at guarantee point.
   d. Detailed mechanical and electrical drawings showing equipment dimensions, size, and locations of connections and weights of associated equipment.
   e. Power and control wiring diagrams, including terminals and numbers.
   f. Complete motor nameplate data, as defined by NEMA, motor manufacturer.
   g. Factory finish system data sheets.

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B. Informational Submittals:

1. Factory Functional Test Reports.
2. Special shipping, storage and protection, and handling instructions.
3. Manufacturer's printed installation instructions.
4. Suggested spare parts list to maintain the equipment in service for a period of 1 year and 5 years. Include a list of special tools required for checking, testing, parts replacement, and maintenance with current price information.
5. List special tools, materials, and supplies furnished with equipment for use prior to and during startup and for future maintenance.
6. Operation and Maintenance Data.

PART 2 - PRODUCTS

2.01 GENERAL

A. Coordinate pump requirements with drive manufacturer and be responsible for pump and drive requirements.

B. Where adjustable speed drives are required, furnish a coordinated operating system complete with pump, drive, and speed controller.

2.02 ACCESSORIES

A. Equipment Identification Plate: 16-gauge stainless steel with 1/4-inch die-stamped equipment tag number securely mounted in a readily visible location.

B. Lifting Lugs: Equipment weighing over 100 pounds.

2.03 FACTORY FINISHING

A. Manufacturer's standard.

2.04 SOURCE QUALITY CONTROL

A. Factory Inspections: for required construction, electrical connection, and intended function.

B. Factory Tests and Adjustments: Test all equipment.

C. Factory Test Report: Include test data sheets, curve test results certified correct by a registered professional engineer.

D. Functional Test: Perform manufacturer's standard.

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E. Performance Test:

1. Shall conform to the Hydraulic Institute Standards (HIS).
2. Adjust, realign, or modify units and retest in accordance with Hydraulic Institute Standards, if necessary.

F. Motor Test: Perform Manufacturer's Standard.

G. Hydrostatic Tests: Perform Manufacturer's Standard.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install in accordance with manufacturer's printed instructions.

3.02 FIELD QUALITY CONTROL

A. Functional Tests: Conduct on each pump.

1. Alignment: Test complete assemblies for correct rotation, proper alignment and connection, and quiet operation.
2. Vibration Test: Test with unit installed and in normal operation, and discharging to the connected piping systems at rates between low discharge head and high discharge head conditions specified and with actual building structures and foundations provided shall not develop vibration at any frequency or in any plane exceeding the limits specified in excess of 3 mils.
3. Flow Output: Measured by plant instrumentation and storage volumes.

B. Operating Temperatures: Monitor bearing areas on pump and motor for abnormally high temperatures.

C. Performance Test:

1. Conduct on each pump.
2. Perform under simulated operating conditions.
3. Test for a continuous 3-hour period without malfunction.
4. Test Log: Record the following:
   a. Total head.
   b. Capacity.
   c. Horsepower requirements.
   d. Flow measured by factory instrumentation and storage volumes.
   e. Average distance from suction well water surface to pump discharge centerline for duration of test.

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f. Pump discharge pressure converted to feet of liquid pumped and corrected to pump discharge centerline.
g. Driving motor voltage and amperage measured for each phase.

3.03 MANUFACTURER'S SERVICES

A. Manufacturer's Representative: Present at Site or classroom designated by OWNER, for minimum person-days listed below, travel time excluded:

B. 2 person-days for performance testing and completion of Manufacturer's Certificate of Proper Installation.

3.04 SUPPLEMENTS

A. The supplements listed below, following "End of Section," are a part of this Specification.

1. Pump Data Sheet and Motor Datasheet.

END OF SECTION

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HORIZONTAL END SUCTION CENTRIFUGAL PUMP DATA SHEET,
44 42 56.10-_____

Tag Numbers: PMP-401, PMP-402, PMP-403, PMP-404

Pump Name: Influent Storage Tank Recirculation Pump #1, 2, 3, 4

Manufacturer and Model Number: (1) Fybroc

(2) _____

SERVICE CONDITIONS

Liquid Pumped (Material and Percent): Groundwater

Pumping Temperature (Fahrenheit): Normal: 86 Max 130 Min 20

Specific Gravity at 60 Degrees F: 1 Viscosity Range, cps: 1

Vapor Pressure at 60 Degrees F: 13mmHg pH: 6.5 - 8.5

Abrasive (Y/N) N (Corrosive) Possible Scale Buildup (Y/N): Y

Total suspended solids (mg/L) 24-540

Min. NPSH Available (Ft. Absolute): 3

PERFORMANCE REQUIREMENTS AT PRIMARY DESIGN POINT

Capacity (US gpm): _____ Rated: 402

Total Dynamic Head (Ft): _____ Rated: 61

Min. Hydraulic Efficiency (%):*

Maximum Shutoff Pressure (Ft):*

Max. Pump Speed at Design Point (rpm): Note 1

Constant (Y/N): Y Adjustable (Y/N): Y

DESIGN AND MATERIALS

ANSI (Y/N) Y Standard (Y/N) N Design: Frame-mounted (Y/N) *

Close-Coupled Casing (Y/N) * Back Pullout (Y/N) *

Discharge Orientation: * Rotation (view from end coupling): *

Casing Materials: FRP, PVC, or othera approved material – Note 2

Case Wear Ring (Y/N) * Material: *

Impeller: Type: * Material: *

Impeller Wear Ring (Y/N): * Material: *

Shaft Material: * Shaft Sleeve Material: *

Shaft Seal: * Packing (Y/N) N Material: *

Mechanical (Y/N) Y Type: *

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Lubrication: *

ABMA L-10 Bearing Life (Hrs): 50,000 Lubrication: *

Coupling: * Falk (Y/N) * Fast (Y/N) *

Baseplate: Design: * Material: *

Drive Type: Direct-Coupled: Y

Other:

DRIVE MOTOR (See Attached Motor Datasheet)

Horsepower: * Voltage: 460 Phase: 3 Frequency: 60 Hz

Service Factor: 1.15 Inverter Duty (Y/N) N

Motor nameplate horsepower shall not be exceeded at any head-capacity point on the pump curve.

Enclosure: TEFC

Mounting Type: Nonreverse Ratchet (Y/N) N

REMARKS

* - Manufacturer to specify

1. Maximum pump rpm to be 1800, unless approved by ENGINEER.

2.Corrosive process fluid

3. Vendor to specify motor enclosure type and provide motor and required horsepower.

4. Assume liquid level is at pump centerline as worst case scenario.

5. Intermittent operation.

6. Area Classification is: non-classified

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HORIZONTAL END SUCTION CENTRIFUGAL PUMP DATA SHEET
44 42 56.10-_____

Tag Numbers: PMP-510, PMP-520, PMP-530, PMP-540

Pump Name: Filter Feed Pump 1 – A Side, Filter Feed Pump 2 – A Side, Filter Feed Pump 1 – B Side, Filter Feed Pump 2 – B Side (respectively)

Manufacturer and Model Number: (1) Fybroc

(2) _____

SERVICE CONDITIONS

Liquid Pumped (Material and Percent): Groundwater

Pumping Temperature (Fahrenheit): Normal: 86 Max 130 Min 20

Specific Gravity at 60 Degrees F: 1 Viscosity Range, cps: 1

Vapor Pressure at 60 Degrees F: 13 mmHg pH: 6.5 - 8.5

Abrasive (Y/N) N (Corrosive) Possible Scale Buildup (Y/N): Y

Total suspended solids (mg/L) 24-540

Min. NPSH Available (Ft. Absolute): 3

PERFORMANCE REQUIREMENTS AT PRIMARY DESIGN POINT

Capacity (US gpm): Rated: 35

Total Dynamic Head (Ft): Rated: 185

Min. Hydraulic Efficiency (%):*

Maximum Shutoff Pressure (Ft):*

Max. Pump Speed at Design Point (rpm): Note 1

Constant (Y/N): Y Adjustable (Y/N): Y

DESIGN AND MATERIALS

ANSI (Y/N) Y Standard (Y/N) N Design: Frame-mounted (Y/N) *

Close-Coupled Casing (Y/N) * Back Pullout (Y/N) *

Discharge Orientation: * Rotation (view from end coupling):

*

Casing Materials: FRP, PVC, or othera approved material – Note 2

Case Wear Ring (Y/N) * Material: *

Impeller: Type: * Material: *

Impeller Wear Ring (Y/N): * Material: *

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Shaft Material: * Shaft Sleeve Material: *

Shaft Seal: * Packing (Y/N) N Material: *

Mechanical (Y/N) Y Type: *

Lubrication: *

ABMA L-10 Bearing Life (Hrs): 50,000 Lubrication: *

Coupling: * Falk (Y/N) * Fast (Y/N) *

Baseplate: Design: * Material: *

Drive Type: Direct-Coupled: Y

Other:

DRIVE MOTOR (See Attached Motor Datasheet)

Horsepower: * Voltage: 460

Phase: 3 Frequency: 60 Hz

Service Factor: 1.15 Inverter Duty: (Y/N) N

Motor nameplate horsepower shall not be exceeded at any head-capacity point on the pump curve.

Enclosure: TEFC

Mounting Type: Nonreverse Ratchet: (Y/N) N

REMARKS

* - Manufacturer to specify

1. Maximum pump rpm to be 1800, unless approved by ENGINEER.

2.Corrosive process fluid.

3. Vendor to specify motor enclosure type and provide motor and required horsepower.

4. Assume liquid level is at pump centerline as worst case scenario.

5. Continuous operation. One pump on A side in standby and one pump on B side in standby.

6. Area Classification is: non-classified

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HORIZONTAL END SUCTION CENTRIFUGAL PUMP DATA SHEET,
44 42 56.10-_____

Tag Numbers: PMP-601, PMP-602___
Pump Name:_Truck Fill Pump 1, ____Truck Fill Pump 2 (Note 5)
Manufacturer and Model Number: (1) ___Fybroc____
(2) __

SERVICE CONDITIONS

Liquid Pumped (Material and Percent): _Groundwater_
Pumping Temperature (Fahrenheit): Normal: _____86_ Max 130_ Min __20___
Specific Gravity at 60 Degrees F: ___1__ Viscosity Range, cps: ___1____
Vapor Pressure at 60 Degrees F: ___13 mmHg___ pH: _6.5 - 8.5___
Abrasive (Y/N) ___N (Corrosive)___ Possible Scale Buildup (Y/N): ____Y____
Total suspended solids (mg/L) 24-540___
Min. NPSH Available (Ft. Absolute): ____3____

PERFORMANCE REQUIREMENTS AT PRIMARY DESIGN POINT

Capacity (US gpm): Rated: 150
Total Dynamic Head (Ft): Rated: 90
Min. Hydraulic Efficiency (%):*
Maximum Shutoff Pressure (Ft):*
Max. Pump Speed at Design Point (rpm): Note 1
Constant (Y/N): __Y____ Adjustable (Y/N): Y___

DESIGN AND MATERIALS

ANSI (Y/N) _Y Standard (Y/N) ____N___ Design: Frame-mounted (Y/N) ___*_____
Close-Coupled Casing (Y/N) _____*____ Back Pullout (Y/N) ___*____

Discharge Orientation: __*___ Rotation (view from end coupling): _*____
Casing Materials: _FRP, PVC, or othera approved material – Note 2_____
Case Wear Ring (Y/N) __*_ Material: _____*____
Impeller: Type: ___*____ Material: _*____
Impeller Wear Ring (Y/N): ___*____ Material: _*____
Shaft Material: ___*____ Shaft Sleeve Material: _*____
Shaft Seal: __*____ Packing (Y/N) __N____ Material: _*____
Mechanical (Y/N) _Y____ Type: _____*____

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Lubrication: *

ABMA L-10 Bearing Life (Hrs): 50,000 Lubrication: *

Coupling: * Falk (Y/N) * Fast (Y/N) *

Baseplate: Design: * Material: *

Drive Type: Direct-Coupled: Y

Other:

DRIVE MOTOR (See Attached Motor Datasheet)

Horsepower: * Voltage: 460 Phase: 3 Frequency: 60 Hz

Service Factor: 1.15 Inverter Duty (Y/N) N

Motor nameplate horsepower shall not be exceeded at any head-capacity point on the pump curve.

Enclosure: TEFC

Mounting Type: Nonreverse Ratchet (Y/N) N

REMARKS

* - Manufacturer to specify

1. Maximum pump rpm to be 1800, unless approved by ENGINEER.

2.Corrosive process fluid.

3. Vendor to specify motor enclosure type and provide motor and required horsepower.

4. Assume liquid level is at pump centerline as worst case scenario.

5. Intermittent Operation.

5. PMP-601 is at the TCS Truck Fill Station /Decontamination Pad, and PMP-602 is at the MW-20 Bench Truck Fill Station

6. Area Classification is: non-classified

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HORIZONTAL END SUCTION CENTRIFUGAL PUMP DATA SHEET,
44 42 56.10-_____

Tag Numbers: PMP-705A/B___

Pump Name: Conditioned Water Transfer Pump 1 & 2 (Note 5)

Manufacturer and Model Number: (1) Fybroc

(2) __

SERVICE CONDITIONS

Liquid Pumped (Material and Percent): Groundwater

Pumping Temperature (Fahrenheit): Normal: 86 Max 130 Min 20

Specific Gravity at 60 Degrees F: 1 Viscosity Range, cps: 1

Vapor Pressure at 60 Degrees F: 13 mmHg pH: 6.5 - 8.5

Abrasive (Y/N) N (Corrosive) Possible Scale Buildup (Y/N): Y

Total suspended solids (mg/L) 24-540

Min. NPSH Available (Ft. Absolute): 3

PERFORMANCE REQUIREMENTS AT PRIMARY DESIGN POINT

Capacity (US gpm): Rated: 35

Total Dynamic Head (Ft): Rated: 185

Min. Hydraulic Efficiency (%):*

Maximum Shutoff Pressure (Ft):*

Max. Pump Speed at Design Point (rpm): Note 1

Constant (Y/N): Y Adjustable (Y/N): Y

DESIGN AND MATERIALS

ANSI (Y/N) Y Standard (Y/N) N Design: Frame-mounted (Y/N) *
Close-Coupled Casing (Y/N) * Back Pullout (Y/N) *

Discharge Orientation: * Rotation (view from end coupling): *

Casing Materials: FRP, PVC, or othera approved material – Note 2

Case Wear Ring (Y/N) * Material: *

Impeller: Type: * Material: *

Impeller Wear Ring (Y/N): * Material: *

Shaft Material: * Shaft Sleeve Material: *

Shaft Seal: * Packing (Y/N) N Material: *

Mechanical (Y/N) Y Type: *

Lubrication: *

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ABMA L-10 Bearing Life (Hrs): 50,000 Lubrication: *

Coupling: * Falk (Y/N) * Fast (Y/N) *

Baseplate: Design: * Material: *

Drive Type: Direct-Coupled: Y

Other:

DRIVE MOTOR (See Attached Motor Datasheet)

Horsepower: * Voltage: 460 Phase: 3 Frequency: 60 Hz

Service Factor: 1.15 Inverter Duty (Y/N) N

Motor nameplate horsepower shall not be exceeded at any head-capacity point on the pump curve.

Enclosure: TEFC

Mounting Type: Nonreverse Ratchet (Y/N) N

REMARKS:

* - Manufacturer to specify

1. Maximum pump rpm to be 1800, unless approved by engineer.

2.Corrosive process fluid.

3. Vendor to specify motor enclosure type and provide motor and required horsepower.

4. Assume liquid level is at pump centerline as worst case scenario.

5. Continuous Operation. One pump in standby and other in operation

6. Area Classification is: non-classified

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Topock 60% Design
MOTOR Data Sheet
Horizontal Centrifugal Pumps

Equipment Tag Number(s): PMP,401, PMP-402, PMP-403, PMP-404, PMP-510, PMP-520, PMP-530, PMP-540, PMP-601, PMP-602, PMP-705/B

ELECTRIC MOTOR DATA

Type: Squirrel-cage induction meeting requirements of NEMA MG1
Manufacturer: For multiple units of this same type of equipment, furnish motors and accessories of a single manufacturer.

Service Factor (rated @ maximum ambient temperature): 1.15 at 50 C ambient

General:

Motor Horsepower: Manufacturer to Specify

Voltage: 460

Phase: 3

Frequency: 60-Hz

Torque: Variable

Enclosure Type: TEFC

Driven Speed:

Constant Speed: Manufacturer to Specify rpm, synchronous

Speed: Manufacturer to Specify (MTS)
___ rpm, synchronous

Optional Features:

Thermal Protection: Temperature switch (NC)

Oversize main terminal (conduit) box for motors

Terminal for connection of equipment grounding wire in each terminal box.

Mounting Type:

Vertical: Non-reverse Ratchet Yes

Shaft Type: MTS

Guaranteed Minimum Efficiency @ Full Load MTS

Guaranteed Minimum Power Factor @ Full Load MTS

Additional Requirements

Motor shall have Class F insulation with Class B Rise at nameplate horsepower and shall be provided with oversize main terminal box.

Area Classification is : non-classified

.

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Bearings and Lubrication:
Thrust Bearings:
a. Manufacturer's standard bearing for application
b. Manufacturer's standard lubrication for application
c. Minimum 50,000 hours L-10 bearing life
Guide Bearings:
a. Manufacturer's standard bearing for application
b. Manufacturer's standard lubrication for application
c. Minimum 100,000 hours L-10 bearing life
Regreasable Antifriction Bearings:
a. Readily accessible, grease injection fittings
b. Readily accessible, removable grease release plugs
Oil Lubrication Systems
a. Oil Reservoirs with sight level gauge
b. Oil fill and drain openings with opening plugs
c. Provisions for necessary oil circulation and cooling.

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SECTION 44 42 56.15
AIR-OPERATED DIAPHRAGM PUMPS

PART 1 - GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section: Hydraulic Institute Standards (HIS).

1.02 DEFINITIONS

A. Terminology pertaining to pumping unit performance and construction shall conform to the ratings and nomenclature of the Hydraulic Institute Standards.

1.03 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. Make, model, and weight of each equipment assembly.
   b. Complete catalog information, descriptive literature, specifications, and identification of materials of construction.
   c. Performance data curves showing head, capacity, air consumption and pressure, displacement per stroke, and pump efficiency over entire operating range of pump, from shutoff to maximum capacity.
   d. Detailed mechanical drawings showing equipment dimensions, size, and locations of connections and weights of associated equipment.
   e. Control wiring diagrams, including terminations and wire numbers.
   f. Factory finish system.

B. Informational Submittals:

1. Factory Functional Test Reports
2. Special shipping, storage and protection, and handling instructions.
3. Manufacturer’s printed installation instructions.
4. Suggested spare parts list to maintain equipment in service for a period of 1 year and 5 years. Include list of special tools required for checking, testing, parts replacement, and maintenance with current price information.
5. List special tools, materials, and supplies furnished with equipment for use prior to and during startup and for future maintenance.

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6. Operation and Maintenance Data: As specified in Section 01 78 23, Operation and Maintenance Data.

1.04 EXTRA MATERIALS

A. Furnish for each pump:

1. One diaphragm.
2. One check valve ball.
3. One complete set of ball check valve seats.
4. One solenoid valve.
5. Two spring assemblies.
6. One complete set of any special tools required to dismantle pump.

PART 2 - PRODUCTS

2.01 SUPPLEMENTS

A. Some specific requirements are attached to this section as supplements.

2.02 ACCESSORIES

A. Equipment Identification Plate: 16-gauge stainless steel with 1/4-inch die-stamped equipment tag number securely mounted in readily visible location.

B. Lifting Lugs: For equipment weighing over 100 pounds.

2.03 FACTORY FINISHING

A. Manufacturer’s standard.

2.04 SOURCE QUALITY CONTROL

A. Functional Test: Perform manufacturer’s standard.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install in accordance with manufacturer’s printed instructions.

3.02 FIELD QUALITY CONTROL

A. Conduct tests on each pump.

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B. Functional Tests: Proper Alignment, connection, and quiet operation.

C. Performance Test: To be performed under actual or approved simulated operating conditions.

3.03 SUPPLEMENTS

A. The supplements listed below, following "End of Section," are a part of this Specification.

1. Pump Data Sheet.

END OF SECTION

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AIR OPERATED DIAPHRAGM PUMP DATA SHEET, 44 42 56.15-

Tag Numbers: PMP-410

Pump Name: Solids Pump

Manufacturer and Products: (1) ARO (2) Wilden

SERVICE CONDITIONS

Liquid Pumped (Material and Percent solids): Remedy Water: up to 100 ppm of silt/sand/soft biological solids

Pumped Liquid Temperature (deg. F): Normal: 75 Max 110 Min 60

Liquid Specific Gravity at 60 Degrees F: 1 Viscosity Range: 0.8 to 1.0 cp

pH: 6.5-8.5

Abrasive (Y/N): Y Possible Scale Buildup (Y/N): Y

Total suspended solids (mg/L): 60

Min. NPSH Available (Ft. Absolute): 3

Will the pump be submerged? (Y/N) N

PERFORMANCE REQUIREMENTS

Capacity (US gpm): Rated: 20

Total Dynamic Head (Ft): Rated: 25

Suction Lift (Ft): Rated: *

Air Consumption (SCFM): *

Inlet Air Pressure (psig): 80 - 100

Largest diameter solid pump can pass (inches): *

PUMP CONSTRUCTION DESIGN AND MATERIALS

Suction Size (inches): * Discharge Size (inches): *

Casing Type: *

Max Allowable Pressure (psig) at 60 deg F: *

Max Allowable Pressure (psig) at normal pumping temperature: *

Hydro Test Pressure (psig): *

Diaphragm Diameter (inches): *

Diaphragm Actuation:

Air Only (Y/N): * Spring Assisted (Y/N): *

Cylinder Assisted (Y/N): * Position Indication (Y/N): *

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Check Valves:

Single (Y/N): N Dual (Y/N): Y

Inlet Diameter (inches): * Outlet Diameter (inches): *

Ball Check with Cleanout (Y/N): * Inline Ball Check (Y/N): *

Flap Check (Y/N): * Ball Valve Seats (Y/N): *

Body Material: * Body Lining: *

Ball Material: * Ball Lining: *

Ball Seats: *

Air Cushion Chamber (Y/N): *

Diameter (inches): * Length (feet): *

Air Header Assembly (Y/N): *

Three-way Solenoid Valve (Y/N): * Size (inches): *

Muffler (inches): * Air Regulator, Size (inches): *

Air Strainer, Size (inches): *

Pressure Gauge (psig): * to *

Casing Material: * Casing Lining: *

Cover Material: * Diaphragm: *

Base Tee: * Base Tee Lining: *

Air Cushion Chamber: *

Solenoid Valves: *

Pump Baseplate: Yes

Type: * Material: *

ADDITIONAL REQUIREMENTS

Drilled and tapped pump body covers for pressure air connections? (Y/N) *

Tapped and plugged air cushion chambers for gauge connections? (Y/N) *

Maximum Allowable Noise Limit (dBA): 85 at 3ft .

To Provide the following accessories: Pulsation Dampeners, Filter-Regulator-Lubricator, Leak Detector, Suction inlet screen, inlet air pressure regulator and Relief Valve.

REMARKS

* - Manufacturer to Specify

1. Location is Outdoor at grade

2. Pump operation is Intermittent

3. Vendor to show air consumption for the specific pump being offered

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SECTION 44 43 13.16
CARTRIDGE FILTERS

PART 1 GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code; Section VIII, Division 1.
2. American National Standards Institute (ANSI): B16.5.

1.02 SUBMITTALS

A. Shop Drawings:

1. Make, model, weight of each assembly.
2. Complete catalog information, descriptive literature, specifications, and identification of materials of construction.
3. Head loss versus flow curves throughout operating ranges.
4. Detailed drawings showing dimensions, size, and locations of components.

B. Quality Control Submittals:

1. Manufacturer's Certificate of Compliance.
2. Special shipping, storage and protection, and handling instructions.
3. Manufacturer's written/printed installation instructions.
4. Routine maintenance requirements prior to plant startup.
5. Manufacturer's Certificate of Proper Installation.
6. Operation and Maintenance Manuals.

1.03 SPARES

A. Filter O-Rings.

B. Filter Cartridges: Replacement sets of cartridges for each filter vessel as specified herein.

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PART 2 PRODUCTS

2.01 MANUFACTURERS

A. The cartridge filters to be provided under this section shall be as supplied by:

1. Harmsco-Geiger.

2.02 SERVICE CONDITIONS

A. Influent Water Characteristics:

	Process Feed
Temperature (degrees F)	20 to 130 Normal = 86
Chlorides (mg/L)	<40
TDS (mg/L)	380 to 580
pH (units)	6.5 to 8.5

B. Flow Rates per Cartridge Filters:

	Process Feed
Normal (gpm)	20
Maximum (gpm)	35

C. Pressures:

1. Inlet Operating Pressure Range: 10 to 75 psig.

2.03 PERFORMANCE REQUIREMENTS

A. Maximum Cartridge (Filter Element) Loading Rate: Each cartridge filter vessel shall contain a sufficient number of cartridges of the specified type such that the maximum loading rate for each cartridge shall be 4.8 gpm per 10-inch equivalent length

B. The cartridges shall be NSF approved and shall have ratings as specified below:

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1. A Side Cartridge Filters: Tag numbers FIL-510A and FIL-520A are the coarse filters and Tag numbers FIL-510B and FIL-520B are the fine filters. Fine Cartridge filters shall have cartridges rated for 90 percent (minimum) removal of 5 micron-size particles or less.
2. B Side Cartridge Filters:
   a. Tag numbers FIL-530A and FIL-540A are the coarse filters and Tag numbers FIL-530B and FIL-540B are the fine filters. Fine Cartridge filters shall have cartridges rated for 90 percent (minimum) removal of 5 micron-size particles or less.
   b. Vendor shall determine appropriate micron size for coarse filters.

2.04 EQUIPMENT/MATERIALS DESCRIPTION

A. Cartridge filter vessels shall be as generally shown on the Drawings and as follows: Provide duplex systems (mount two cartridge filters to each skid).

	Inlet Feed
Type	Vertical Duplex
Nominal Diameter (in.)	*
Overall Height (vertical) or Length (horizontal), Maximum (in.) (excluding cover lift device)	*

B. Filter Vessel: Each filter housing shall be of Type 316L stainless steel and pressure-retaining welds shall be crevice-free. The vessel shall be rated for 150 psi working pressure maximum, constructed per ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 and code stamped. Carbon Steel base

C. Flanges: Type 316L stainless steel, flat face, 150-pound, ANSI B16.5 flanges.

D. Cartridges: All cartridges shall be FDA approved for potable use.

PART 3 EXECUTION

3.01 INSTALLATION

A. Install in accordance with manufacturer's printed instructions and in accordance with Piping Materials Specification Section.

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3.02 TESTING

A. All testing described below should be performed by Subcontractor following manufacturer's recommendations.

B. Contractor shall be responsible for providing all necessary equipment to complete testing described herein.

C. After installation, conduct pressure and leakage tests for each unit as part of the piping tests for the pipe sections.

D. Conduct a pressure head loss test on each fully loaded cartridge filter at a flow rate adequate to show that, at maximum flow rate, the maximum allowable pressure differential is not exceeded.

3.03 MANUFACTURER'S SERVICES

A. Manufacturer's Representative: Present at Site or classroom designated by OWNER, for minimum person-days listed below, travel time excluded:

1. 1 person-day for installation assistance and inspection of each filter assembly.

B. See Section on Manufacturers' Field Services and Equipment Testing and Facility Startup.

3.04 SUPPLEMENT

A. The supplement listed below, following "END OF SECTION," is a part of this Specification:

1. Equipment Data Sheet

END OF SECTION

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Project No.: 435062	CH2MHILL®	By: R. Harris
Owner: PG&E		Date: 07-18-2012
		Equipment No.: FIl-510A/B, FIL 520A/B, FIL-530A./B, FIL-540A/B
	EQUIPMENT DATA SHEET	Quantity: 4 duplex skid (8 total cartridge filters)

FLUID PROPERTIES			
Fluid:	Remedy Water	Specific Gravity:	1
Viscosity:	1 cp	Flow Rate:	35 gpm

DESCRIPTION OF PARTICULATE MATTER			
Type:	Silt, sand, bio solids	Weight % Solids:	<60 ppm
Particulate Size Dist.:	TBD μ		

FILTRATION REQUIREMENTS			
Media Rating (Nom.):	Note 1	Media Rating (Abs.):	
Filtration Ratio:		Beta Ratio:	

MATERIALS OF CONSTRUCTION			
Housing:	316SS	Cover:	
Fasteners/Clamps:		Cartridge[s]:	*
Cartridge Type:	☐ Pleated	☐ Wound	☐ Other

HOUSING OPTIONS			
Jacket:	N/A	Corrosion Allowance:	1/16″
Special Finish:	Electropolish	Flange Orientation:	*
Lining:		Vertical Duplex	Yes
Horizontal Duplex:	N/A		

DESIGN PARAMETERS			
ΔP Across Housing:	* psi	ΔP Across Clean Elements:	* psi
Max. ΔP Across Housing:	psi	Max. ΔP Across Dirty Elements:	psi

ASME SECTION VIII CODE STAMP

☐ U ☐ UM ☐ None ☐ Other

NOZZLES

Service	Req'd	Size	Rating	Type	Face	Note[s]
Inlet	1	2″	150#	Flanged	RF	
Outlet	1	2″	150#	Flanged	RF	

NOTE[S]

* - Manufacturer to provide information

1. Fine Filters to be 5 microns or less.

2. Provide 4 duplex filter systems (total of 8 filters) equipped with drain manifold. Include painted CS base with fork lift access and tie-downs.

3. Provide differential pressure switch for each filter with status indication on panel

Issue:	Date:	Released for:	Approved:	Owner Approval:
IFR	07-18-2012			

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Appendix F
Remedy-produced Water Management Technical Memorandum

Management of Water Produced from Operation and Maintenance of Groundwater Remedy, PG&E Topock Compressor Station, Needles, California

TO: Pacific Gas and Electric Company

FROM: CH2M HILL

DATE: August 15, 2011 (Draft); November 18, 2011 (Rev. 0, Preliminary [30%] Design); April 5, 2013 (Rev. 1, Intermediate [60%] Design)

This technical memorandum summarizes the plan for managing water produced during the operation and maintenance (O&M) of the Topock groundwater remedy (referred to herein as "remedy-produced water") at the Pacific Gas and Electric Company (PG&E) Topock Compressor Station (TCS) in Needles, California. This water primarily consists of water generated from maintenance activities of remediation wells such as backwashing and rehabilitation. Other types of water generated from remedy O&M (smaller volume) will also need to be managed such as monitoring well sampling purge water, equipment decontamination wastewater, and rainfall that collects in secondary containment areas of remedy facilities. For clarity, remedy-produced water does not include freshwater extracted from the ground. The remedy is reliant on the dozens of wells used for the in-situ reactive zone (IRZ), freshwater and carbon-amended injection, and groundwater extraction. For all wells, especially for the injection and IRZ wells, regular maintenance is vital to keep efficient and effective operations during the 30-year projected life of the remedy. Well maintenance will also prevent or reduce the need for drilling new replacement wells. The management strategy for remedy-produced water must be sensible and flexible to meet the needs of the system and the regulatory requirements, be cost-effective, and must not constrain remedy operations.

This memorandum discusses the evaluation of remedy-produced water management options, the preferred management plan, and the design basis/design criteria. The design basis covers three parts of the management system: transport, conditioning, and reuse/disposal. The approach described herein is for the operation phase of the final remedy. It is assumed that water produced during remedy construction will be managed at the Interim Measure Number 3 (IM-3) treatment system or by trucking off-site, or by the remedy-produced water management system (if it is available). This assumption will be revisited throughout the design and construction process.

The information presented here has been developed from PG&E's experience maintaining the IM-3 injection wells and operation of the IRZ system at the Hinkley site. This experience includes both routine well cleaning and backwashing and rehabilitation work. Since the submittal of the preliminary (30%) Basis of Design (BOD) report in November 2011, the Hinkley testing of backwashing frequency was completed in June 2012 and the IM-3 injection wells underwent a mechanical rehabilitation event in May 2012 using Aqua Gard™. The information gained from these operations has been incorporated into this intermediate design and Section 4 (Well Maintenance and Decommissioning) of the Operations and Maintenance Plan (Volume 1 of the O&M Manual which is included as Appendix L of this 60% BOD report). The design and the well maintenance procedures will be updated as additional operational data become available.

This memorandum was originally transmitted to the California Department of Toxic Substances Control (DTSC) and the U.S. Department of the Interior (DOI) on August 15, 2011. DTSC and DOI comments on the original memorandum were incorporated, and an updated memorandum was included in the Draft BOD Report/Preliminary (30%) Design along with responses to agencies' comments. Comments were received on the updated memorandum from DOI, DTSC, and the Hualapai Indian Tribe; responses to those comments are provided in Appendix I of this BOD report.

Transport

Within the project area, water generated from well maintenance activities can be either trucked or conveyed via pipelines, or both. The preferred approach is to use both methods. Conveyance piping will be constructed to remediation wells requiring frequent maintenance such as the IRZ, carbon amendment, and freshwater injection wells. For wells requiring less frequent maintenance such as extraction and monitoring wells, trucking is the preferred option for conveying the remedy-produced water. Trucking is also the preferred option for wells where installing pipelines would be difficult.

The advantages of piping over trucking are that piping has a lower visual impact, lower safety risk during operation, lower risk of spills, lower carbon dioxide emissions, and will require less cleared space at the wellhead for maintenance activities. Using piping to convey remedy-produced water also allows automation of the backwashing for the injection and IRZ wells. This would entail installing dedicated backwashing pumps, valves, and controls, to enable the backwashing to occur on a regular schedule (all equipment can be installed in the well vault to reduce visual impacts). The backwashing sequencing would be planned such that one (or more) well is being backwashed at a time to optimize the system hydraulics. Automated backwashing could be done on a cyclic basis with 3 on-off cycles of 10 minutes on and 5 minutes off for a total of 30 minutes of pumping time. The duration and number of on-off cycles will be further evaluated during the design and refined during operation. Automated backwashing offers several benefits, including reducing the number of vehicles and crews traveling across the site and minimizing disturbance as well as the visual impacts from operations.

The piping for remedy-produced water may also serve as a backup for the main pipes carrying water to or from the wells. For example, if a pipe carrying freshwater to a freshwater injection well became unusable, the remedy-produced water pipe (after appropriate flushing) can be used to carry freshwater while the primary pipe is repaired. Having this backup minimizes such unplanned downtime.

Figure F-1 shows a layout of the remedy-produced water conveyance piping network. Piping will primarily be installed underground, but may also be installed aboveground in certain locations. To minimize disturbance from construction, all piping will be installed in common trenches, to the extent practicable, with other pipes and utilities serving the wells. The design basis and criteria for remedy-produced water piping are described in Section 3.4 (Remedy-produced Water Management) and Appendix C (Design Criteria) of the Basis of Design Report.

Remedy-produced Water Conditioning and Reuse/Disposal

The remedy-produced water conditioning aspect is divided into the three components that are used to evaluate and design the system: quantity of remedy-produced water, quality of remedy-produced water, and the degree of conditioning required.

Estimate of Remedy-produced Water Quantity

The initial quantity of remedy-produced water was estimated to range from 3 to 16 million gallons (MG) per year in the revised Corrective Measures Implementation/Remedial Design Work Plan (CH2M HILL 2011), and was refined to 7.3 MG per year in the 30% design. Subsequent evaluation/modeling has resulted in further design refinement, and the current estimate is approximately 7.6 MG per year, as shown in Table F-1. Backwash operation continues to be the largest contributor to the annual volume, with over 61 percent of the total amount, with rehabilitation operation as the second largest contributor at 2.56 MG per year, or about 34 percent. The remaining remedy-produced water (< 5 percent) includes rainwater that falls within remedy facility containment and monitoring well purge and sampling equipment decontamination water.

These estimates will be further refined through the design and the operational experience to be gained from injection wells at both PG&E's Hinkley and Topock sites. A variable that will have a significant impact on the volumes produced is the frequency of backwash events. Backwashes will be more frequent than rehabilitations, and will result in a large cumulative volume of remedy-produced water. But the backwashing process requires less

Future Provisional Well for Freshwater Supply

COLORADO RIVER

Northern Aerial Crossing

Southern Aerial Crossing

Interstate 40

HNWR-1

Topock-2

Topock-3

IRZ-1 IRZ-02 IRZ-03 IRZ-04 IRZ-05 IRZ-06 IRZ-07 IRZ-08 IRZ-09 IRZ-10 IRZ-11 IRZ-12 IRZ-13 IRZ-14 IRZ-15 IRZ-16 IRZ-17 IRZ-18 IRZ-19 IRZ-20 IRZ-21 IRZ-22 IRZ-23 IRZ-24 IRZ-25 IRZ-26 IRZ-27 IRZ-28 IRZ-29 IRZ-30 IRZ-31 IRZ-32 IRZ-33 IRZ-34 IRZ-35 IRZ-36 IRZ-37 IRZ-38 IRZ-39 IRZ-40

RB-1 RB-2 RB-3 RB-4 RB-5

IRL-1 IRL-2 IRL-3 IRL-4 IRL-5 IRL-6 IRL-7

FW-1 FW-2

TCS-1 TCS-2

TWB-1 TWB-2 TWB-3 TWB-4

ER-1 ER-2 ER-3 ER-4 ER-5 ER-6

A B C D E F G H I J K L M N P Q R S

Compressor Station

Chemical Storage

Process Tanks

Freshwater Pre-Injection Conditioning Plant

Conditioned Water Storage Tanks

Remedy-Produced Water Conditioning Building

Influent Water Storage Tanks

TCS Freshwater Storage Tanks

Conditioning Water Storage Tank

Transwestern Bench

New Septic System

New Maintenance Facility

New Storage Building

New Carbon Amendment Storage Tank (3,000 gallons)

New Carbon Amendment Building

MW-20 Bench

New Carbon Amendment Storage Tank (15,000 gallons)

New Carbon Amendment Building

LEGEND

- Existing Monitoring Well
- Existing Freshwater Supply Well
- Area of Potential Effects (APE)
- Approximate extent of hexavalent chromium [Cr(VI)] concentrations exceeding 32 micrograms per liter (µg/L) at any depth in groundwater based on fourth quarter 2011 sampling events. Dashed where based on limited data.

Remedy Wells

- Contingent Freshwater Source
- Freshwater Source
- Remedy Monitoring Well
- Extraction Well (East Ravine)
- Extraction Well (NTH IRZ)
- Extraction Well (Riverbank)
- Extraction Well (Transwestern Bench)
- Freshwater Injection Well
- Injection Well (Inner Recirculation Loop)
- Injection Well (NTH IRZ)
- Injection Well (Topock Compressor Station)
- Future Provisional Extraction Well
- Future Provisional Injection Well

Pipeline Corridor for Remedy

- Aboveground Pipe
- Underground Pipe/Conduit
- Future Provisional/Contingent Fresh Water Pipe

Remedy Facilities

- Proposed New Remedy Structure
- Future Provisional Electrical Transformer
- Proposed Electrical Transformer Location

Note:
Note that in compliance with EIR mitigation measure CUL-1a-9, as well as PA and CHPMP mitigation measures, the pipeline along the dirt road west of National Trails Hwy is located in an existing, previously disturbed, access road. In addition, the location of the road and pipeline was field verified and does not create any direct physical impact or effect on the Topock Maze, as it is manifested archaeologically, in compliance with EIR mitigation measure CUL-1a-10, PA, and CHPMP mitigation measures .

N

0 300 600 1,200 Feet

FIGURE F-1
GENERAL REMEDY SYSTEM LAYOUT

GROUNDWATER REMEDY BASIS OF DESIGN REPORT
INTERMEDIATE (60%) DESIGN
PG&E TOPOCK COMPRESSOR STATION,
NEEDLES, CALIFORNIA

CH2MHILL

Path: D:\Projects\Topock\MapFiles\2013\CMS\60%Report\GeneralRemedyLayout.mxd

TABLE F-1

Current Estimate of Remedy-produced Water Quantity During Groundwater Remedy Implementation

Management of Water Produced from Operation and Maintenance of Groundwater Remedy
PG&E Topock Compressor Station, Needles, California

Source	Proposed Well Count	Events/ Year/ Well	Average Volume/ Event/ Well (gal)	Annual Volume (MG)	Anticipated Quality of Remedy-produced Water [a]
Backwash [b]					
Freshwater Injection Wells	2	51	9,000	0.92	Similar to water from Arizona aquifer, plus sediment
Inner Recirculation Loop (IRL) Injection Wells – receiving fresh water and/or water from river bank extraction wells	4	51	13,500	2.8	The wells receiving fresh water will have water quality similar to water from the Arizona aquifer, plus sediment and rehabilitation chemicals. The wells receiving river bank well water will have water quality similar to water from the riverbank extraction wells, plus sediment, IRZ byproducts[c], and rehabilitation chemicals [g]
TCS Injection Wells	2	51	2,250	0.23	Similar to water from the East Ravine and extraction wells northeast of the TCS plus sediment and IRZ byproducts [c]
IRZ Injection Wells	24	30	1,000	0.72	Similar to water in the aquifer at well, plus sediment and IRZ byproducts [c]
Well Rehabilitation [f]					
Freshwater Injection Wells	2	1	175,000	0.35	Similar to water from the Arizona aquifer, plus sediment and rehabilitation chemicals [g]
IRL Injection Wells – receiving fresh water and/or water from river bank extraction wells	4	1	175,000	0.70 [e]	The wells receiving fresh water will have water quality similar to water from the Arizona aquifer, plus sediment and rehabilitation chemicals. The wells receiving river bank well water will have water quality similar to water from the riverbank extraction wells, plus sediment, IRZ byproducts[c], and rehabilitation chemicals [g]
TCS Injection Wells	2	1	36,000	0.07 [e]	Similar to water from the East Ravine and the extraction wells northeast of the TCS plus sediment and IRZ byproducts[c], and rehabilitation chemicals [g]
IRZ Injection and Extraction Wells	28	1 [d]	48,000	1.3	Similar to water from the aquifer at well, plus sediment, IRZ byproducts[c], and rehabilitation chemicals [g]
Extraction – Floodplain (Riverbank Extraction Wells)	5	0.2	75,000	0.08	Similar to water from the aquifer at well, plus sediment, IRZ byproducts[c], and rehabilitation chemicals [g]
Freshwater Supply Well (Extraction)	1	0.2	75,000	0.02	Similar to water from Arizona aquifer, plus sediment and rehabilitation chemicals [g]
Extraction – East Ravine/ Transwestern Bench	7	0.2	30,000	0.04	Similar to water from the aquifer at well, plus sediment, IRZ byproducts[c], and rehabilitation chemicals [g]

TABLE F-1

Current Estimate of Remedy-produced Water Quantity During Groundwater Remedy Implementation

Management of Water Produced from Operation and Maintenance of Groundwater Remedy
PG&E Topock Compressor Station, Needles, California

Source	Annual Volume (MG)	Anticipated Quality of Remedy-produced Water
Other Water		
Rainwater from containment areas	0.3	Anticipated to contain trace amounts of chemicals stored in remedy facility containment areas
Sampling well purge water and equipment decontamination	0.1	Similar to water from aquifer at wells; may include chromium, IRZ byproducts, hydrocarbons[c]
Wastewater from construction of wells in the future	Variable [h]	Similar to drilling water, water from aquifer at well, could contain residues from drilling such as hydrocarbons or organic carbon
Total	**7.6**[d,e]	

Notes:

gal = gallons; IRZ = In-situ Reactive Zone; MG = million gallons; TCS = Topock Compressor Station.

[a] Water removed from wells during well backwash and rehabilitations will be primarily the water in the surrounding aquifer. For injection wells, the water quality will essentially be determined by the injection source and other components as listed in this column.

[b] Volumes are calculated by assuming the backwash rate is twice the injection rate and backwashing will last for 30 minutes per event. Total volumes are calculated by using the aggregate injection flow for each well type or using the individually specified injection rates. Injection rates are calculated by dividing the total design flow for a well type by the number of wells of that type (based on Tables 3.2-1 through 3.2-3 and Table 3.3-1 in this BOD Report). For example, there are 4 IRL injection wells pumping 900 gpm resulting in an average of 225 gpm per well. The backwash rate is then 2 times 225 gpm or 450 gpm. The average design flow rate for freshwater injection wells is 150 gpm (300 gpm divided by two wells), and for the TCS injection wells it is 37.5 gpm. IRZ wells are assumed to be in service 6 months every 2 years, so 30 backwashes are assumed per well, but only IRZ injection wells will be backwashed. The aggregate IRZ injection flow rate is 400 gpm divided by 24 wells for an average of 16.7 gpm. The backwash flow rate will be twice that, or 33.3 gpm, which results in 1,000 gallons per backwash.

[c] IRZ byproducts = iron, arsenic, manganese, organic carbon.

[d] The Hinkley IRZ pilot test was completed and confirmed the selection of weekly backwashing frequency and annual rehabilitation.

[e] Well count is based on flow and fate and transport modeling (see Basis of Design Report). The number of wells could increase or decrease based on scenarios evaluated during the ongoing groundwater modeling efforts.

[f] Well rehabilitation volumes are estimated based on experience at Topock or other sites with similar wells. IRZ and injection wells are assumed to require annual rehabilitations, while extraction wells are assumed to need rehabilitation every 5 years.

[g] The potential well maintenance reagents include acids (some with dispersants) to dissolve mineral deposits and break up biofilms (muriatic acid, phosphoric acid, glycolic acid, etc.); oxidizing agents to disinfect and degrade microbial biofilms (hydrogen peroxide, chlorine); biocides to inhibit microbial growth (Tolcide®); carbon dioxide, and chelating agents to aid acid and disinfectant penetration, remove mineral deposits, and break down and disperse biofilms (e.g., citric acid).See Section 4 of Volume 1 of the O&M Manual for additional details on well maintenance..

[h] Future well construction will produce water roughly comparable to the volumes produced during a rehabilitation of that type of well. It is assumed that large well rehabilitations and development of new wells will not both need to be managed simultaneously by the remedy-produced water management system.

time and effort than rehabilitations, and can reduce the frequency of more labor-intensive and obtrusive well maintenance activities. The IM-3 injection wells have been backwashed about twice monthly or more frequently based on well performance since early 2008. Backwashing frequency has been based on the measured injection well performance to maintain injection well capacity. The current assumption is that backwashing will be performed weekly for 30 minutes at a rate of twice the injection rate. Injection rates were assumed to be the average of the type of well. For example, there are four inner recirculation loop (IRL) injection wells with a total flow of 900 gallons per minute (gpm). This is an average of 225 gpm per well injection rate, and at a rate of twice the injection rate gives a backwashing rate of 450 gpm for the injection wells. Pumping or backwashing at this rate for 30 minutes results in 13,500 gallons of remedy-produced water.

For rehabilitation, it is assumed that the injection and IRZ wells will undergo one rehabilitation event per year and the extraction wells will undergo one rehabilitation event every 5 years.[1] The estimated quantity of water produced from rehabilitation was derived from operational experience of injection wells associated with the interim measure at Topock and other sites. Since early 2008, the IM-3 injection wells have undergone rehabilitation every one to two years (mostly mechanical rehabilitation events with one chemical rehabilitation event in 2010). In May 2012, the IM-3 injection wells underwent a mechanical rehabilitation event in which carbon dioxide was injected into the wells (Aqua Gard™) to agitate and loosen any plugging material that may have precipitated in the filter pack and surrounding formation since the last rehabilitation event. Test results are currently being evaluated; if determined to be effective, this rehab technique could extend the period between backwash/rehab events, and could result in less produced water. This technique was approved in the IM-3 Injection Well O&M Plan (CH2M HILL 2006); the mechanical means to deliver carbon dioxide into the well have been incorporated into the fresh water injection well design.

Actual well maintenance requirements of the remediation wells at Topock will not be known until actual operation begins. An important performance metric, specific injectivity (height of water column during injection versus static water levels divided by the injection rate), will be used to gauge well performance.

As part of PG&E's chromium remediation using an IRZ at Hinkley, the optimization of backwashing frequency of IRZ wells was studied. Backwashing frequency was adjusted to learn the effects on well fouling rates and well performance, as measured by specific capacity. This evaluation was intended to determine whether the use of routine backwashing will extend the time period of satisfactory well performance before rehabilitating the well becomes necessary. Test results confirmed the weekly backwashing frequency presented in Table F-1.

Estimate of Remedy-produced Water Quality

Water quality varies depending upon whether the stream is from backwashing or rehabilitation, the type of well, and the water source, as indicated by the information shown in Table F-1. Another way to evaluate water quality is shown in Table F-2, which presents a summary of the constituents likely to be found in the waste streams of the various types of wells. Water quality will be used to determine the appropriate conditioning process and also match the waste streams with possible disposal/reuse options. In keeping with the objective to have a flexible approach to managing the remedy-produced water, it is helpful to discuss the cleaning activities in a broader way and the effects on water quality.

The backwash stream will contain sediment that either is carried in injected water or in aquifer materials drawn into the well during backwashing. This is a result of vigorous pumping and surging similar to what occurs during well development. High pumping rates can draw accumulated solids from inside the filter pack or aquifer material surrounding the filter pack to recover some of the well capacity. Dissolved constituents present in the aquifer around the remediation well or in the injected water stream could be found in the backwash stream. The backwash stream from the IRZ and IRL injection wells is anticipated to contain carbon and in-situ byproducts (iron, manganese, and arsenic).

[1] The IM-3 extraction wells were scheduled for rehabilitation late in 2011 or early in 2012, approximately 6 years after startup. However, the rehabilitation event has been postponed based on further evaluation of well performance data.

The rehabilitation streams can be thought of as having two distinct water quality characteristics – one at the beginning and the other at the end of the rehabilitation process. Based on experience with the chemical rehabilitation of injection wells at Topock in October-November 2010, the initial step used acid to lower the pH so that mineral deposits can be dissolved, and as a result, the first flush will be at very low pH (pH 2.0 – 3.0) and will contain high concentrations of solid ionic materials (e.g., part per million levels of total chromium, manganese, iron, and nickel) and rehabilitation chemicals. No hazardous waste (pH < 2.0) is expected to be generated. The next steps involve pumping and cleaning the well using mechanical methods such as swabbing and jetting. As remedy-produced water continues to be pumped from the well, the water quality becomes more similar to that of the aquifer water. Eventually, this water quality will be more similar to backwash water and can be managed in a similar manner.

TABLE F-2
Summary of Constituents Expected in Water Streams of Various Well Types
Management of Water Produced from Operation and Maintenance of Groundwater Remedy
PG&E Topock Compressor Station, Needles, California

Wells	Sediment	Chromium	Iron	Manganese	Arsenic	Organic Carbon	Acid	Other Rehabilitation Chemicals
Fresh water injection	B, R	-	-	-	-	-	R	R
Carbon-amended injection	B, R	?	B, R	B, R	B, R	B, R	R	R
In-situ reactive zone (IRZ)	B, R	?	B, R	B, R	B, R	B, R	R	R
Extraction - floodplain	B, R	B, R	B, R*	B, R*	B, R*	B, R*	R	R
Extraction - freshwater	B, R	B, R	-	-	B, R	-	R	R
Extraction - bedrock	B, R	B, R	B, R	?	B, R	-	R	R
Monitoring well purge	-	Some	Some	Some	Some	-	-	-

Notes:
B = Well backwash
R = Well rehabilitation
? = uncertain
* Initially but may decrease over the period of operation.

In October 2011, samples were collected from tanks used to haul IM-3 injection well backwash water. These samples were collected to characterize the backwash water and the results are shown on Table F-3.

A pilot test was conducted at Hinkley to evaluate backwashing frequency at the IRZ well SA-RW-19 and to characterize the quality of backwash water. Based on the results collected from June 2011 through June 2012, an initial backwashing frequency of once a week is planned for Topock. Operational data will be collected to evaluate this frequency and make adjustments, as discussed in Section 4 of Volume 1 of the Operations and Maintenance Manual. It is also anticipated that IRZ injection wells will also require mechanical and chemical rehabilitation, and for the purpose of this design, a frequency of once a year has been used. Table F-4 shows the analytical results of the backwash water samples collected from the wellhead during backwashing. One notable observation is that frequent backwashing appears to reduce the buildup of solids and organic carbon in the tested well. The solids are attributed to buildup of biomass, which uses the carbon for growth and absorbs particulate matter. It was observed that the biomass settles quickly in the settling tanks. The operation of the backwashing at Hinkley for development of a design basis at Topock is complete. However, backwashing at Hinkley is ongoing at IRZ well SA-RW-19 for remediation purposes.

TABLE F-3
IM-3 Injection Well Backwash Water Characterization – IW-2 and IW-3
Management of Water Produced from Operation and Maintenance of Groundwater Remedy
PG&E Topock Compressor Station, Needles, California

Analyte	Units [a]	Result [b]
Nitrate as N	mg/L	2.7
Sulfate	mg/L	490
Alkalinity	mg/L	32
Alkalinity, Bicarbonate (As $CaCO_3$)	mg/L	32-41
Alkalinity, Carbonate (As $CaCO_3$)	mg/L	<5
Alkalinity, Hydroxide (As $CaCO_3$)	mg/L	<5
Suspended Solids (Residue, Non-Filterable)	mg/L	<10 - 11
pH	pH Units	7.4 – 7.68
Antimony, dissolved	µg/L	<10
Barium, dissolved	µg/L	13 - 14
Beryllium, dissolved	µg/L	<1
Cadmium, dissolved	µg/L	<3
Calcium, dissolved	µg/L	140,000
Cobalt, dissolved	µg/L	<3
Copper, dissolved	µg/L	7.8 - 10
Iron, dissolved	µg/L	47 - 84
Lead, dissolved	µg/L	<10
Magnesium, dissolved	µg/L	29,000
Manganese, dissolved	µg/L	<10
Molybdenum, dissolved	µg/L	16
Nickel, dissolved	µg/L	<5
Silver, dissolved	µg/L	<3
Sodium, dissolved	µg/L	1,400,000-1,900,000
Vanadium, dissolved	µg/L	<3
Zinc, dissolved	µg/L	<10 – 110
Arsenic, dissolved	µg/L	0.16 - 0.31
Chromium, dissolved	µg/L	0.96 – 4.7
Selenium, dissolved	µg/L	3.2
Thallium, dissolved	µg/L	<2.5
Mercury, dissolved	µg/L	<0.2

Notes:
[a] µg/L = micrograms per liter; mg/L = milligrams per liter
[b] <n = less than the reporting limit value shown

TABLE F-4
Summary of Backwash Sample Analytical Results – Hinkley IRZ SA-RW-19
Management of Water Produced from Operation and Maintenance of Groundwater Remedy
PG&E Topock Compressor Station, Needles, California

Analyte	Sample Date (2011/2012)									
	6/29	7/12	7/19	7/26	8/2	8/9	8/18	9/1	11/22	4/4/12
Alkalinity Hydroxide, mg/L[a]	<5[b]	<5	<5	<5	-[c]	-	-	-	210	250
Alkalinity, Bicarb. as $CaCO_3$, mg/L	170	170	200	170	180	210	220	210	<5	<5
Alkalinity, Carb. as $CaCO_3$, mg/L	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Alkalinity, Total as $CaCO_3$, mg/L	170	170	200	170	180	210	220	210	210	250
Chloride, mg/L	39	37	38	37	-	-	-	-	1.6	1.8
Nitrate as Nitrogen, mg/L	<0.5	<0.05	<0.05	<0.05	-	-	-	-	2.7	7.1
Nitrite as Nitrogen, mg/L	<0.5	<0.05	<0.05	<0.05	-	-	-	-	74	80
Sulfate, mg/L	46	42	27	53	-	-	-	-	72	78
Orthophosphate, Dissolved, mg/L	<0.1	<0.02	<0.02	<0.02	-	-	-	-	---	---
Calcium, mg/L	51	44	46	43	45	55	62	67	9.4	0.65
Calcium (Dissolved), mg/L	50	50	50	52	44	54	64	65	24	17
Iron, mg/L	8.2	6.6	6.7	4.5	2.2	2.1	1.1	1.3	110	360
Iron (Dissolved), mg/L	3	1.6	0.97	1.5	0.03	0.026	0.041	0.17	23	34
Iron, 0.1µ Filter[d], Dissolved, mg/L	1.7	1.5	1	1.5	-	-	-	-	---	---
Magnesium, mg/L	9.3	9.6	10	8.6	9.2	11	11	11	0.11	0.16
Magnesium (Dissolved), mg/L	8.8	9.6	8.8	9.3	8.6	10	11	11	0.97	5.6
Sodium, mg/L	56	-	-	-	-	-	-	-	12	13
Sodium (Dissolved), mg/L	56	-	-	-	-	-	-	-	12	14
Arsenic, µg/L[e]	4.6	3.4	2.7	11	6	4.7	2.4	3.5	0.25	0.26
Arsenic (Dissolved), µg/L	1.9	1.6	0.57	0.98	1.9	1.6	1.6	1.8	0.24	0.72
Manganese, mg/L	1.1	1	0.82	2.3	1.5	1.1	0.33	0.5	---	---
Manganese (Dissolved), mg/L	0.47	0.46	0.66	0.3	0.062	0.13	0.11	0.22	---	---
Hexavalent Chromium, µg/L	-	-	-	-	-	-	47	36	---	---
Total Chromium (Recoverable), µg/L	130	130	130	490	220	160	88	120	8	7.6
Total Dissolved Chromium, µg/L	14	30	10	47	55	52	58	39	---	---
Total Dissolved Solids (TDS), mg/L	580	410	410	400	380	420	470	480	---	---
Total Suspended Solids (TSS), mg/L	540	210	130	510	56	120	24	44	---	---
pH, pH Units	-	-	-	-	7	7.3	7.2	7.2	500	540
Dissolved Organic Carbon, mg/L	100	130	120	200	15	16	3	1.1	53	26
Total Organic Carbon, mg/L	110	94	140	170	52	66	9.6	12	34	130

Notes:
[a] mg/L = milligrams per liter
[b] <n = less than the reporting limit value shown
[c] "-" = no sample collected
[d] 0.1 micron (µ)
[e] µg/L = micrograms per liter

Degree of Conditioning Required

The degree of conditioning needed is a function of how the remedy-produced water will be reused or disposed of, and the discharge requirements that are imposed. The options under evaluation are as follows:

1. Trucking off-site
2. Discharge to TCS evaporation ponds
3. Reuse by blending with freshwater and use in TCS cooling towers
4. Reuse by blending with other water (e.g., backwash water from IRL injection wells , well rehab water from second flush) and injection into the IRZ injection wells
5. Discharge to an infiltration gallery built in Bat Cave Wash near the Compressor Station – this option is deferred until the Soil Resource Conservation and Recovery Act Facility Investigation/Remedial Investigation (RFI/RI) and Corrective Measures study/Feasibility Study (CMS/FS) are complete and will not be carried into the design at this time (see Table F-5 for details)
6. Discharge to Moabi Regional Park wastewater ponds – this option is deferred (preserved for potential future use) and will not be carried into the design at this time (see Table F-5 for details)

Three options previously considered and subsequently eliminated from further consideration are blending conditioned produced water with freshwater for freshwater injection, discharge to ground surface, and use of designated well(s) for disposal. Blending conditioned produced water with freshwater for freshwater injection was eliminated because the water quality may not suitable for re-injection outside the plume or may cause operational (well fouling) issues.

Ground surface discharge was eliminated due to concerns over high visual impact, stakeholder and regulatory acceptance, and permitting challenges. The use of a designated well or wells for disposal of remedy-produced water, while technically viable, could negatively affect the number of wells available for use in the groundwater remediation and therefore constrain the remedy.

Table F-5 summarizes the options under evaluation and provides information available to date. Given the constraints and uncertainties discussed above, the design approach is to use a combination of multiple reuse/disposal options to provide operational flexibility and to ensure that the remedy-produced water management system does not prevent proper maintenance of the groundwater remedy system.

The conditioning of produced water can be accomplished with fixed and/or mobile units. Mobile conditioning equipment may be used during well maintenance periodically for filtration, but not for conditioning of dissolved metals. The primary reason is that the amount of equipment required for such conditioning would exceed the available space in the areas where wells are likely to be installed. Furthermore, using mobile equipment for full conditioning could increase the potential for leaks and spills. For the above reasons, the conditioning system will be fixed units and designed to be housed in a building at the Compressor Station. The conditioning system will be designed for continuous and intermittent operation to allow for operational flexibility.

TABLE F-5
Summary of Disposal/Reuse Options Under Evaluation
Management of Water Produced from Operation and Maintenance of Groundwater Remedy
PG&E Topock Compressor Station, Needles, California

Disposal/Reuse Options	Description	Infrastructure Required Prior to Use
Trucking off-site	Transport unconditioned produced water to a permitted facility off-site.	Trucking off-site will require constructing a loading station at TCS or the MW-20 bench. This would be equipped with pumps, hoses, secondary containment, and controls, located inside a secured facility.
Discharge to TCS evaporation ponds	The Compressor Station's lined evaporation ponds receive cooling tower blowdown water and evaporate it as part of normal Compressor Station operations. Solids are removed from the ponds periodically. The ponds operate under Waste Discharge Requirements (WDRs) issued by the California Regional Water Quality Control Board (Water Board). Excess capacity of the ponds is estimated to be 1,000,000 gallons per year. The WDRs for the ponds or its equivalent substantive requirements will need to be revised in order for the ponds to accept remedy-produced water.	Conveying remedy-produced water to the TCS evaporation ponds will be accomplished by installing a pipeline on TCS property that connects to the existing cooling tower blowdown pipeline that discharges to the ponds.
Reuse by blending with freshwater and use in TCS cooling towers	The cooling towers use fresh water to cool compressed natural gas. The water is re-circulated in the tower and the volume is reduced through evaporation. Make-up water is added so the cooling demand is met. Water is blown down (discharged) from the system to control concentration of dissolved salts or other impurities in the circulating water. The blowdown discharges to the existing evaporation ponds through an existing pipeline. Conditioned remedy-produced water with low dissolved and suspended solids concentrations is likely to be suitable for use in the cooling towers, and may be beneficial to cooling tower operation. In addition, as the circulating water is currently treated to prevent fouling and corrosion in the cooling towers, this reuse option will be evaluated/ designed to ensure a similar level of protectiveness. The cooling tower water usage between January 2009 and March 2011 ranged from 11 to 110 gpm (using monthly water volumes converted to instantaneous rates).TCS cooling towers cannot accept remedy-produced water with high levels of dissolved iron and manganese.	Conveying remedy-produced water to the TCS cooling towers will be accomplished by installing a connection to the existing cooling tower makeup pipe that feeds freshwater to the cooling towers.
Reuse by blending with other water (carbon-amended water) and injection into IRZ injection wells	The IRZ injection wells could take remedy-produced water with minimal conditioning, except for solids removal. This may benefit the remedy in further accelerating the plume movement toward the IRZ line on National Trails Highway (NTH). However, it is not known how much excess capacity the wells could take without affecting the plume movement. The groundwater modeling being performed will be used as a tool to understand the relative difference in the allowable fresh water and carbon-amended injection rates so that flow ranges can be defined for effective operation.	Re-injecting remedy-produced water with carbon-amended water will require a connection to the carbon-amended and IRZ injection pipelines. Remedy-produced water flow will be metered in, so as to not disrupt the remedy system hydraulics. UPDATE: As of this writing, the modeling team has confirmed that the additional flow to the IRZ injection wells will not negatively affect system hydraulics.

TABLE F-5
Summary of Disposal/Reuse Options Under Evaluation
Management of Water Produced from Operation and Maintenance of Groundwater Remedy
PG&E Topock Compressor Station, Needles, California

Disposal/Reuse Options	Description	Infrastructure Required Prior to Use
Discharge to an infiltration gallery built in Bat Cave Wash near the Compressor Station	An injection gallery in Bat Cave Wash is another potential method to dispose of conditioned water. This also has the advantage of accelerating the plume movement toward the IRZ line along NTH. At this point, this option will be deferred until the soil RFI/RI and CMS/FS process is complete. For the purpose of the remedy design, the option will be preserved for potential use in the future (see Basis of Design Report for more details).	An infiltration gallery is similar to a septic leach field with buried slotted or perforated piping that delivers remedy-produced water across the gallery area. Fill around the pipes needs to be coarse enough to allow the remedy-produced water to exit the pipes and by gravity infiltrate into the subsurface. At Topock, the fill would likely be gravel or crushed rock. Since the concept is to install it in Bat Cave Wash, an active natural stormwater channel, it would be necessary to bury the pipe sufficiently deep to prevent stormwater scour/moving rocks or other storm-related effects from damaging the pipe. The exact depth has not been analyzed yet, but it can be expected to be 6 feet or more below surface. Other design data needed includes percolation rates to calculate the area needed for remedy-produced water disposal and limits on the amount of water that can be infiltrated without disrupting remedy system hydraulics.
Discharge to Moabi Regional Park wastewater ponds	The Moabi Regional Park sewage treatment system ponds receive the wastewater from the Moabi Regional Park facilities and Pirate's Cove resort. Four ponds have been constructed, although only one pond appears to be in service at any one time, suggesting that there is significant excess capacity in this system. In this option, conditioned remedy-produced water would be pumped in a pipeline running along NTH to an outfall directly at the ponds, or would be connected to another portion of the sewage treatment system. PG&E contacted San Bernardino County and obtained the following information about the ponds: • The ponds apparently are clay lined and evaporation rates are high. • To date, the ponds are strictly sewage wastewater ponds. Future plan is to continue to use the ponds to meet the sewerage needs of Moabi Regional Park. • There appears to be excess capacity; however, expansion plans from current concession tenant will need to be factored in to assess the true excess capacity. For the purpose of the design, this option will be preserved for potential future use. A pipe connector will be designed as a tie-in point along NTH for the potential future use of this option.	Conveying remedy-produced water to the Moabi Regional Park wastewater ponds could be done by extending the conditioned remedy-produced water pipeline underground along National Trails Highway to a tie-in to the Moabi Regional Park wastewater sewer line.

In summary, the degree of conditioning required for the remaining options to carry forward into the design is described below.

- Trucking off-site to permitted disposal facility –No onsite conditioning is assumed for this option; any conditioning that is required for management of the remedy-produced water is assumed to be performed by the permitted receiving facility. All remedy-produced water sources are assumed to be acceptable to one or more offsite facilities
- Discharge to TCS evaporation ponds – Remedy-produced water discharged to the evaporation ponds must not be hazardous. The only anticipated parameter with the potential to be hazardous is pH (acidic conditions); water with pH less than or equal to 2.0 (characteristic waste level) cannot be directly discharged to the ponds.
- Reuse by blending with freshwater and use in TCS cooling towers – The cooling towers need relatively clean water to keep the cooling towers operating effectively. Therefore near-neutral pH, low concentrations of dissolved iron, silica, and manganese, similar water quality to the current supply which has low total dissolved solids, and low solids concentrations are preferred to prevent fouling. The plan is to achieve low dissolved iron, silica, and manganese by only sending remedy-produced water low in these constituents (such as freshwater injection well backwash) to the tower. Therefore, no conditioning for removal of dissolved iron, silica, and manganese is anticipated.
- Reuse by blending with other water (e.g., backwash water from IRL wells, well rehab water from second flush) and injection into IRZ wells – These wells will have elevated levels of IRZ byproducts, carbon, and possibly chromium because they will be located within the chromium plume. Injection wells need similar water to the formation water (i.e., near-neutral water [pH 6.5 to 8.5]) to not cause adverse geochemical reactions that might precipitate or dissolve minerals. Therefore, pH adjustment is required if the pH is acidic (such as from a well rehabilitation). Elevated levels of IRZ byproducts and low chromium levels are acceptable since they will be taken care of in the reducing zone. Therefore no conditioning for removal of organic carbon or dissolved iron and manganese is anticipated. Solids need to be filtered to prevent clogging.

Remedy-produced Water Management Plan

The reuse/disposal plans for the various types of remedy-produced water differ. Multiple options are maintained where possible to provide operational flexibility. Table F-6 describes the management plan. The plan is subject to change if underlying assumptions prove incorrect. This plan is intended to be flexible and to evolve with operational experience during the groundwater remedy implementation.

This analysis indicates that the following minimal options need to be available for onsite disposal/re-use:

- For disposal, TCS ponds are made available, or some of the remedy-produced water will have to be transported offsite.
- Re-use will occur by injection into IRZ injection wells.

The rationale as embodied in Table F-6 is based in large part on diverting the most impacted water to the TCS evaporation ponds (provided its pH is greater than 2.0, as noted above) or trucking it offsite for disposal. Cleaner water is pumped to the following options, listed in order of preference:

1. TCS cooling towers – Will not affect the remedy wells directly and will reduce TCS water usage. However, the remedy-produced water will be blended with cooling tower make-up water and the total must not exceed the cooling requirements of the compressors. Any excess water has to be diverted elsewhere.
2. IRZ injection wells – Flow limits to maintain system hydraulics, iron, and manganese could also foul wells and increase frequency of maintenance.

TABLE F-6
Reuse/Disposal Management Plan for Water Produced During Groundwater Remedy
Management of Water Produced from Operation and Maintenance of Groundwater Remedy
PG&E Topock Compressor Station, Needles, California

Source	Estimate (MG/year)	Management Plan – Listed in Order of Preference
Backwash of freshwater injection wells/IRL injection wells receiving fresh water	2.32	1. Compressor station cooling towers 2. IRZ injection wells
Backwash of IRZ injection wells, TCS injection wells, IRL injection wells receiving water from river bank extraction wells, and IRZ CIP[c]	2.35 [a]	1. IRZ injection wells
Well rehabilitation (all wells) - first flush	0.77 [a]	1. TCS ponds 2. Trucked offsite 3 If first flush water is neutralized in the field and/or filtered with a transportable treatment unit, send water to Remedy-produced water conditioning plant for processing and re-inject into IRZ injection wells.
Well rehabilitation (all wells) – second flush	1.8 [a]	Same as backwash from corresponding well
Other water – cleaner streams	0.3	Relatively clean water, such as rainwater in containment and some decontamination water, will be managed by the same means as the backwash water from freshwater injection wells.
Other water – some purge and decontamination water	0.1	1. IRZ injection wells 2. TCS ponds 3. Trucked offsite
Other water – produced water from construction of wells in the future	Variable	High-solids water: TCS ponds or truck offsite Low-solids water: IRZ injection wells

Notes:
MG = million gallons
[a.] Testing of IRZ well maintenance schemes at Hinkley is complete and confirmed the weekly backwashing and annual rehabilitation frequency. Assumed that roughly 30% of rehabilitation water will be high-solids or low-pH "first flush" water. Remainder assumed to be similar in nature to backwash water.
[c] Spent solutions from Clean-in-Place System could also be shipped off-site for disposal.

Possible Future Changes

As the Topock groundwater remedy operation progresses over its expected multi-decade life, PG&E may find the need to optimize or otherwise change the system. Possible examples of changing conditions include new sources or characteristics of remedy-produced water; the need for additional wells; the need to further condition the water produced; new disposal or reuse options; or new waste discharge restrictions. These changing conditions may necessitate a change to the remedy-produced water management system, such as different, larger conditioning processes, which will in turn trigger the need for agencies' approval and stakeholders' involvement.

Remedy-Produced Water Management System Design

Design Criteria

Water produced during the remedy implementation will require some conditioning for most of the reuse/disposal options. Three possible water conditioning systems, representing the range required by the varying options, are:

- **Solids removal.** Solids must be removed if water is to be re-injected into the aquifer to minimize impact on well injectivity loss due to plugging. In this case, if low-pH water needed to be neutralized, it would be conditioning at the well head and would be transported to the centralized management facility for solids removal.
- **Solids removal and neutralization.** If low-pH water from well rehabilitation is to be re-injected into the aquifer, it must be neutralized to prevent mobilization of minerals and/or precipitation of solids in the aquifer, which would cause a loss of well injectivity. Neutralization will also be performed to meet waste discharge requirements.
- **Solids removal, neutralization, and dissolved constituent removal.** If strict water quality requirements are mandated for re-injection options, removal of dissolved constituents (such as arsenic, manganese, iron, calcium, and selenium) may be required.

The preferred system is **solids removal with neutralization.** Figure F-2 shows the currently planned conceptual process schematic for this system. This is based on the following assumptions:

- Remedy-produced water that has significantly higher concentrations of solids or dissolved constituents (e.g., byproducts) than what exists in the aquifer water will be sent to the TCS evaporation ponds, or transported offsite for disposal. The preferred approach is to send the water produced at the beginning of rehabilitation events to the TCS ponds (or truck offsite) and to manage the water produced later in the rehabilitation process by the same means as for backwash water. The cutover from “early” stage to “later” stage is proposed to be defined through easily measured onsite water quality tests such as pH, turbidity, and conductivity. If the water is neutralized in the field and/or filtered with a transportable treatment unit, send water to Remedy-produced water conditioning plant for processing and re-inject into IRZ injection wells.
- Flexibility for neutralizing non-hazardous low-pH water (pH less than about 6.5 but greater than 2.0) from well rehabilitations will be provided either through the remedy-produced water management system by caustic addition to the equalization tanks or by an alternative approach such as sending the water to the TCS evaporation ponds, transporting to offsite disposal, or neutralizing with temporary portable systems at the well head.
- Under the management plan presented in Table F-6, removal of dissolved constituents will not be required because the injected water quality will be similar to the aquifer water quality in/near the IRZ injection wells. Temporary fluctuations in water quality will occur during remedy implementation prior to achieving Remedial Action Objectives. Institutional controls will prevent use of affected groundwater while the remedy is being implemented. There are currently no municipal or private wells in the chromium plume area, to PG&E’s knowledge. Furthermore, contaminant migration to the river that could potentially affect water quality goals or beneficial uses will not occur during remedy implementation because of the groundwater extraction along the river bank. PG&E believes that this interpretation is consistent with the requirements of the anti-degradation provisions of 40 CFR 131.12 and State Water Resources Control Board Resolution No. 68-16.

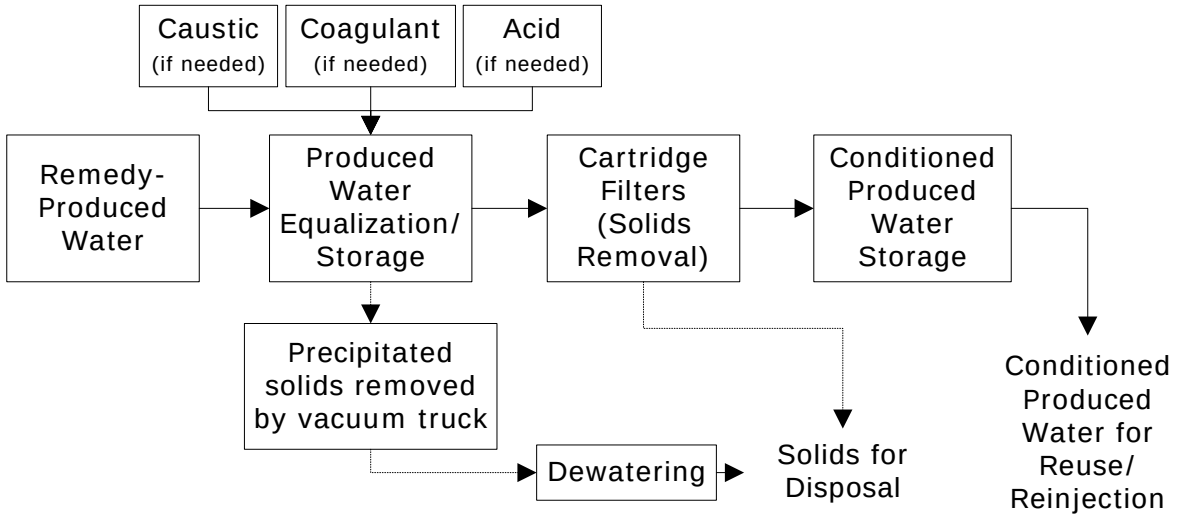


FIGURE F-2
Conditioning Process Schematic
Management of Water Produced During Groundwater Remedy
PG&E Topock Compressor Station, Needles, California

Table F-7 at the end of this memo summarizes the preliminary design criteria for the remedy-produced water management system.

System Sizing

The remedy-produced water conditioning system will be sized for solids-removal and neutralization equipment (pumps, filters, and caustic and acid storage) to meet the design criteria shown on Table F-7. Space will be reserved within the system's building for equipment that may be needed in the future. This includes additional cartridge filters to remove smaller particles (1 micron) if this proves necessary to protect remediation wells, and portable granular activated carbon units if needed to remove trace hydrocarbons from rainwater or decontamination water. Space for other supporting functions such as an onsite laboratory, operators' control room, and limited equipment storage will also be provided. Due to space constraints within the TCS, the majority of the maintenance functions and storage will be consolidated at the central maintenance building/ storage building at the Transwestern Bench.

The conditioning equipment will be housed in a building. It should be noted that the total footprint of the system is larger than the building itself, due to the water equalization requirements and the supporting functions (e.g., operator's office and on-site laboratory, equipment storage). Due to space constraints at the TCS, the remedy-produced water tanks and buildings cannot be fit into a single area but will instead be placed at locations around the station so as not to interfere with existing compressor station facilities.

References

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TABLE F-7
Remedy-produced water Management System Design Criteria
Management of Water Produced from Operation and Maintenance of Groundwater Remedy
PG&E Topock Compressor Station, Needles, California

Design Criteria	Value	Notes
Flow – Average	20 gpm	Best current estimate is 7.6 million gallons per year. If 80% uptime, system would process 18 gallons per minute while running.
Flow – Peak	35 gpm	To manage 50,000 gallons per day.
Equalization volume	>50,000 gal 4 tanks	Largest projected daily production of water is 50,000 gallons per day (during rehabilitation of largest injection well). Provide multiple tanks to allow segregation of varying types of remedy-produced water. At least one of the tanks will be fitted with pumps and venturi eductors to aid in pH adjustment or coagulation. To allow for operational flexibility to segregate/manage various produced water streams and to optimize processes in the future, the conditioning system will be configured with two parallel trains: 1) Remedy A-side and 2) Freshwater B-side. Both trains will be equipped initially with identical processes/units as illustrated in Figure F-2.
Effluent water quality requirements	Total suspended solids (TSS) - < 5 microns pH – 6.5-8.5	Effluent TSS will be < 5 microns to limit injectivity loss in wells used for re-injection. Based on experience at Interim Measure No. 3 (IM-3), Hinkley, and other re-injection sites. Effluent pH will be 6.5 to 8.5 to achieve near neutral pH and not cause adverse geochemical reactions
Solids dewatering	One dewatering system available at all times	Use phase separators (such as at IM-3) for dewatering solids precipitated in pH adjustment steps. Could also be used for the disposal of spent filter cartridges and solid wastes from future sampling.
Influent solids loading	Typical: 60 mg/L TSS	Estimated value consistent with Hinkley results.
Degree of automation	Full	System is to be able to run un-manned (such as nights, weekends, and holidays). Automated to detect non-compliant effluent and shut down system.
Uptime	80%	System can be down for extended periods (~1 week) without jeopardizing well injectivity. Therefore, full system redundancy is not provided. Parallel process streams (A-side Remedy and B-Side Freshwater) equipped with two pairs of duplex filters
Operating time	24 hours per day	Using automation, the system will be able to run full time while unattended. The system will be designed for continuous and intermittent operation based on levels in the influent tanks.
Effluent discharge	Ability to convey water to all reuse/disposal options	Include connections to allow for trucking of conditioned water from system effluent tanks.

Notes:
gpm = gallons per minute; mg/L = milligrams per liter

Appendix G
Evaluation of Arched Bridge Integrity and Space Availability to Support Freshwater Supply Pipeline

TOPOCK BRIDGE (Old Trails Bridge) ASSESSMENT

TO

ASSESS SUITABILITY OF TOPOCK BRIDGE TO SUPPORT A NEW 12" WATERLINE TO BE OWNED BY PACIFIC GAS & ELECTRIC COMPANY

AT

Topock, Arizona

Old Route 66 Arch Bridge Crossing Rio Colorado
Between Arizona and California



October 3, 2011

PREPARED BY:

Danielle Martin, El Paso Corporation Engineering Intern
Juan C. McLane, P.E., El Paso Corporation

INTRODUCTION

The purpose of this report is to assess the structural capacity of the Topock Bridge (Old Trails Bridge) to support a proposed 12-inch waterline supported by the bridge. The bridge is owned by El Paso Natural Gas Company (EPNG) and it currently carries two (2) 30-inch pipelines transporting natural gas. Pacific Gas and Electric Company (PG&E) plans on installing a 12-inch waterline on the Topock Bridge that would be owned and maintained by PG&E. PG&E has asked EPNG to conduct this assessment of the Topock Bridge prior to PG&E installing the proposed new waterline. The report contains that assessment and is separated into the following sections:

a) A background narrative.
b) Pipe materials data.
c) Results and Discussion.
d) A conclusion and recommendation.
e) References.

BACKGROUND

The Topock Bridge (Old Trails Bridge) was constructed in 1914 and is located in Topock which is an unincorporated community in Mohave County, Arizona. The bridge was part of the Transcontinental National Old Trails Road, and by 1926, was part of Route 66 that crossed the Colorado River. The bridge carried vehicle traffic up until 1947. The bridge was only one lane and was rated at 11 Tons. Then, in 1948, the deck was removed so the bridge could accommodate a natural gas pipeline. [(1)]

The bridge currently carries two such 30-inch natural gas transmission pipelines. EPNG transports natural gas on its interstate transmission pipeline system on Line 1104 to the middle of the bridge where custody of the gas and ownership of the pipeline transfers to PG&E. The second natural gas pipeline on the bridge, which is known as Line 1900, is owned by Mojave Pipeline Company, L.L.C. which is an affiliate of EPNG.

DATA

1. SEPTEMBER 1914 BRIDGE DESIGN LOADS

   Truck load 10-Ton [(2)] (See Exhibit 1)

   *Note: "Lane Load" concept did not develop until 1923 and the "Truck Train Loading" and equivalent load was developed in 1929[(2)].

2. HISTORICAL INSPECTIONS

   On June 28, 2010, EPNG hired Acuren Inspection, from Denver, Colorado to inspect the bridge. The Acuren inspection consisted of a visual inspection that included: inspection of the pipelines coatings, inspection of pipeline supports and supporting structures, and insertion of horizontal and vertical alignments. A few pipe supports were found to be have some corroded areas but with sufficient integrity to support the bridge as well as the current and anticipated loads. The inspection report evaluates the bridge as in "good condition." As of the date of this report, EPNG is evaluating bids to have the entire bridge painted and the corrosion spots repaired.

3. EXISTING AND PROPOSED BRIDGE LOADS

   a. Existing 30-inch pipeline, 194 lbs/ft pipeline Number 1104.
   b. Existing 30-inch pipeline, 194 lbs/ft pipeline Number 1900.
   c. Proposed 12" waterline, 88 lbs/ft. (pipe and fluid for testing)
   d. Assume 1000 lbs point load for pipe supports and fittings.

4. ASSUMPTIONS AND CLARIFICATIONS

For purposes of this report, the following assumptions and clarifications apply:

   a. Although the bridge was rated at 11-Ton at the time, a 10-Ton vehicle was used for the design. This assumption is a bit more conservative in the sense that the calculations are comparing the proposed loading to lower bridge design stresses produced by the 10-Ton vehicular load.

   b. The bridge loading concept developed in 1929 was a calculated determination. (See Exhibit A, 3 of 3). This concept involves placing concentrated loads and an equivalent load such that they produce the largest moment or shear on the structure. Although the concentrated and equivalent loads application produced the largest moment, the single truck load was used to evaluate the bridge (See Results and Discussion section). Again, this is conservative approach.

   c. No wind or earthquake evaluation was done. It is assumed that the original Topock bridge design did not include any seismic loading. In 1933, however, it became mandatory to include 8 percent of the weight for seismic design [(4)]. Similarly, it was not until 1927 when the Uniform Building Code was published that wind load was included. There is no record that the bridge was ever analyzed for wind and earthquake loads [(5)] to bring the bridge to Code compliance.

   d. Vehicular impact loading was not added to the vehicle loads. The calculation is more conservative without applying the vehicular impact loads in the sense that the calculations are comparing the proposed loading to lower bridge design stresses.

   e. The deck span of the bridge is 592 ft. long (See attached drawing PB3-EB6-6). It is supported by cables within the arch portion of the bridge and supported by columns on the cantilever portion of the bridge at every 18.5 ft. It is assumed that the supports are the critical element in the bridge. Thus an 18.5 ft section of the bridge was used to compare the original design capacity of the bridge with the proposed loading (pipelines).

   f. Assume 1000 lbs. point load for pipe supports and fittings.

RESULTS AND DISCUSSION

The bridge is an arched three hinged structure. As stated in the assumptions, the deck is supported at 18.5 ft. intervals; the bridge was analyzed: (1) by loading one 18.5 ft section of the bridge with the 10-Ton design vehicle used in 1914, (2) by loading the same 18.5 ft section with the proposed pipeline loads, and (3) by loading the 18.5 ft section with the concentrated and distributed load concept. The results were compared to assess the bridge structural capacity.

1. PROPOSED BRIDGE LOADING CALCULATIONS – (2) 30” gas pipelines and (1) 12” waterline full with water.

   The calculations show that the design moment is equal to 25.1 ft-k, and the design shear is equal to 4.9 kips (See Exhibit A, 1 of 3)

2. ORIGINAL BRIDGE DESIGN CALCULATIONS – 10-Ton Design Truck

   The calculations show that the design moment is equal to 45.2 ft-k, and the design shear is equal to 13.9 kips (See Exhibit A, 3 of 3)

3. CONCENTRATED AND DISBRIBUUTED LOAD CONCERPT (from 1929)

   The calculations show that the design moment is equal to 110.6 ft-k, and the design shear is equal to 18.9 kips (See Exhibit A, 3 of 3)

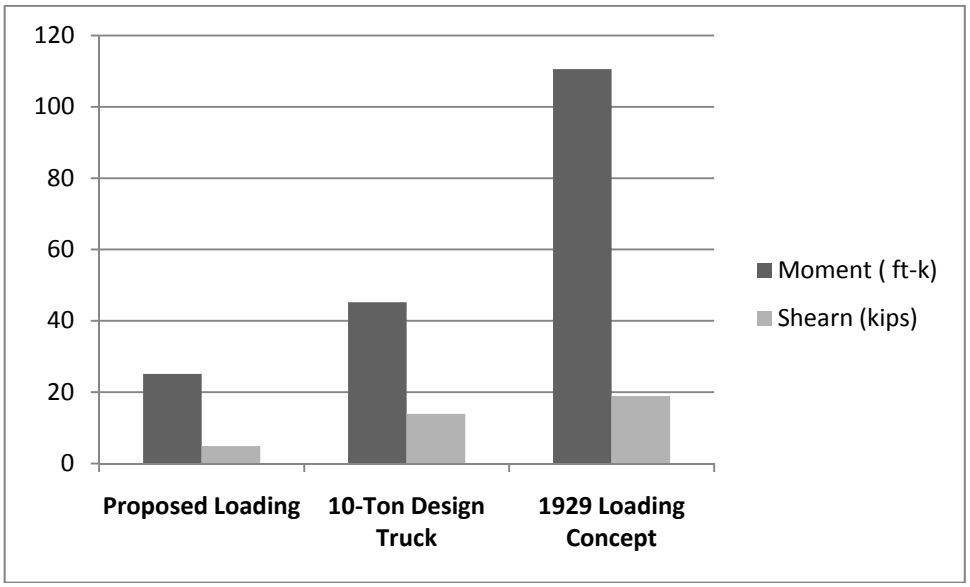


TABLE 1

Table 1 shows the stress comparison among the proposed loading, the original 10-Ton bridge design, and the 1929 loading concept. The stress comparison between the proposed loading of (12” waterline and two 30” pipelines) and the 10-Ton truck loading produces a moment that is 55% percent of the original 10-Ton truck bridge design moment capacity and a shear that is 36% of the original 10-Ton truck bridge design shear capacity. The 1929 loading concept is shown for reference. The latter is not used in the recommendation.

CONCLUSIONS

The proposed 12-inch waterline load on the bridge will be within acceptable design loads for the Topock Bridge. The proposed loading produces a moment that is 55 percent of the design moment and produces a shear that is 36 percent of the design shear. The structural analysis results for the bridge are conservative since the design truck impact loads and the lane loading pattern were not included in the calculation.

RECOMMENDATIONS

It is recommended that during construction, equipment larger than 16 kips not be used in any 18.5 ft. long deck section. Additionally, the bridge deck supports shall be visually inspected prior to construction.

REFERENCES

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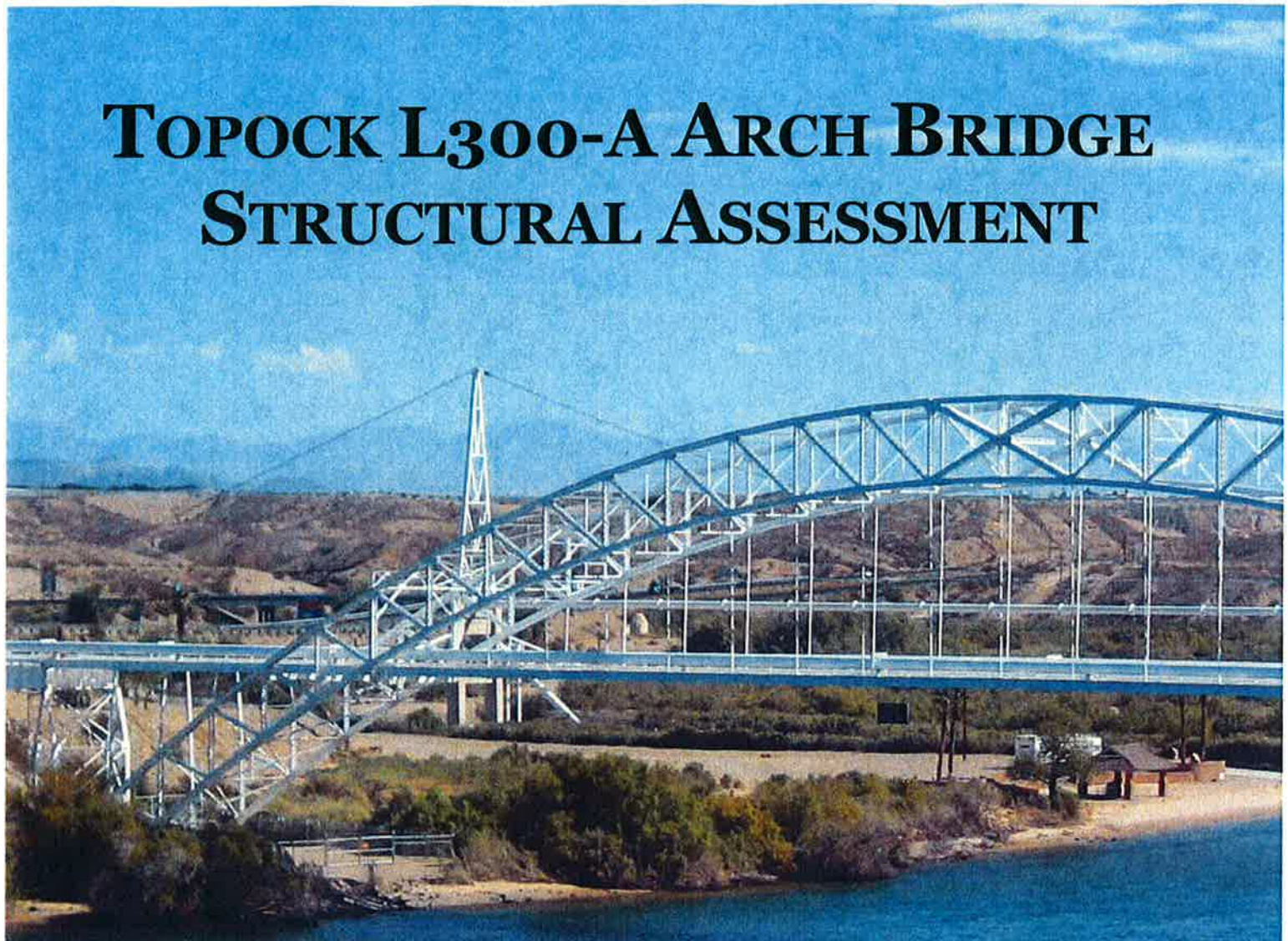
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TOPOCK L300-A ARCH BRIDGE STRUCTURAL ASSESSMENT



FINAL REPORT

December 13, 2011

AECOM
2101 Webster Street, Suite 1000
Oakland, CA 94612

TOPOCK L300-A ARCH BRIDGE STRUCTURAL ASSESSMENT FINAL REPORT

PREPARED FOR PG&E

December 13, 2011



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TABLE OF CONTENTS

1.0 INTRODUCTION 1

2.0 DESIGN INPUT 1

2.1 Geometry and Section Properties 1

2.2 Design Codes 2

2.3 Wind Parameters 3

2.4 Seismic Parameters 3

3.0 DESIGN LOADS 4

3.1 Load Cases 4

3.2 Load Combinations 5

4.0 METHOD OF DESIGN 6

4.1 SAP2000 6

4.2 Truss Structures 6

4.3 Tension-Only Members 6

5.0 RESULTS 6

5.1 Normal Operating Conditions 6

5.1.1 Deck Braces 6

5.1.2 Longitudinal Deck Beams 6

5.1.3 Transverse Deck Beams 7

5.1.4 Top Chord Horizontal Truss Braces 7

5.1.5 Bottom Chord Horizontal Truss Braces 7

5.1.6 Vertical Truss Members 7

5.1.7 Vertical Truss Braces 8

5.1.8 Bridge Support Braces 8

5.2 Dead Loads Only 8

5.1 Pressure Test Conditions 8

6.0 CONCLUSIONS 8

APPENDICES

A Bridge Photos

B Design Input

C Design Loads

D Construction Drawings

1.0 INTRODUCTION

The Topock (Old Rivers) Bridge is an arched steel structure constructed in 1914 as part of the Transcontinental National Old Trails Road and was used as a means of transportation for vehicles traveling along Route 66 between California and Arizona until 1947. In 1948 the bridge deck was removed in order to accommodate the natural gas pipeline which it continues to carry today.

Currently the existing structure supports two 30-inch gas pipelines and one 6-inch waterline. Located in Topock, an unincorporated area of Arizona, the bridge spans 608 feet across the Colorado River and is supported at 18½ foot intervals. The following report assesses the capability of the Topock Bridge to support an additional 12-inch waterline as proposed by Pacific Gas & Electric Company (PG&E). It also considers the effect of adding water to the existing gas lines in order to pressure test the pipes.

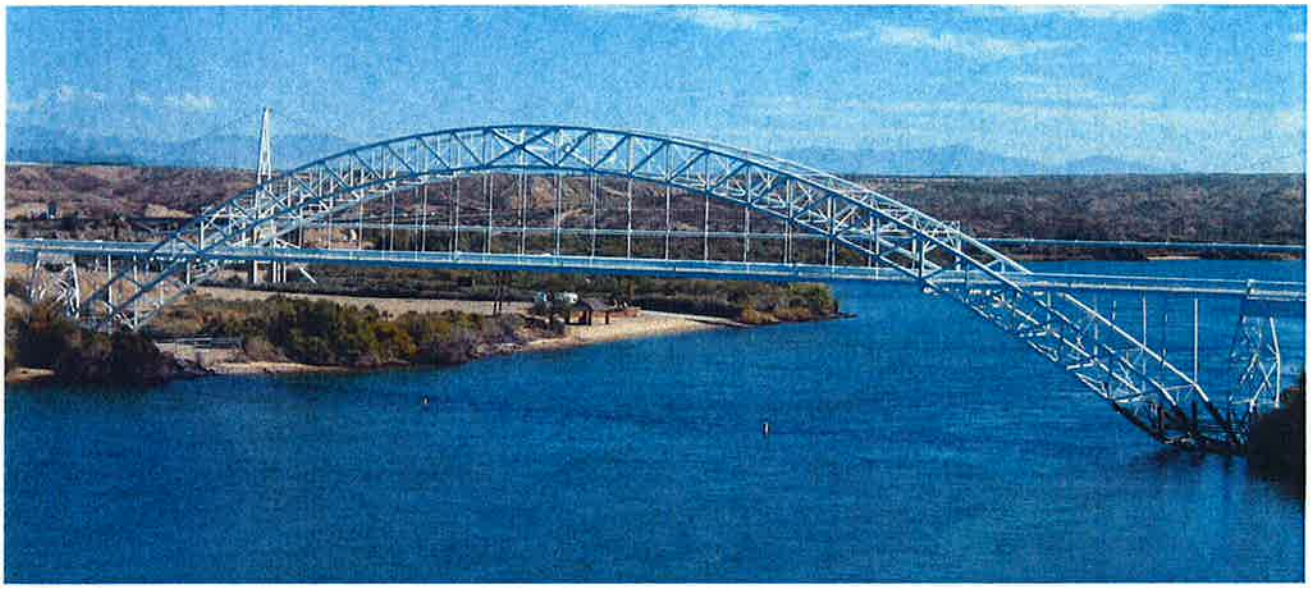


Figure 1.1: Topock L300-A Arch Bridge

2.0 DESIGN INPUT

2.1 Geometry and Section Properties

Due to the age of the bridge, very little of the original design information was available. It was assumed that all steel members were made from 36 ksi steel based upon investigations of material properties used in the early 20th century.

As one of the owners, the El Paso Corporation was able to provide an erection plan drawing indicating the overall geometry of the bridge but lacking any member sizes. Hand measurements were taken of any easily accessible members but it was necessary to scan the bridge using CYRAX scanning equipment in order to estimate the remaining dimensions and member properties.

A large portion of the bridge is composed of built-up sections which had to be individually defined for the analysis. Both the top and bottom chords of the truss consist of back-to-back channels connected with flat bars in a crisscrossed pattern. Similarly, the diagonal truss members contain a series of flat tie bars that run between pairs of double angles. Any additional strength due to such tie bracing was conservatively ignored in the structural analysis. Appendix B shows the cross-sections that were used for such built-up members in the bridge model.

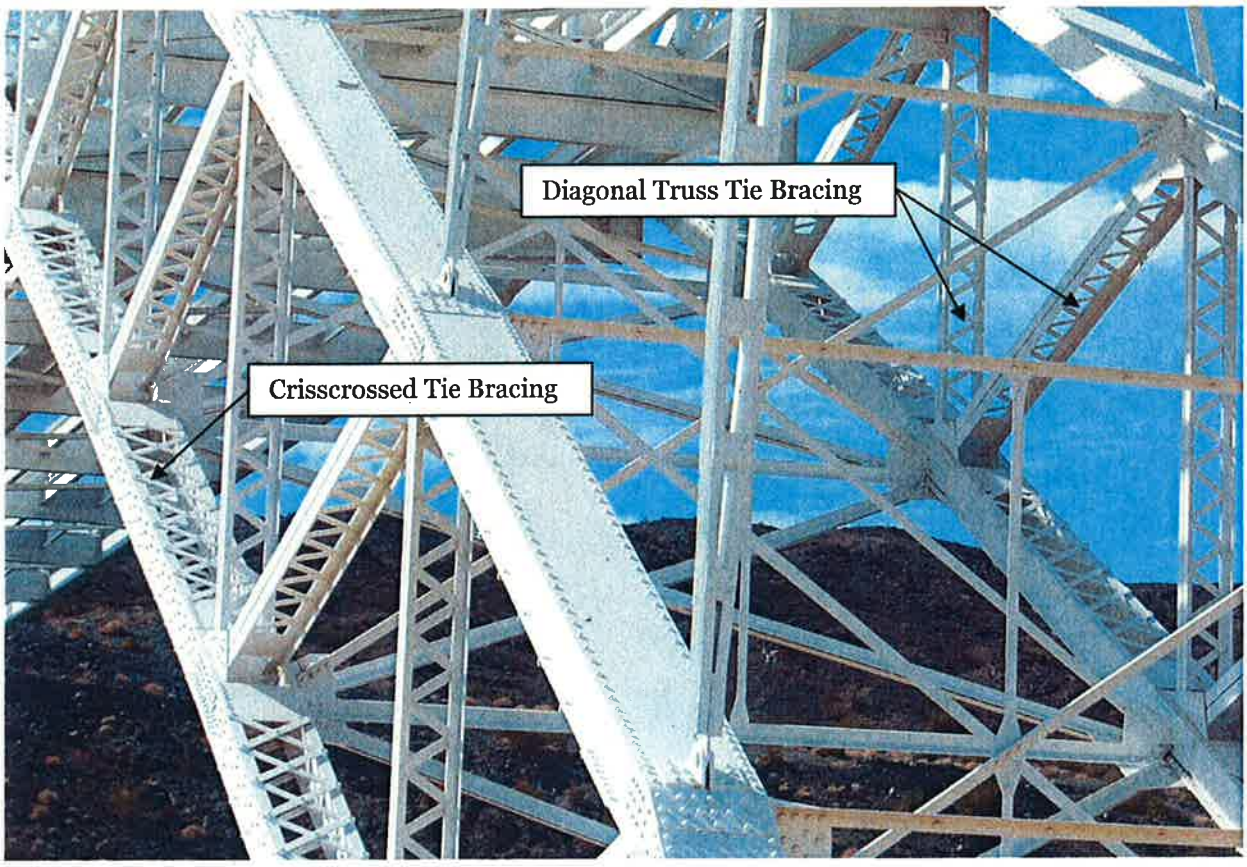


Figure 2.1: Tie Bracing

2.2 Design Codes

Analysis of the bridge was performed in accordance with the following design codes.

- California Building Code (CBC-2010)
- International Building Code (IBC-2009)
- Minimum Design Loads for Buildings and Other Structures (ASCE 7-05)
- AISC Manual of Steel Construction, 13th Edition (AISC 360-05)

2.3 Wind Parameters

The following parameters were used to calculate the wind forces according to the provisions of ASCE 7-05.

- Basic Wind Speed: V = 90 mph under normal operating conditions
  V = 30 mph during pressure testing
- Exposure Category C
- Importance Factor, $I_W = 1.15$

2.4 Seismic Parameters

Seismic forces were calculated using the following seismic parameters in accordance with the provisions of ASCE 7-05.

- Site Location: Latitude = 34.714225; Longitude = -114.493332
- Mapped Spectral Response Acceleration: $S_S = 0.216$; $S_1 = 0.133$
- Site Class D
- Site Coefficients: $F_a = 1.6$; $F_v = 2.268$
- Design Spectral Response Acceleration: $S_{DS} = 0.231$; $S_{D1} = 0.201$
- Seismic Occupancy Category IV
- Importance Factor, $I_E = 1.5$
- Seismic Design Category D

3.0 DESIGN LOADS

3.1 Load Cases

Loads were applied to the structure as outlined in the following load cases. Longitudinal wind and seismic forces do not govern the design so they were not included in the analysis. Detailed load calculations can be found in Appendix C.

- DEAD: Dead load on the structure includes the self weight of all steel members as well as the weight of each of the two gas pipelines and two waterlines (including weight of the water). Pipe loads were applied to the transverse deck beams at vertical pipe support locations based upon tributary lengths.

- TEST WT: Similarly to the pipe dead loads, the additional weight of water present during testing was applied to transverse deck beams at vertical pipe support locations. Testing loads were applied to each gas line separately in load case TEST WT 1 and TEST WT 2.

- WIND: Wind loads were applied to the structure based upon the surface area of members. Loads were applied at the joints along the top and bottom chords of the truss as well as the outermost deck beam. Wind loads on the deck were reduced based upon the assumption that a certain amount of shielding would occur.

- TEST WIND: Test wind loads are the same as wind loads except with reduced magnitudes based on 30 mph basic wind speeds instead of 90 mph winds.

- PIPE WIND: Wind pressure on the surface area of each of the pipes was applied as point loads in the positive y-direction at horizontal pipe support locations.

- TEST PIPE WIND: Reduced wind pressures acting on the surface area of each of the pipes were used during pressure testing.

- SEISMIC: Seismic loads on the structure were applied to all steel members in the positive y-direction as a fraction of their weight.

- PIPE EQ: Seismic forces acting on the pipes were input by applying a fraction of the weight of each pipe at the location of horizontal pipe supports.

3.2 Load Combinations

The following table summarizes how the load cases were combined and input into SAP2000. It was assumed that wind speeds would not exceed 30 mph during testing of the pipes, therefore reduced wind loads were used in combinations that include test weight loads. Additionally, it was considered unlikely for an earthquake to occur concurrently with testing, thus test weight loads were not included in any load cases containing seismic forces.

Load Combination	Load Factor	Load Case
1.4D (Test 1)	1.4	DEAD
		TEST WT 1
1.4D (Test 2)	1.4	DEAD
		TEST WT 2
1.2D + 1.6W	1.2	DEAD
	1.6	WIND
		TEST WIND
1.2D + 1.6W (Test 1)	1.2	DEAD
		TEST WT 1
	1.6	TEST WIND
		TEST PIPE WIND
1.2D + 1.6W (Test 2)	1.2	DEAD
		TEST WT 2
	1.6	TEST WIND
		TEST PIPE WIND
$(1.2+0.2S_{DS})D + 1.0E$	1.25	DEAD
	1.0	SEISMIC
		PIPE EQ

4.0 METHOD OF DESIGN

4.1 SAP2000

The bridge was modeled using SAP2000 which is a proprietary structural analysis software produced by Computers and Structures Inc. (CSI). SAP2000 uses a graphical user interface to create 3D structural models with a variety of loading and analysis options. Such models may be checked against the provisions of both U.S. and international design standards. SAP2000 will also automatically calculate the properties of user-defined sections and include them within the design code check. A verification of the software can be found in Appendix E.

4.2 Truss Structures

In the analysis of the bridge structure, the top and bottom chord of the arch were assumed to be continuous members with a hinge connection at the center. All remaining vertical and horizontal elements were modeled as truss members with pin connections at each end and free of bending moments.

4.3 Tension-Only Members

Bracing members with long unbraced lengths and high slenderness ratios were assumed to act as tension-only members. It was assumed that any compression forces in these members would be redistributed as tension in adjacent members.

5.0 RESULTS

5.1 Normal Operating Conditions

Normal operating conditions were used to assess the capability of the bridge to support an additional 12-inch waterline. Members with loads exceeding their capacity by more than 5% were considered to be overstressed. Compressive forces in tension-only members were combined with the tension in adjacent braces and then checked against their tensile capacity. The governing load combination for all members was 1.2D + 1.6W.

5.1.1 Horizontal Deck Braces

Horizontal braces along the bridge deck were considered to be tension-only members. After combining tension and compression forces, three pairs of braces were found to be overstressed on each side of the bridge.

5.1.2 Longitudinal Deck Beams

Large axial forces produced in intermediate longitudinal deck beams by the computer analysis were disregarded due to the fact that these beams do not participate in the shear transfer of the horizontal truss system. With the absence of axial force, none of the beams are overstressed.

5.1.3 Transverse Deck Beams

Several transverse deck beams are indicated as being overstressed due to large minor-axis moments caused by high axial forces in the longitudinal deck beams. Since the longitudinal beams don't actually carry such forces, minor moments were disregarded and none of the transverse beams were found to be overstressed.

5.1.4 Top Chord Horizontal Truss Braces

Steel rods bracing the top of the truss were considered to be tension-only members. When the compressive forces are redistributed, none of the rods are overstressed.

5.1.5 Bottom Chord Horizontal Truss Braces

The capacity of double angle braces along the bottom of the truss were found to be insufficient to withstand the applied loads even after considering them as tension-only members.

5.1.6 Vertical Truss Members

Vertical members of the truss are shown as overstressed where they connect to the bridge deck at a location 222 feet from the center. Minor-axis moments are created within the truss due to an eccentricity in the model between the transverse deck beam and the vertical truss member. A closer look at this connection shows that such an eccentricity will not occur and thus minor moments may be disregarded.



Figure 5.1: Connection of Truss to Bridge Deck

5.1.7 Vertical Truss Braces

After checking the tensile capacity of vertical truss members against their combined total force, it was found that only the braces located 222 feet from the center were overstressed.

5.1.8 Bridge Support Braces

Vertical braces on the face of the tower support at 304 feet and those of the support at 360 feet were both indicated as being overstressed. When analyzed as tension-only members, all braces were found sufficient to carry the applied loads.

5.2 Dead Loads Only

Results generated from the computer analysis indicated that some vertical braces were failing in compression due to dead loads. When these braces are considered to be tension-only, the capacity of such members is taken as zero and the compressive forces are redistributed to the adjacent columns. A second model was therefore created to make sure that such adjacent members would have sufficient capacity to withstand any additional forces caused by the removal of tension-only members. The analysis does not consider seismic and wind forces, however the additional dead loads experienced during testing of the 30-inch gas lines were included. Results show that none of the members will be overstressed when subjected to dead loads only.

5.3 Pressure Test Conditions

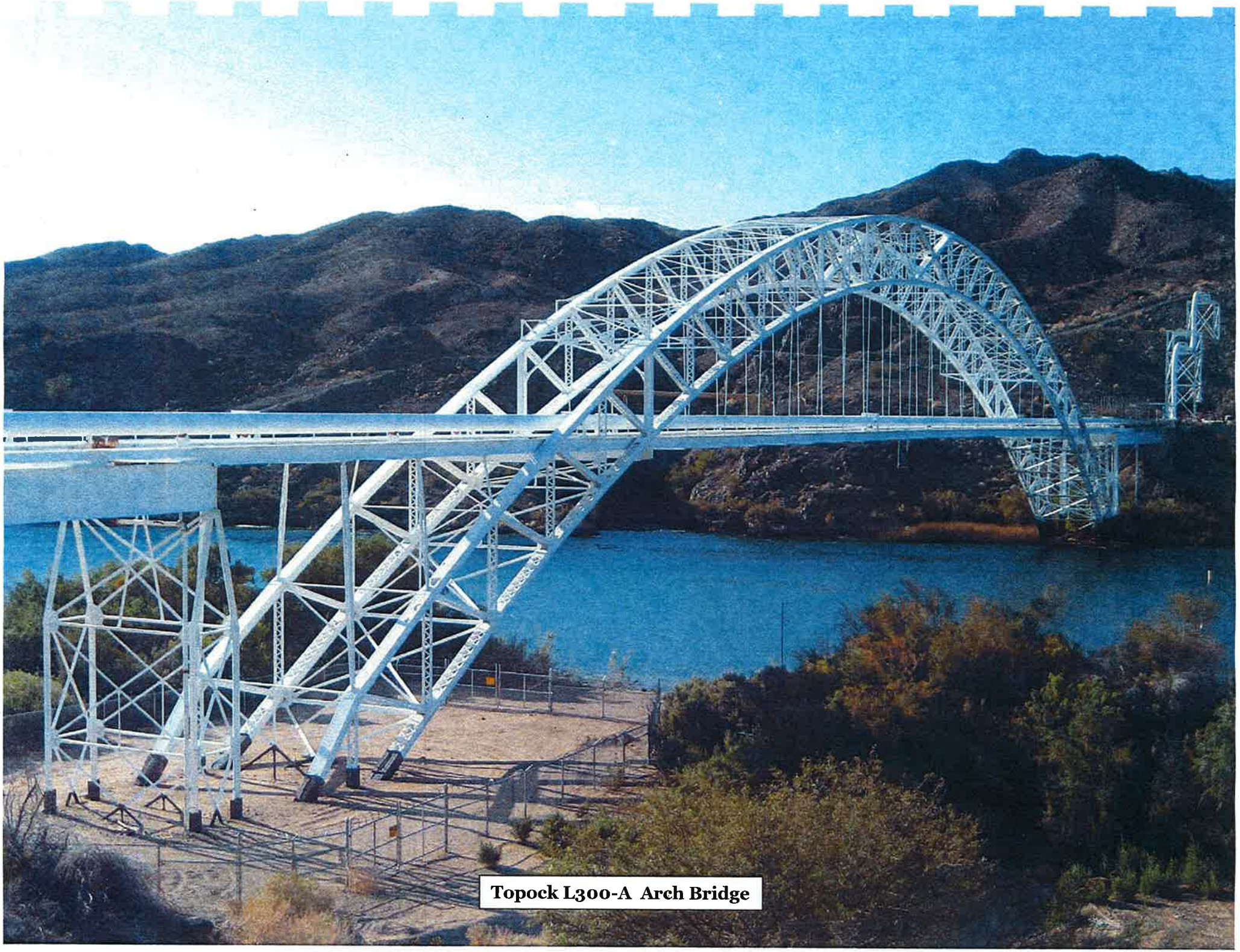
During testing of the 30-inch gas lines additional dead loads due to water were applied in conjunction with reduced wind loads. Seismic forces were not included due to the unlikelihood of an earthquake and pressure testing occurring simultaneously. Results from this analysis show some bracing members not being able to withstand the applied loads, however when they are taken as tension-only members none are overstressed.

6.0 CONCLUSIONS

The capacity of Topock L300-A Arch Bridge was investigated with a new 12-inch diameter waterline and checked for conformance to current design codes. Members which exceeded allowable stress levels are identified in Section 5.0 and their recommended modifications are detailed in Section 7.0. The bridge foundations are not shown on any design drawings so it was not possible to investigate their capacity. Since the additional weight added to the bridge is only 10% of the total weight it is assumed that existing foundations will continue to sufficiently support the structure under the new loads.

APPENDIX A

BRIDGE PHOTOS



Topock L300-A Arch Bridge

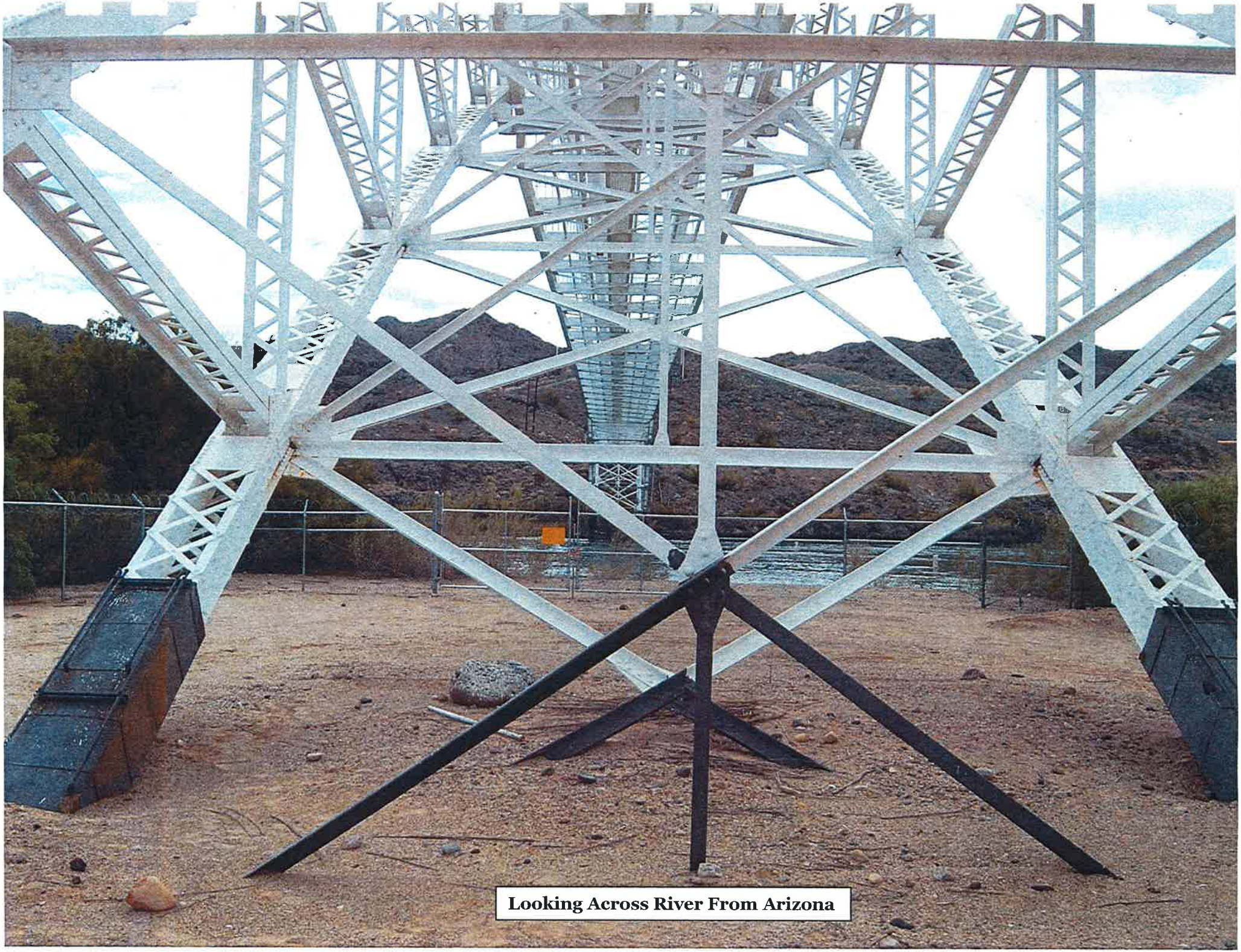


Looking Across River From California



Looking Across the Bridge Deck

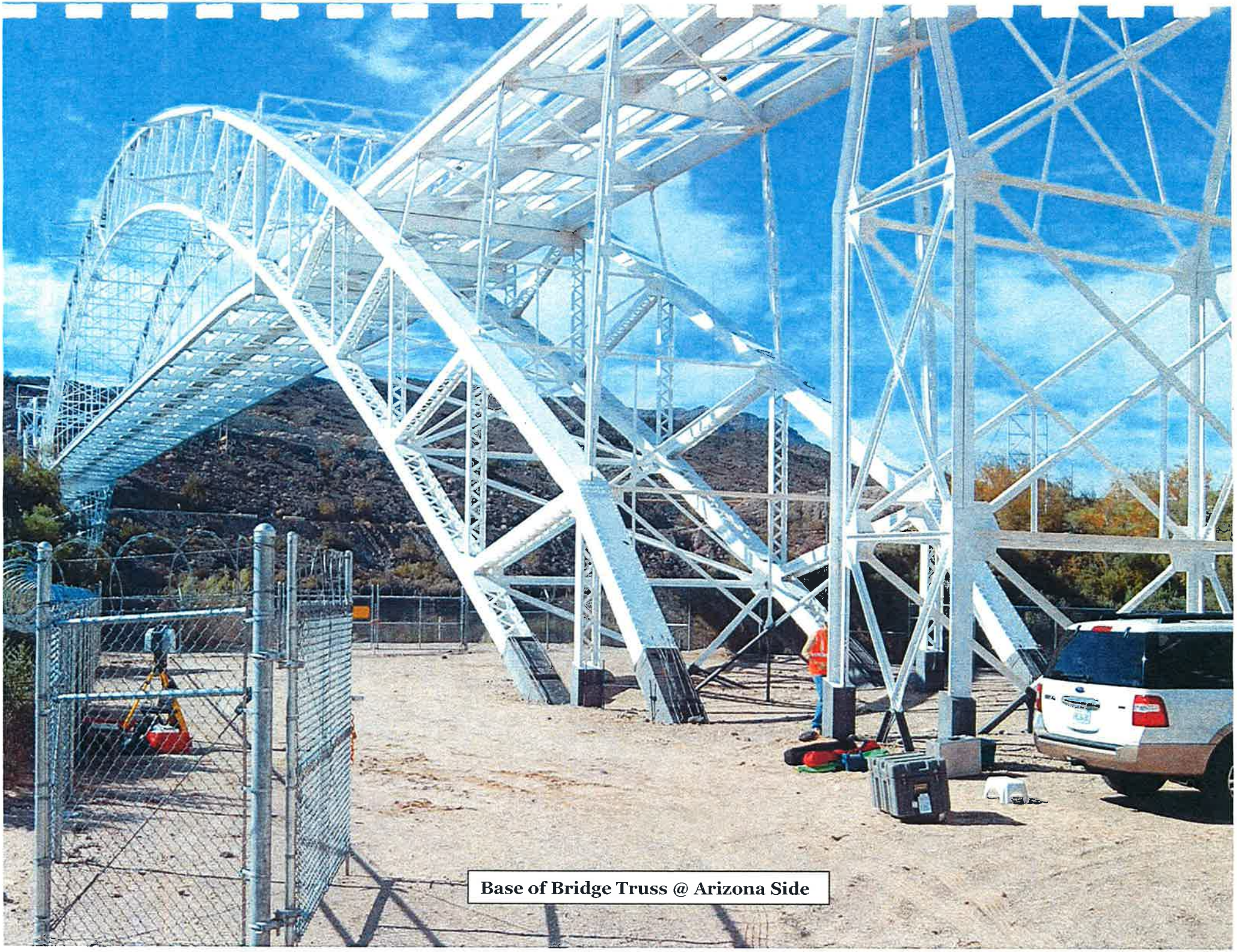

Top Hinge Connection @ Center



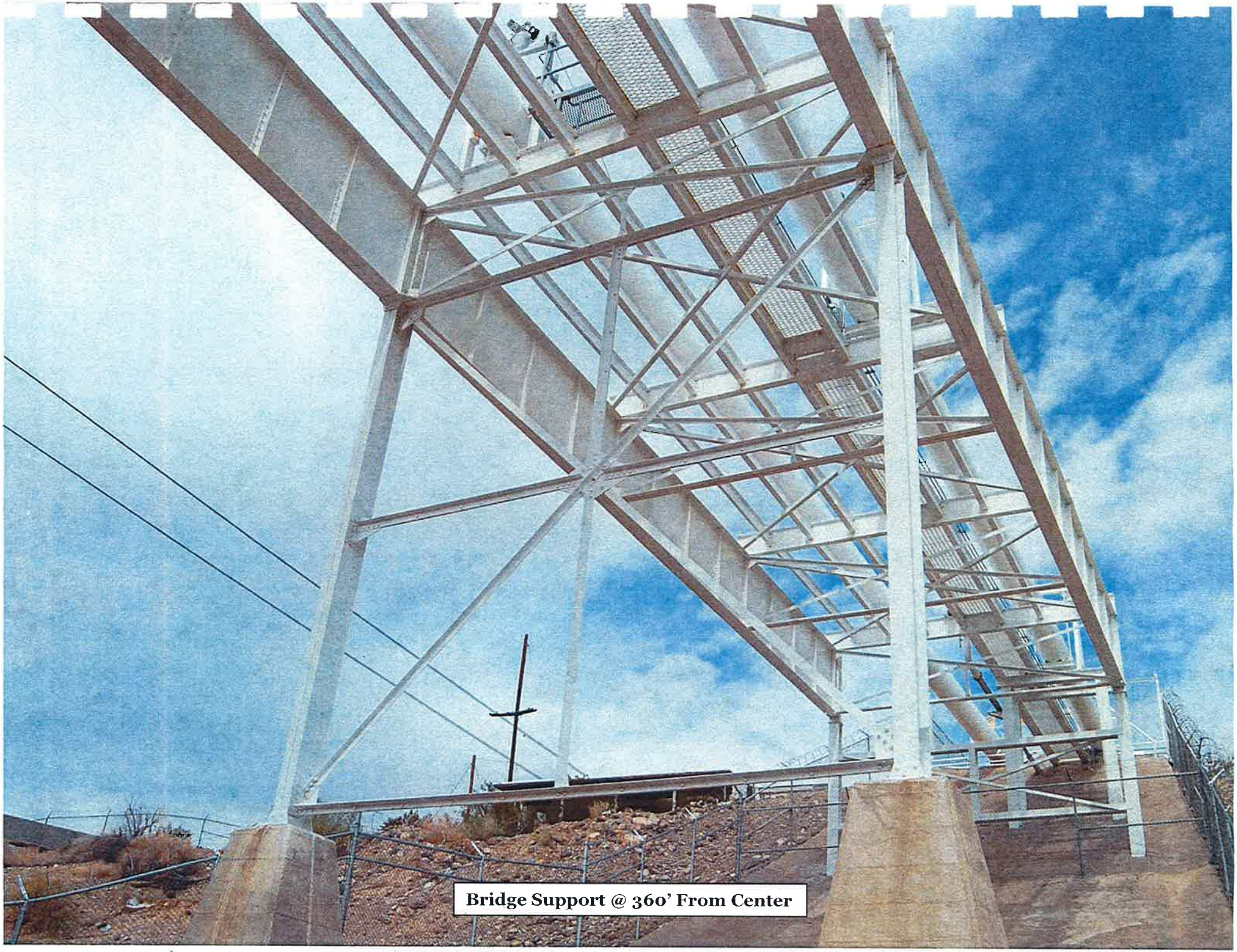
Looking Across River From Arizona



Underside View



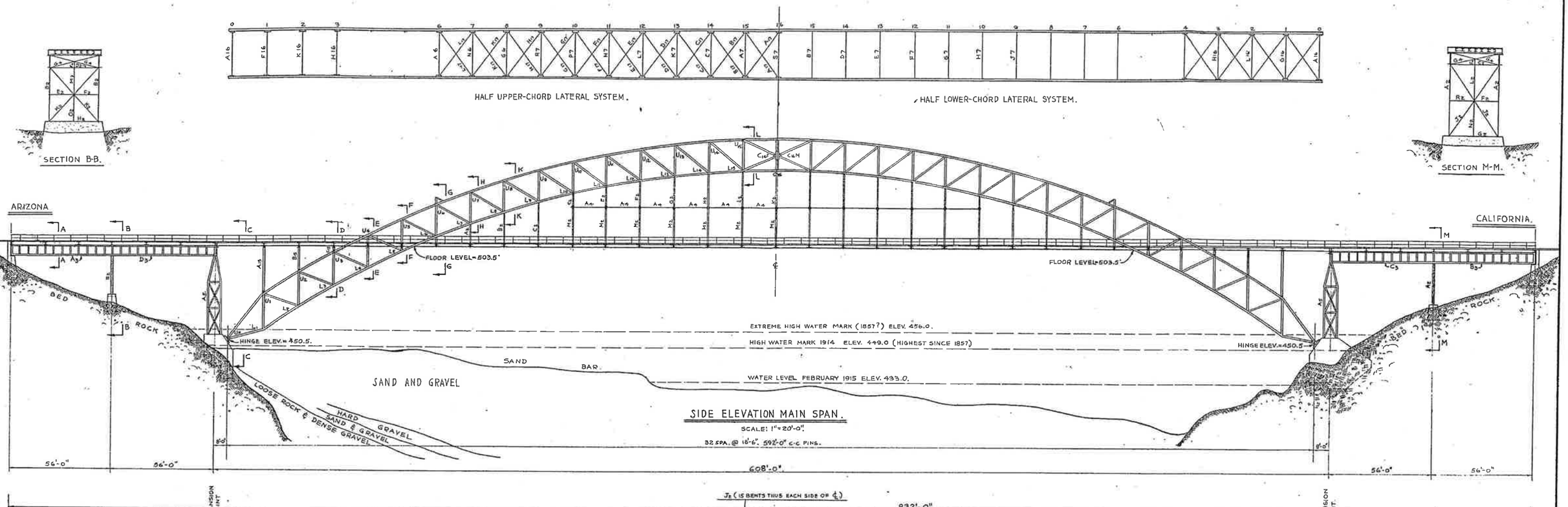
Base of Bridge Truss @ Arizona Side



Bridge Support @ 360' From Center

APPENDIX B

DESIGN INPUT



NOTE:
RETRACED FROM KANSAS-CITY STRUCTURAL STEEL CO'S DWG.
ORDER 7744-7745-7746.

REFERENCES
SHOP DETAILS DWG: # F-1589.

SCANNED

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		TABLE OF CHANGES	

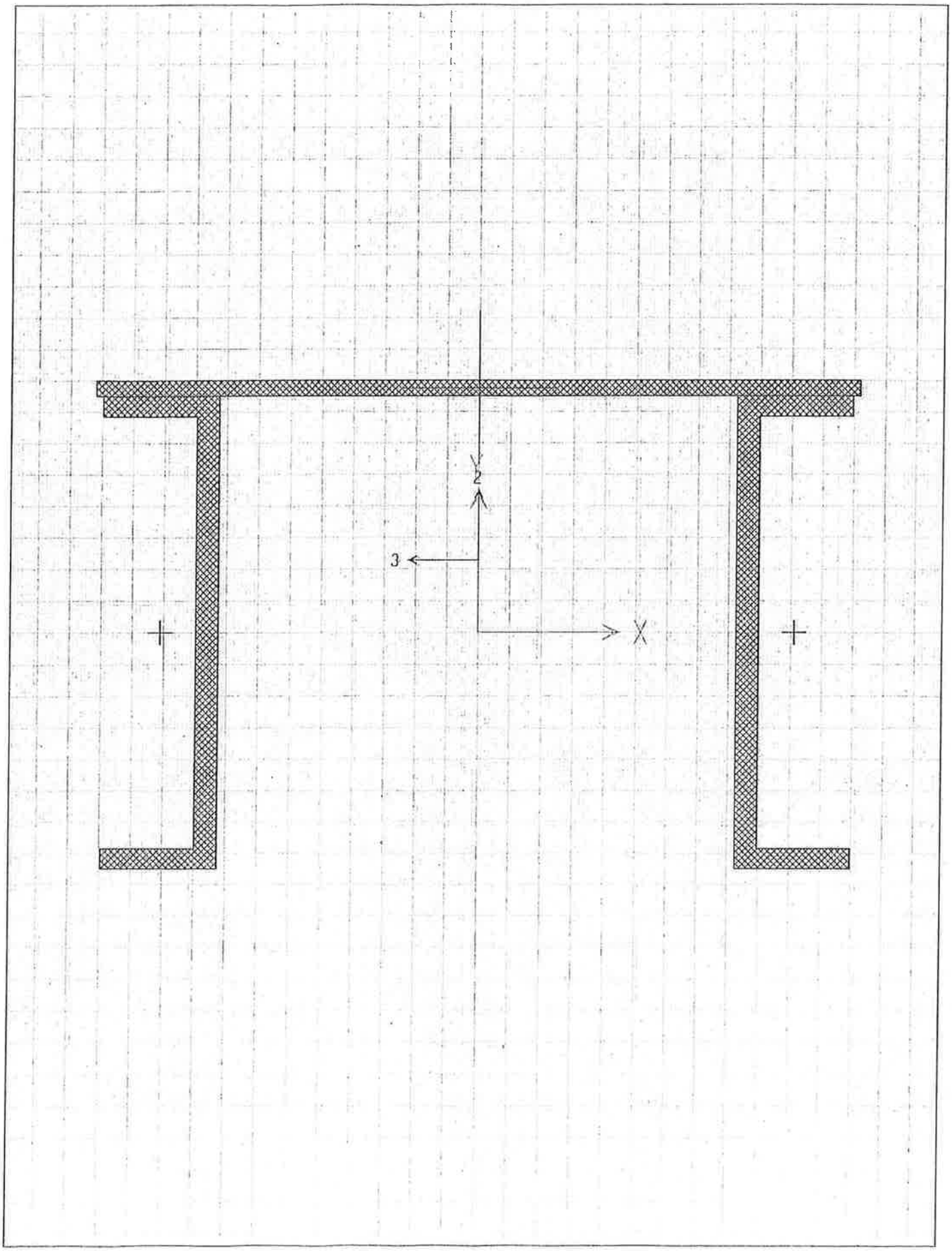
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BY Dept of G.O. DR. W.F. Peckhoff CH. Stone
CK.
DATE 6-16-50
SCALES As Shown.

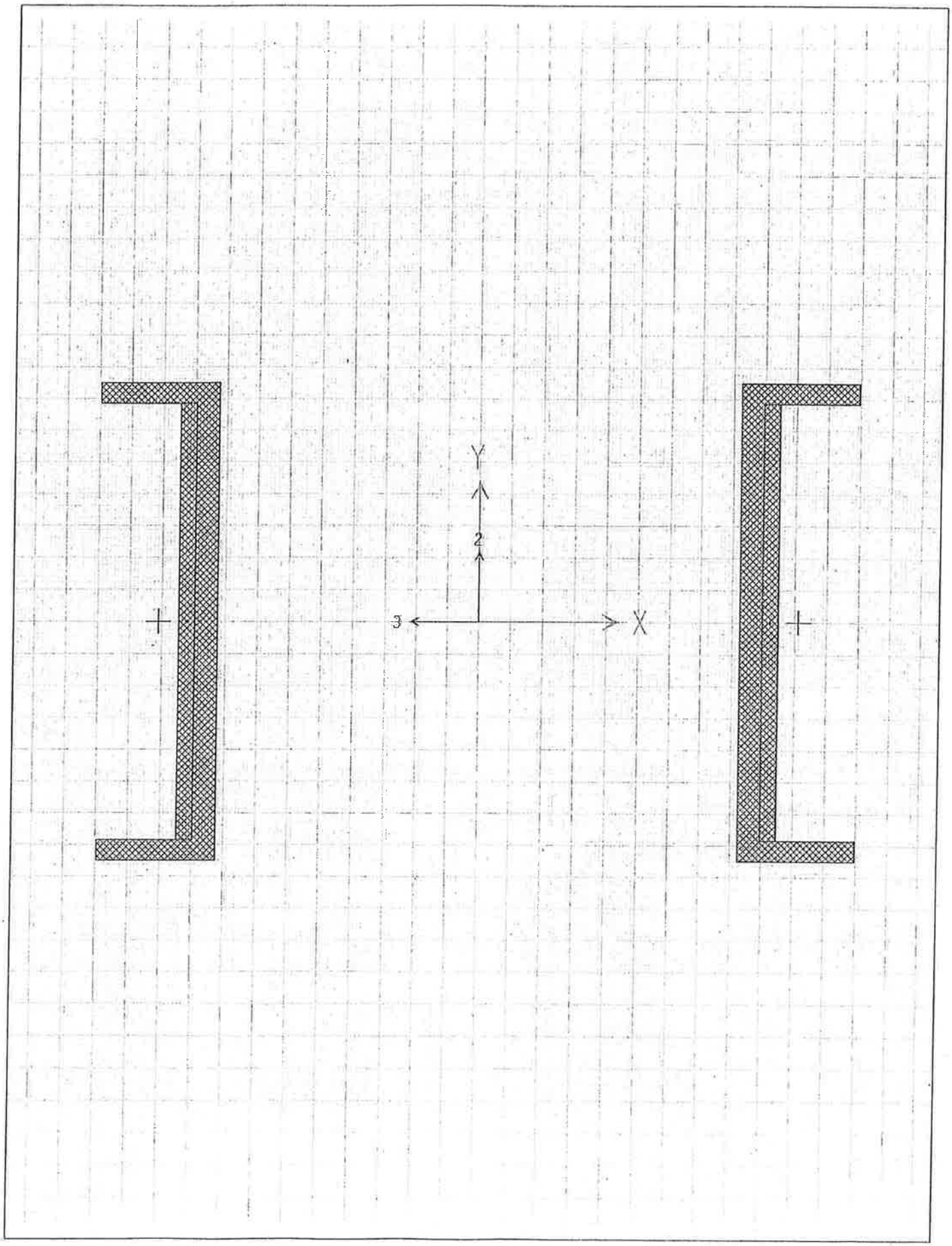
ERECTION PLAN
COLORADO RIVER HIGHWAY BRIDGE
TOPOCK-MILPITAS, MAIN 300

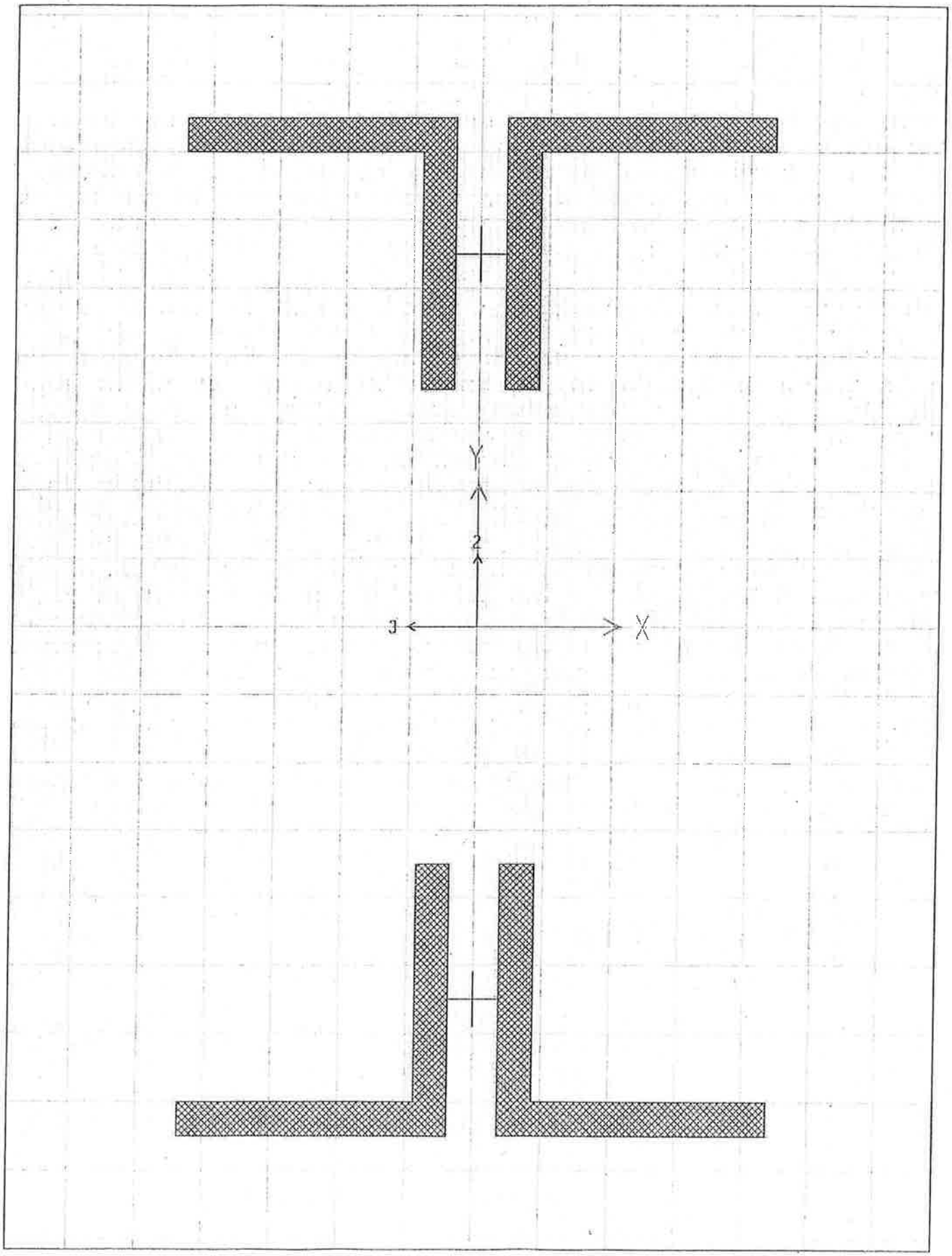
DEPARTMENT OF GAS OPERATION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO CALIFORNIA

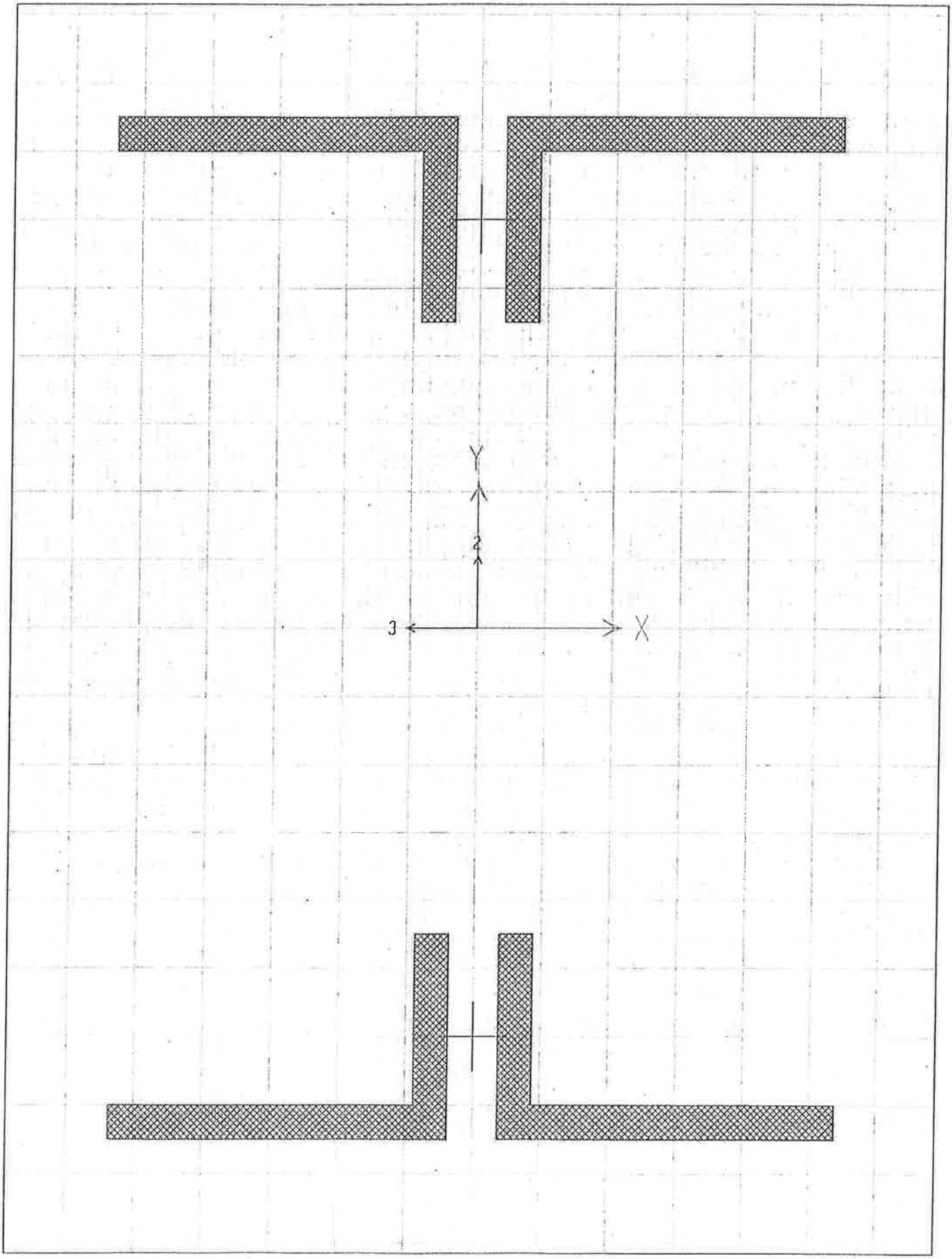
BILL OF MATERIAL
SUPERSEDES
SUPERSEDED BY
SHEET NO. SHEETS
DRAWING NUMBER CHANGE
481620

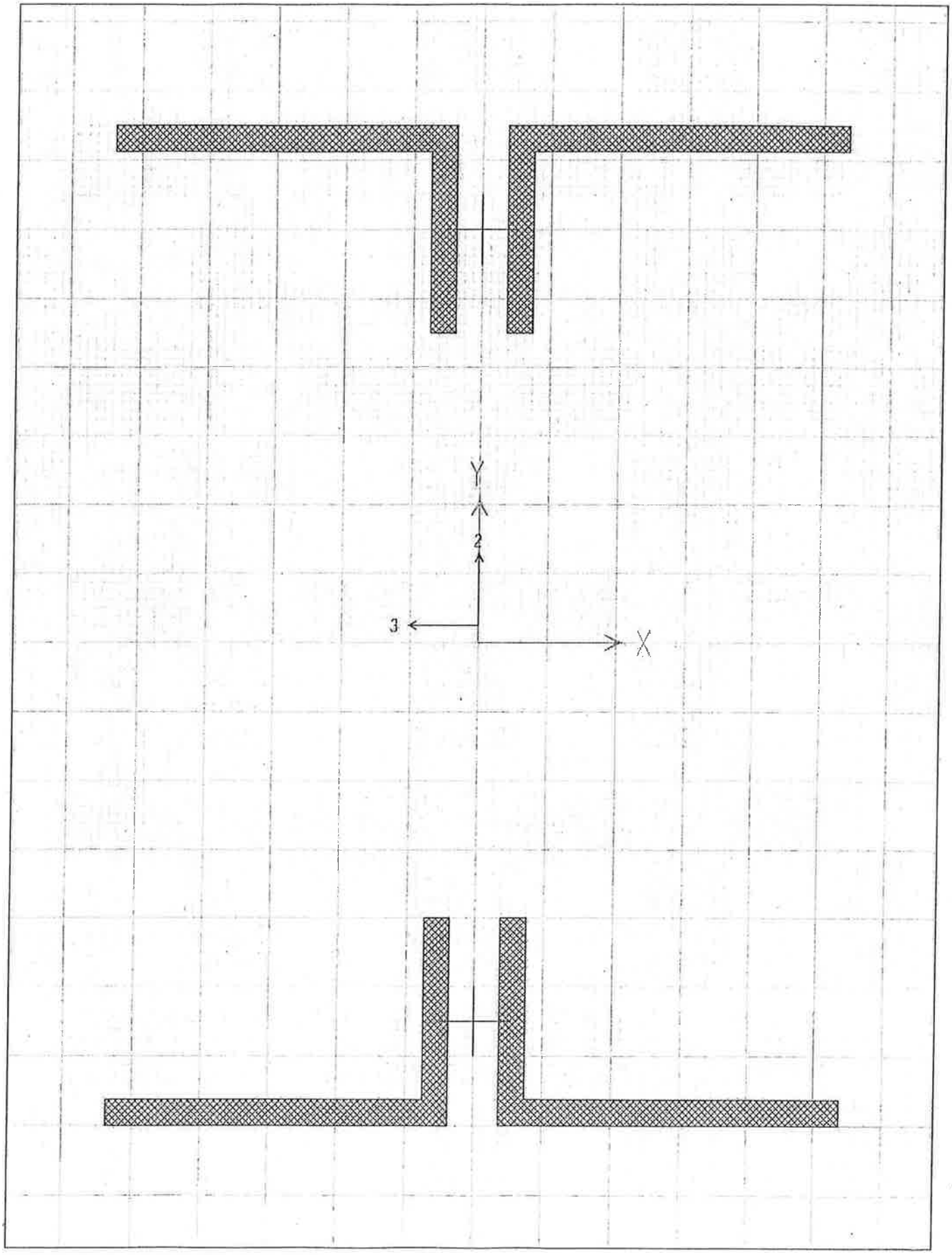
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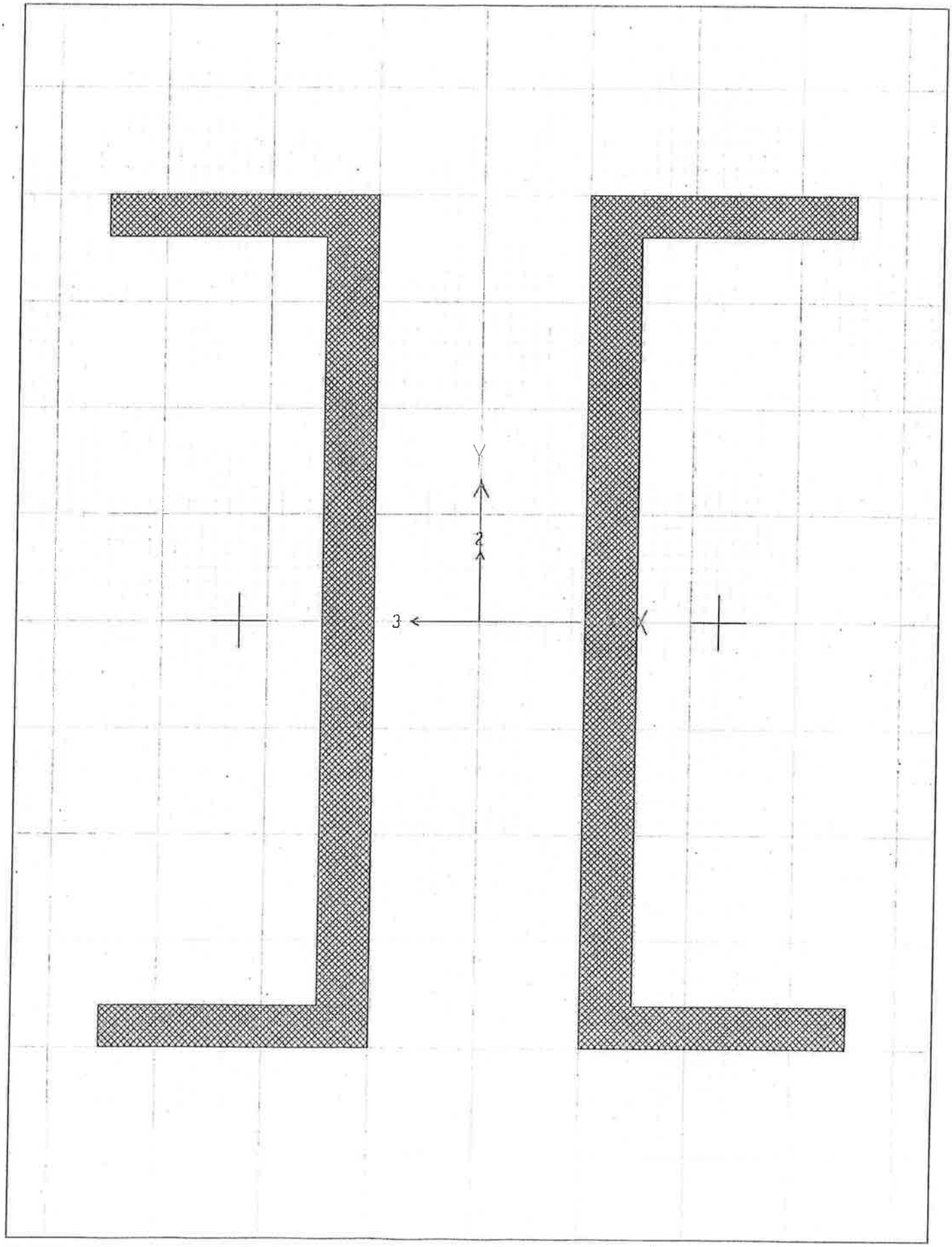

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3
X

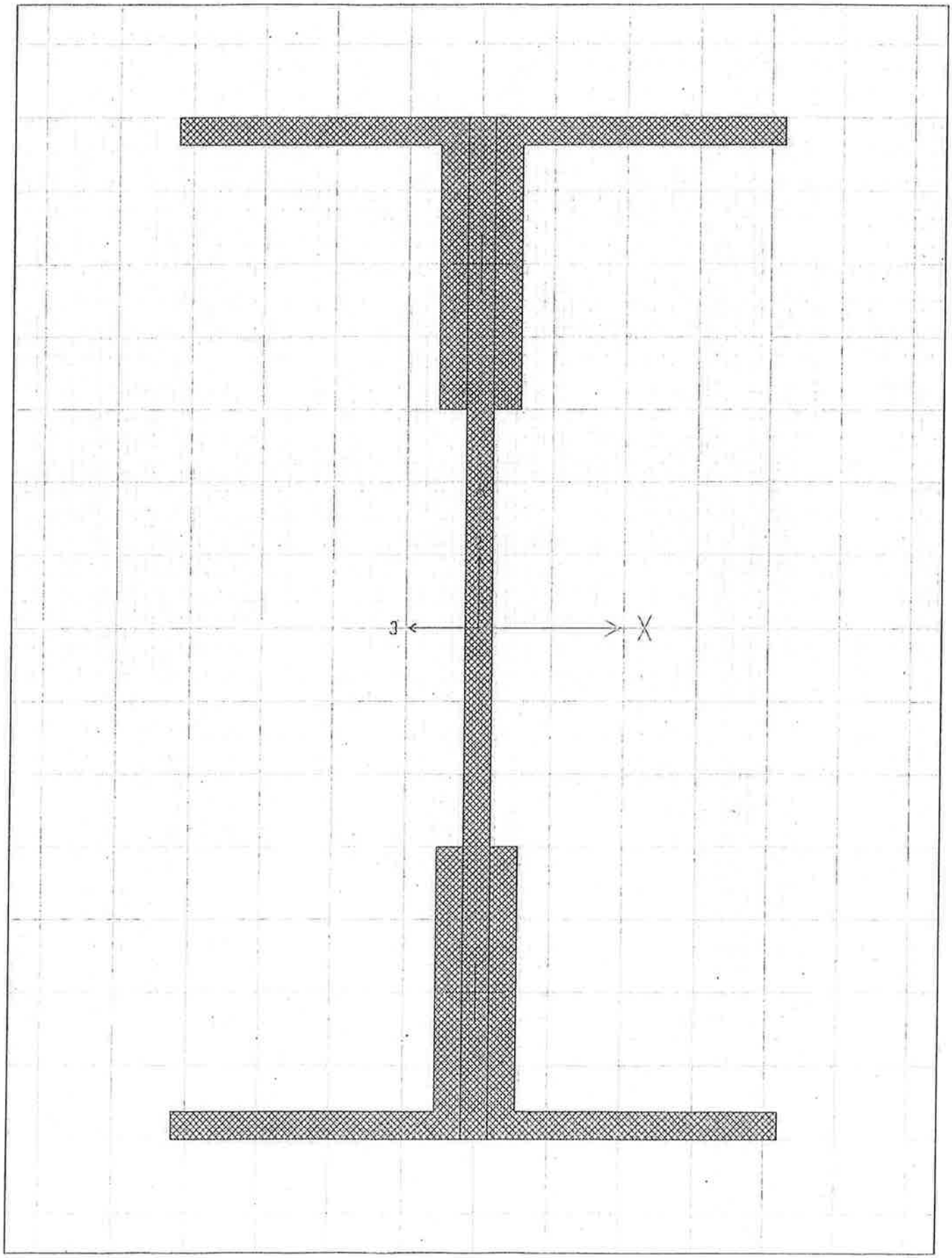

Y
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X


Y
2
3
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Y
2
3
X


Y
2
3
X


Y
2
3
X


2
3
X

APPENDIX C

DESIGN LOADS

AECOM

PROJECT: Topock Compressor Station | PAGE:
CLIENT: PG&E | DESIGN BY:
JOB NO.: | DATE: | REVIEW BY:

ASCE 7-05 Wind Load Calculation for Non-building Equipment Supported at Grade

Basic Wind Speed, V = 90 (mph) (Figure 6-1)

Exposure Category = C (Section 6.5.6.3)

Important Factor, Iw = 1.15 (Section 6.5.5 & table 6-1 for category IV structure)

Topographic Factor, Kzt = 1 (Section 6.5.7.2) -- Flat

Wind directional Factor, Kd = 0.95 (Table 6-4, consevatively use the Max. value)

Velocity Pressure Coefficient, Kz (Table 6-3)

Exposure C

Elevation (ft)	Kz
0 - 15	0.85
20	0.9
25	0.94
30	0.98
40	1.04
50	1.09
60	1.13
70	1.17

Velocity Pressure, qz = 0.00256 * Kz * Kzt * Kd * Iw * V^2 (section 6.5.10)

Elevation (ft)	qz (psf)
0 - 15	19.26
20	20.39
25	21.29
30	22.20
40	23.56
50	24.69
60	25.60
70	26.51

Net Force Coefficient, Cf = 1.4 (Figure 6-21, h/D < or = 7 for various cross section)

Gust Factor, G = 0.85 (Section 6.5.8.1)

Desing Wind Pressure, P = qz * G * Cf

Elevation (ft)	P (psf)
0 - 15	22.91
20	24.26
25	25.34
30	26.42
40	28.04
50	29.38
60	30.46
70	31.54

AECOM	Job Title:	Topock L300-A Arch Bridge			Subject:	Seismic Loads
	Job No:					
	Prepared By:		Date:			
	Checked By:		Date:			

SEISMIC LOADS

Seismic Parameters:

Site Location: Latitude = 34.714225 Longitude = -114.493332

Mapped Spectral Response Acceleration: $S_S := 0.216$ $S_1 := 0.133$

Site Class D

Site Coefficients: $F_a := 1.6$ $F_v := 2.268$

Design Spectral Response Acceleration: $S_{DS} := 0.231$ $S_{D1} := 0.201$

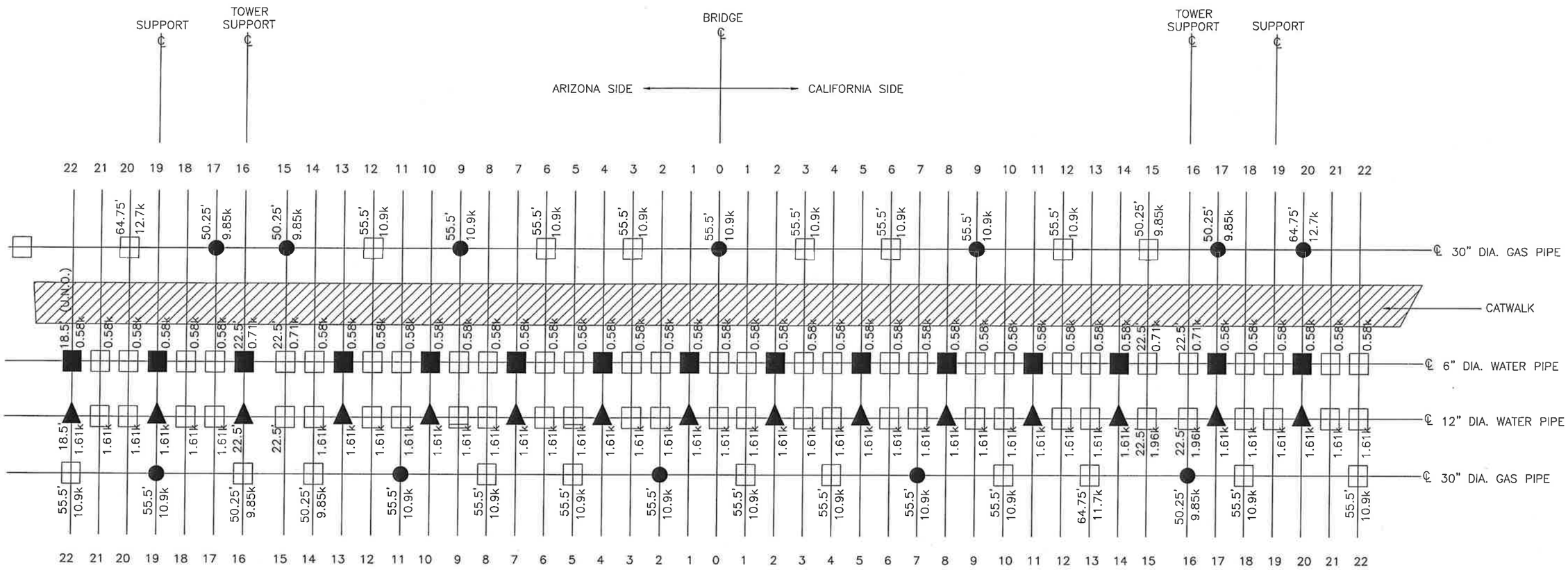
Seismic Occupancy Category IV

Importance Factor: $I_E := 1.5$

Seismic Response Coefficient:

Response Modification Coefficient: $R := 3$

$$C_S := \frac{S_{DS}}{\left(\frac{R}{I_E}\right)} \qquad C_S = 0.116$$



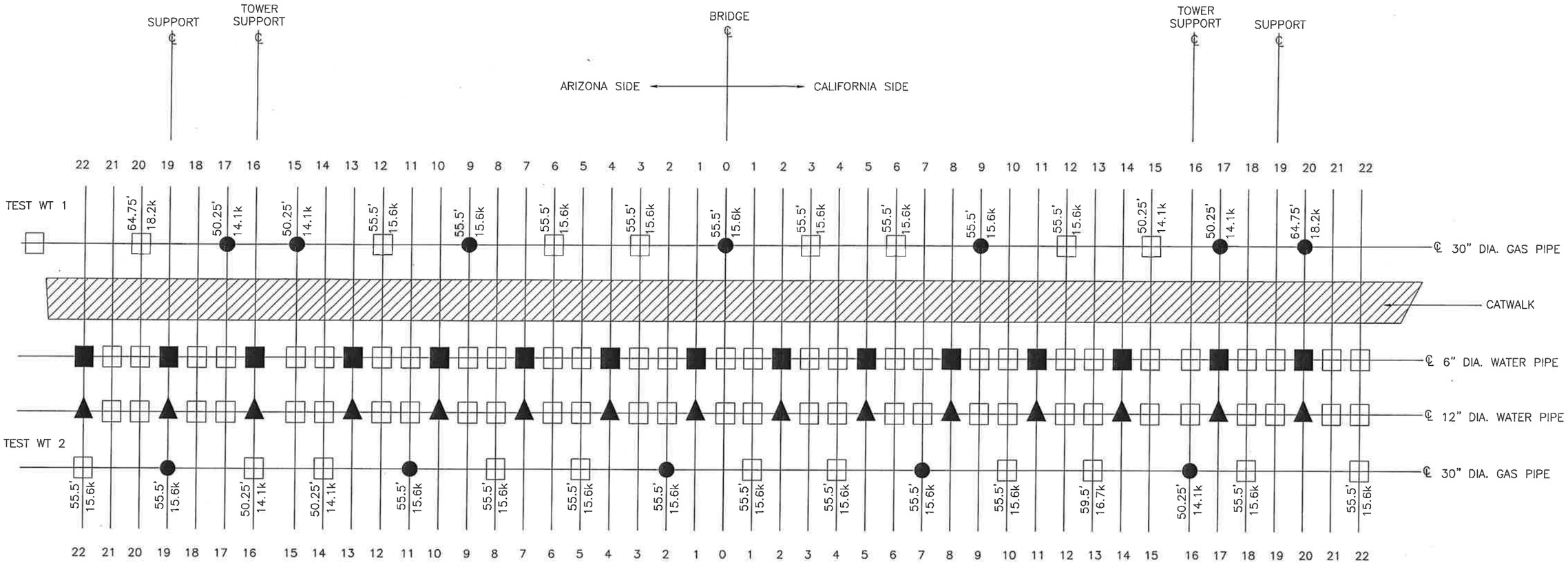
DEAD LOADS

30"ø GAS PIPE = 196 #/FT (EMPTY)

6"ø WATER PIPE = 31.5 #/FT (INCL. WATER)

12"ø WATER PIPE = 87 #/FT (INCL. WATER)

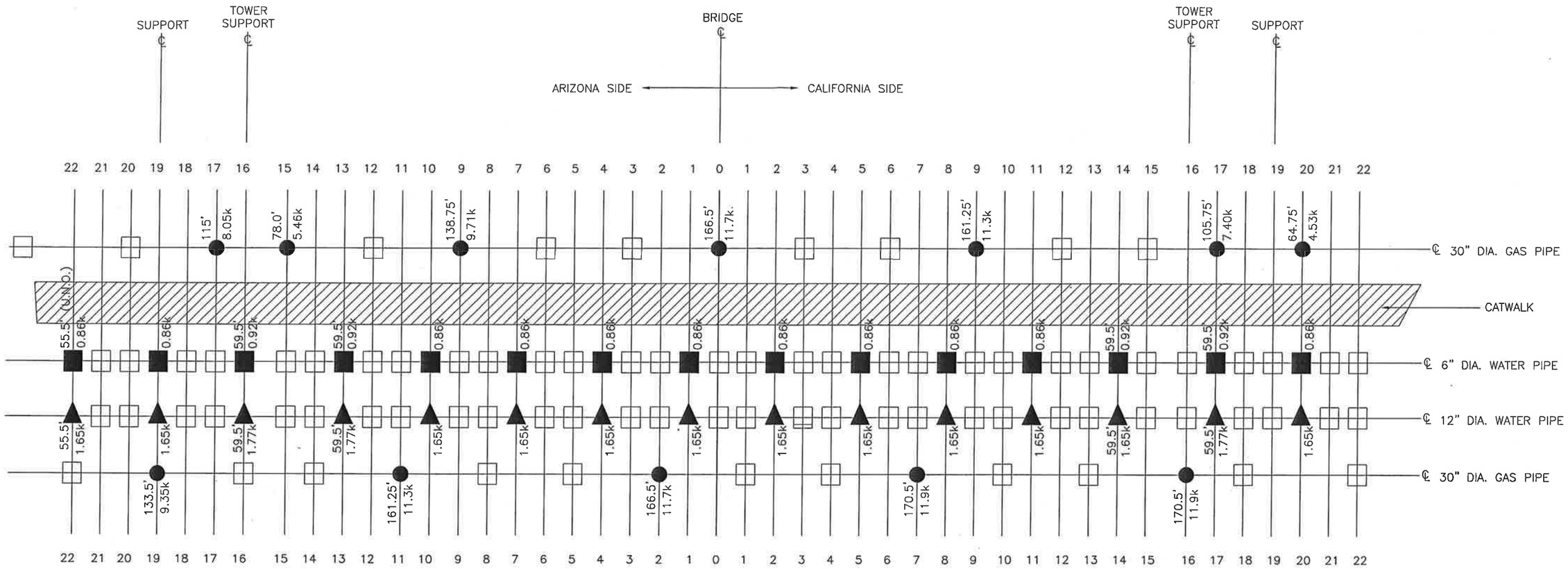
- VERTICAL SUPPORT ONLY FOR (6" 12" & 30" PIPES)
- VERTICAL & HORIZONTAL SUPPORT FOR 30" PIPE
- VERTICAL & HORIZONTAL SUPPORT FOR 6" PIPE
- VERTICAL & HORIZONTAL SUPPORT FOR 12" PIPE



TEST LOADS

30"ø GAS PIPE = 281 #/FT (WT OF WATER ONLY)

- □ VERTICAL SUPPORT ONLY FOR (6" 12" & 30" PIPES)
- ● VERTICAL & HORIZONTAL SUPPORT FOR 30" PIPE
- ■ VERTICAL & HORIZONTAL SUPPORT FOR 6" PIPE
- ▲ VERTICAL & HORIZONTAL SUPPORT FOR 12" PIPE



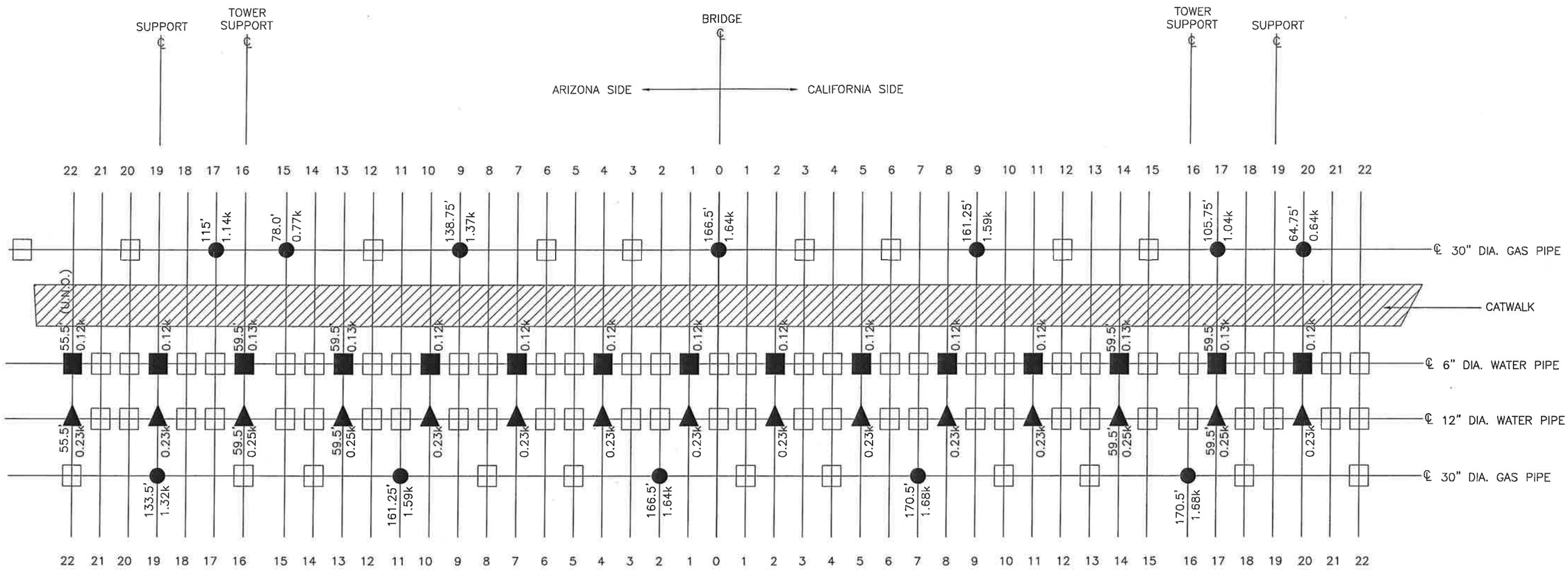
PIPE WIND LOADS

30"ø GAS PIPE = 28 PSF*(30"/12) = 70 #/FT

6"ø WATER PIPE = 28 PSF*(6.625"/12) = 15.5 #/FT

12"ø WATER PIPE = 28 PSF*(12.75"/12) = 29.75 #/FT

- VERTICAL SUPPORT ONLY FOR (6" 12" & 30" PIPES)
- VERTICAL & HORIZONTAL SUPPORT FOR 30" PIPE
- VERTICAL & HORIZONTAL SUPPORT FOR 6" PIPE
- VERTICAL & HORIZONTAL SUPPORT FOR 12" PIPE



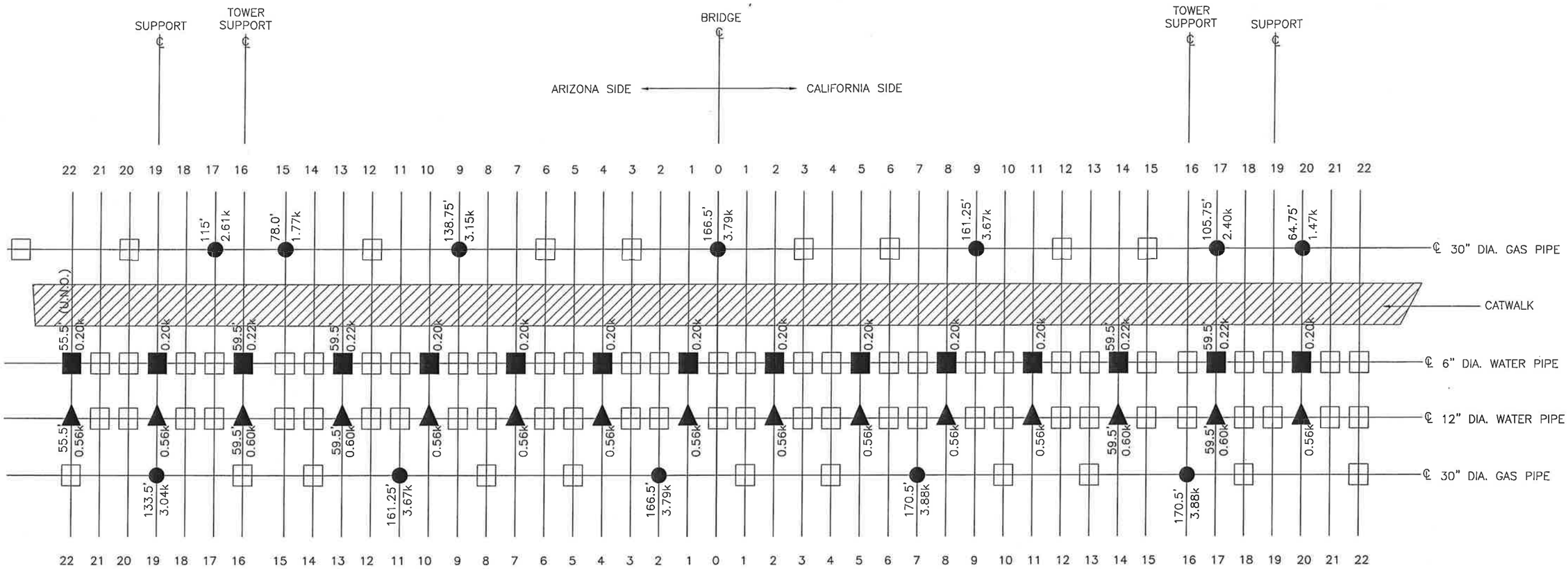
TEST PIPE WIND LOADS

30"ø GAS PIPE = 3.95 PSF*(30"/12) = 9.875 #/FT

6"ø WATER PIPE = 3.95 PSF*(6.625"/12) = 2.18 #/FT

12"ø WATER PIPE = 3.95 PSF*(12.75"/12) = 4.20 #/FT

- VERTICAL SUPPORT ONLY FOR (6" 12" & 30" PIPES)
- VERTICAL & HORIZONTAL SUPPORT FOR 30" PIPE
- VERTICAL & HORIZONTAL SUPPORT FOR 6" PIPE
- VERTICAL & HORIZONTAL SUPPORT FOR 12" PIPE



PIPE EQ LOADS

V = 0.116*DEAD LOAD

- VERTICAL SUPPORT ONLY FOR (6" 12" & 30" PIPES)
- VERTICAL & HORIZONTAL SUPPORT FOR 30" PIPE
- VERTICAL & HORIZONTAL SUPPORT FOR 6" PIPE
- VERTICAL & HORIZONTAL SUPPORT FOR 12" PIPE

APPENDIX D

CONSTRUCTION DRAWINGS

HALF UPPER-CHORD LATERAL SYSTEM.

HALF LOWER-CHORD LATERAL SYSTEM.

DETAIL (2) TYP. EACH SIDE 48(620-SH2

SECTION B-B.

SECTION M-M.

ARIZONA

CALIFORNIA

FLOOR LEVEL=503.5'

FLOOR LEVEL=503.5'

BED ROCK

BED ROCK

HINGE ELEV.=450.5.

HINGE ELEV.=450.5

EXTREME HIGH WATER MARK (1857?) ELEV. 456.0.

HIGH WATER MARK 1914 ELEV. 449.0 (HIGHEST SINCE 1857)

WATER LEVEL FEBRUARY 1915 ELEV. 433.0.

SAND BAR.

SAND AND GRAVEL

LOOSE ROCK & DENSE GRAVEL

HARD SAND & GRAVEL

GRAVEL

SIDE ELEVATION MAIN SPAN.

SCALE: 1"=20'-0".

32 SPA. @ 18'-6", 592'-0" C-C PINS.

56'-0" 56'-0" 608'-0" 56'-0" 56'-0"

DETAIL (1) TYP. EACH SIDE 48(620-SH1

EXPANSION JOINT

GIRD B3 GIRD C3 GIRD A3 GIRD D3

J_2 (15 BENTS THUS EACH SIDE OF ℄)

832'-0"

EXPANSION JOINT

GIRD A3 GIRD D3 GIRD C3 GIRD B3

DETAIL (3) TYP. 2 PLACES 48(620-SH3

FLOOR SYSTEM

SECTION A-A.

SECTION D-D.

SECTION E-E.

SECTION F-F.

SECTION G-G.

SECTION H-H.

SECTION K-K.

SECTION L-L.

SECTION C-C.

SIDE VIEW

HALF FLOOR SECTION THRU TRUSSES.

HALF TYPICAL FLOOR SECTION.

(SECTION THROUGH TRUSSES)

HALF LONGITUDINAL FLOOR SECTION.

EXPANSION

TYPICAL CURB SPLICE

REGISTERED PROFESSIONAL ENGINEER SAVAS KOLIMBATA S 3563 EXP. 12/31/2012 STRUCTURAL STATE OF CALIFORNIA

MODIFICATIONS ONLY

NOTE:
RETRACED FROM KANSAS-CITY STRUCTURAL STEEL CO.'S DWG.
ORDER 7744-7745-7746.

REFERENCES
SHOP DETAILS DWG: # F-1589.

SCANNED

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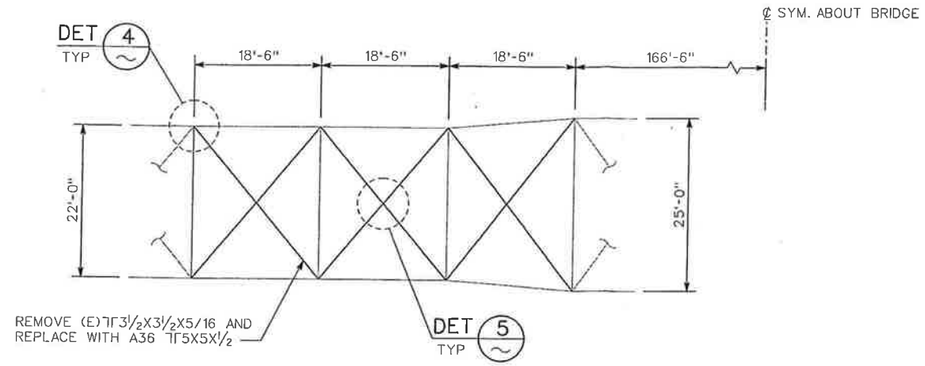
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APPROVED BY GM 10/6/88.
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BY Dept. of G.O.
DR. W. Frankhoff
CH. Asst.
DA.
DATE 6-10-88
SCALES As Shown.

ERECTION PLAN
COLORADO RIVER HIGHWAY BRIDGE
TOPOCK-MILPITAS, MAIN 300
DEPARTMENT OF GAS OPERATION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO CALIFORNIA

BILL OF MATERIAL
SUPERSEDES
SUPERSEDED BY
SHEET NO. SHEETS
DRAWING NUMBER CHANGE
481620 1

481620-1-1-88

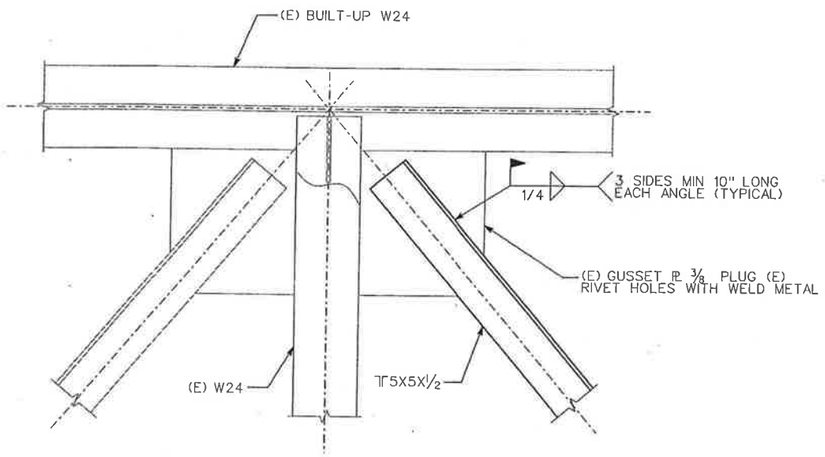


HORIZONTAL DECK BRACES

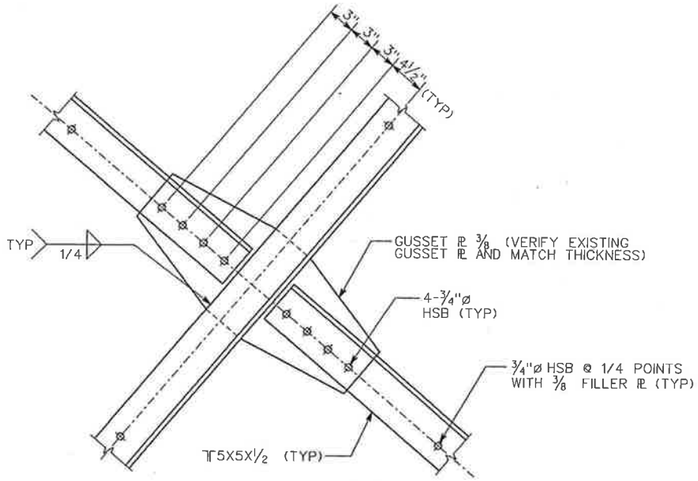
DETAIL 1 — SCALE: 3/32"=1'-0" — 481620 / 481620-SH1

NOTES

1. FOR LOCATION SEE DWG 481620.
2. CODES AND SPECIFICATIONS
   - A. INTERNATIONAL BUILDING CODE IBC-2009
   - B. MINIMUM DESIGN LOADS FOR BUILDINGS AND OTHER STRUCTURES, ASCE 7-05
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DETAIL 4 — SCALE: 1½"=1'-0"



DETAIL 5 — SCALE: 1½"=1'-0"

DRAWING REFERENCES:

481620 —— ERECTION PLAN

REGISTERED PROFESSIONAL ENGINEER SAVAS KOLANKAYA S 3563 EXP. 12/31/2012 STRUCTURAL STATE OF CALIFORNIA

AECOM
2101 WEBSTER STREET SUITE 1000
OAKLAND, CA 94612-3060
PROJECT NO. 60229232

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	02-03-12	ISSUED FOR CONSTRUCTION		KG	SK		

REVISIONS

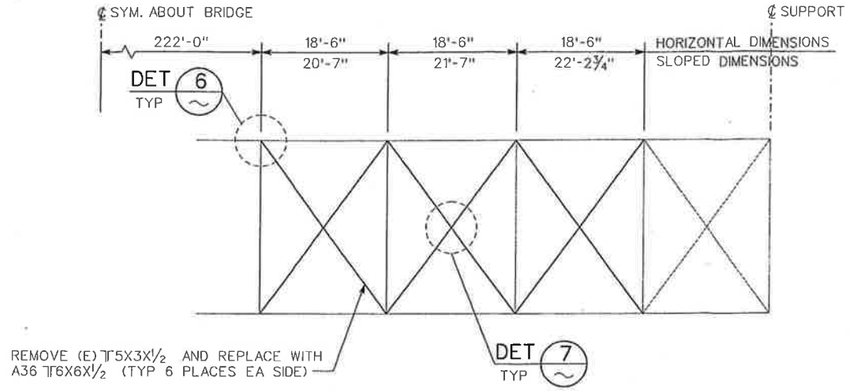
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STRUCTURE - DETAILS
ARCH BRIDGE MODIFICATIONS
300A TRANSMISSION LINE

GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

MICROFILM
BILL OF MATL
DWG LIST
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SHEET NO. 481620-SH1 OF SHEETS
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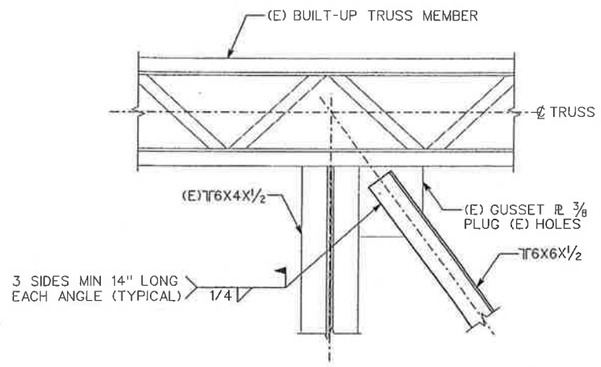


BOTTOM CHORD HORIZONTAL BRACES

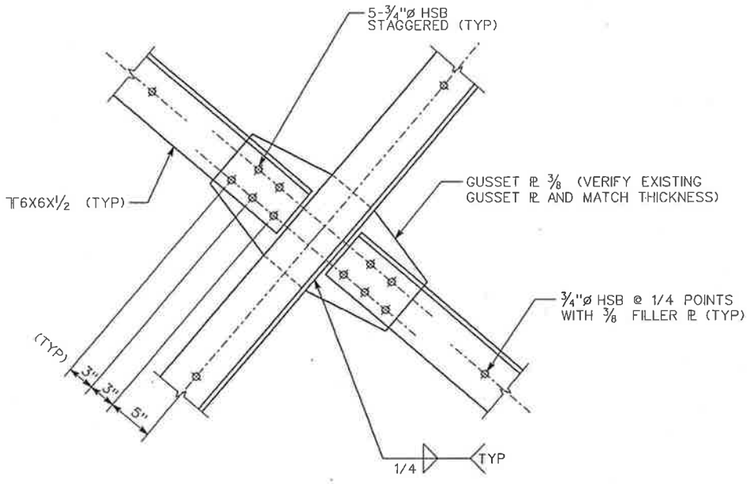
DETAIL 2 — 481620
SCALE: 3/32"=1'-0" — 481620-SH2

NOTES

1. FOR LOCATION SEE DWG 481620.
2. CODES AND SPECIFICATIONS
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DETAIL 6
SCALE: ¾"=1'-0"



DETAIL 7
SCALE: 1½"=1'-0"

DRAWING REFERENCES:

481620 —— ERECTION PLAN

REGISTERED PROFESSIONAL ENGINEER
SAVAS KOLANKAYA
S 3563
EXP. 12/31/2012
STRUCTURAL
STATE OF CALIFORNIA

MICROFILM

AECOM
2101 WEBSTER STREET SUITE 1000
OAKLAND, CA 94612-3060
PROJECT NO. 60229232

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0	02-03-12	ISSUED FOR CONSTRUCTION	KG	SK			

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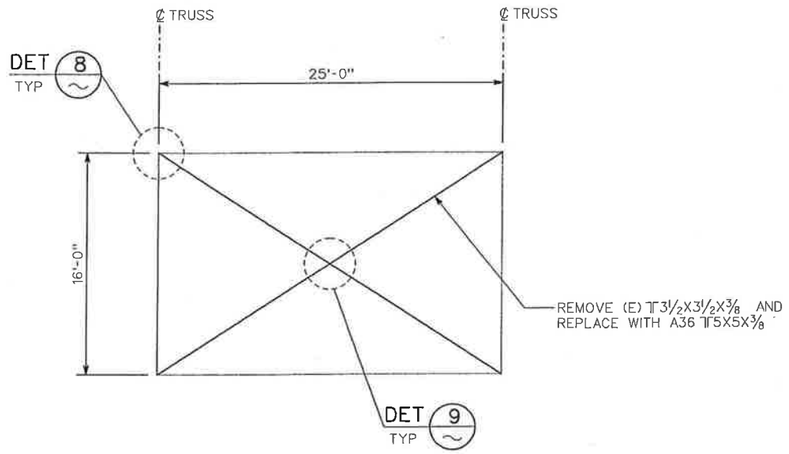
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	SO
	SUPV
	DSGNS.KOLANKAYA
	DWN K. GRAHAM
	CHKDS.KOLANKAYA
	OK
	DATE 02-03-12
	SCALES AS NOTED

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ARCH BRIDGE MODIFICATIONS
300A TRANSMISSION LINE

GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
SAN FRANCISCO, CALIFORNIA

BILL OF MATL	
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SHEET NO. OF SHEETS	
481620-SH2	REV 0

FILENAME: 481620-SH2.DGN 02-03-12

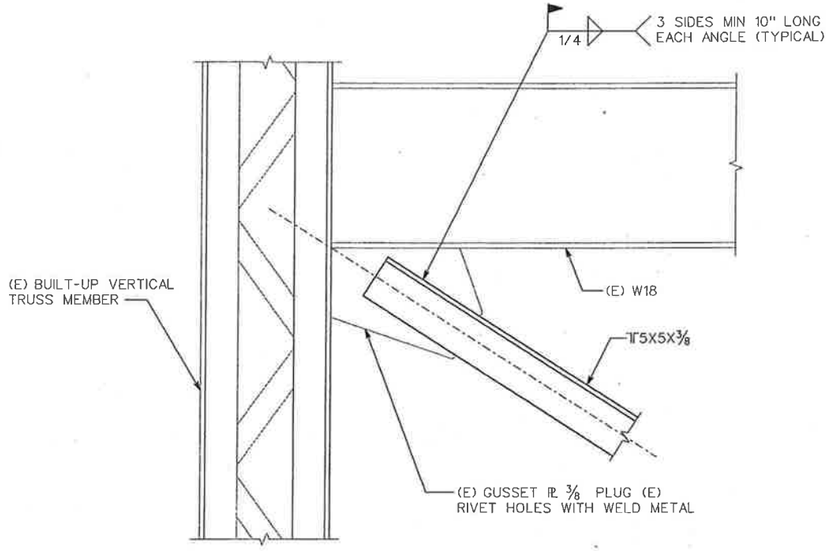


VERTICAL TRUSS BRACES @ 222'

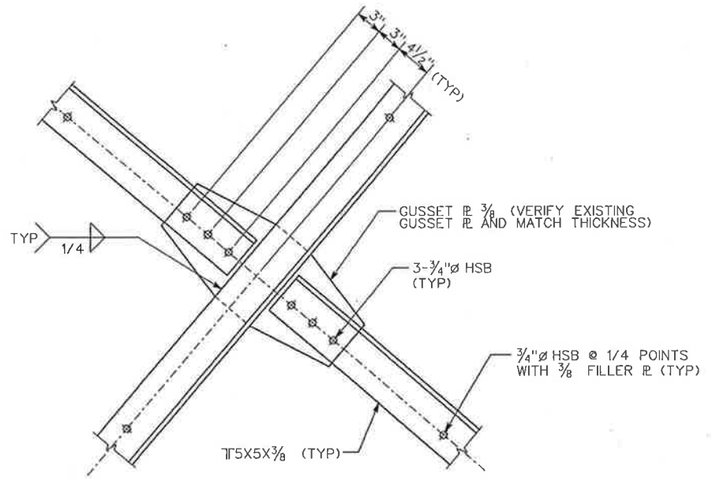
DETAIL 3 (481620)
SCALE: 3/32"=1'-0" 481620-SH3

NOTES

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DETAIL 8
SCALE: 1½"=1'-0"



DETAIL 9
SCALE: 1½"=1'-0"

DRAWING REFERENCES:

481620 —— ERECTION PLAN

REGISTERED PROFESSIONAL ENGINEER
SAVAS KOLANKAYA
S 3563
EXP. 12/31/2012
STRUCTURAL
STATE OF CALIFORNIA

AECOM
2101 WEBSTER STREET SUITE 1900
OAKLAND, CA 94612-3060
PROJECT NO. 60229232

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY

REVISIONS

NO.	DATE	DESCRIPTION	GM/SPEC	DWN	CHKD	SUPV	APVD BY
0	02-03-12	ISSUED FOR CONSTRUCTION		KG	SK		

REVISIONS

APPROVED BY	SO
	SUPV
	DSGNS.KOLANKAYA
	DWN K. GRAHAM
	CHKDS.KOLANKAYA
	QK
	DATE 02-03-12
	SCALES AS NOTED

STRUCTURE - DETAILS
ARCH BRIDGE MODIFICATIONS
300A TRANSMISSION LINE

GAS TRANSMISSION & DISTRIBUTION
PACIFIC GAS AND ELECTRIC COMPANY
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FILENAME: 481620-SH3.DGN 02-03-12

Appendix H
Updated Cost Estimate

APPENDIX H

Updated Cost Estimate

This Appendix details the updated cost estimate for the intermediate (60%) design. As discussed in Section 8, the comparison point for this estimate was the 30% design (the CMS/FS Report and 30% design values are included here). The intermediate design has resulted in providing more details and addressing stakeholder comments on the 30% design, resulting in additional scope and increased cost.

Table H-1 compares the construction costs of the 30% Design and the CMS/FS report. Additional scope changes are summarized in Table H-2. The following five attachments provide more detail on the project cost estimate:

- Attachment A – Basis of Estimate;
- Attachment B – Well Installation Cost Estimate;
- Attachment C – O&M and Start-Up Cost Estimate Update;
- Attachment D – Monitoring Program; and
- Attachment E – Post-Remediation Deconstruction.

There was a fundamental shift in cost estimating methodology between the 60% design cost estimate and the 30% cost estimate. The 60% design cost estimate is a "bottom-up" estimate as described in Attachment A. Because the 60% design cost estimate is not equivalent to the 30% design cost estimate, no redlined version of Appendix H is provided in this 60% Basis of Design document.

Overall Costs

Present value costs were calculated based on the three project elements: construction, operations maintenance and monitoring, and post-remediation deconstruction costs. As described in the CMS/FS (CH2M Hill, 2009), present value costs were calculated using a discount factor of 3.17 percent. The best estimate is $223 million present value.

TABLE H-1
COMPARISON OF CONSTRUCTION COST ESTIMATES
INTERMEDIATE (60%) DESIGN
PG&E TOPOCK COMPRESSOR STATION, NEEDLES, CALIFORNIA

CONSTRUCTION COSTS DESCRIPTION	CMS/FS Values QTY	UNIT	UNIT COST	TOTAL	PRELIMINARY DESIGN QTY	UNIT COST	UNIT TOTAL	INTERMDIATE DESIGN QTY	UNIT COST	UNIT TOTAL	NOTES
Wells											
Injection & Extraction Wells	1	LS	$5,701,860	$5,700,000	1	$10,241,900	$10,200,000	1	$17,910,000	$17,910,000	47 new remedy wells
Monitoring	28	WELL	$60,800	$1,700,000	28	$60,800	$1,700,000	1	$2,949,750	$2,949,750	
New well survey	1	LS	$0	$0	1	$20,000	$20,000	1	$20,000	$20,000	
SUBTOTAL				$7,400,000			$11,920,000			$20,879,750	
In Situ Systems											
IRZ	1	LS	$4,034,500	$4,030,000	1	$2,492,100	$2,490,000	1	$6,500,000	$6,500,000	IRZ carbon amendment systems, remedy-produced water conditioning system, and SCADA
				$0			$0				
SUBTOTAL				$4,030,000			$2,490,000			$6,500,000	
Ex Situ Treatment											
As/F Freshwater Plant	0		$10,000,000	$0	1	$2,959,078	$2,960,000	1	$9,460,000	$9,460,000	Per CH2MHill
SUBTOTAL				$0			$2,960,000			$9,460,000	
Infrastructure											
Pipelines & Conduit / Wire & Trench	1	LS	$8,860,766	$8,860,000	1	$5,259,798	$5,260,000	1	$8,916,677	$8,916,677	
Access Roads	3	1,000 LF	$16,200	$50,000	1	$23,504	$23,500	1	$870,000	$870,000	Permanent and temporary roads, Included in Infrastructure and Process Construction
Fresh water											
Wells	1	LS	$158,700	$160,000	0	$0	$0	1	$191,038	$191,038	No new well required - modify existing HNWR-1
Pipeline	1.6	1,000 LF	$100,000	$160,000	0	$0	$0	1			Freshwater pipeline included with all pipelines
Electrical Power - wells	0			$0	1	$2,518,912	$2,520,000	1	$7,083,247	$7,083,247	
SCADA	0			$0	1	$1,250,000	$1,250,000	1	$0	$0	Combined with IRZ systems
Install Power Station - (Electrical Generator)	0	LS	$158,700	$0	1	$607,153	$610,000	1	$6,014,832	$6,014,832	Per AECOM's Power Study
Transwestern Bench								1	$4,195,000	$4,195,000	Central maintenance facility
MW-20 Bench									$414,000	$414,000	
Start-up & Test	0	LS	$100,000	$0	1	$193,278	$190,000	1	$838,864	$838,864	
SUBTOTAL				$9,230,000			$9,850,000			$28,523,658	
Remove IM3 Treatment Plant											
IM3 treatment - restoration and deconstruction	1	LS	$1,600,000	$1,600,000	1	$1,600,000	$1,600,000	1	$3,000,000	$3,000,000	
SUBTOTAL				$1,600,000			$1,600,000			$3,000,000	
SUBTOTAL				$22,300,000			$28,800,000			$68,363,408	
Prime Contractor Cost Factors [a]											
General Conditions (sub mob, sub GC)	10%			$2,230,000			$2,880,000			$ 339,236	
Field Construction Management and Engineer SDC	10%			$2,450,000			$3,170,000			$9,000,000	
Pre-construction (work plans, design, as-builts)	14%			$3,780,000			$4,880,000			$4,730,000	
Project Management	5%			$1,540,000			$1,990,000			$1,661,715	Based on duration
Contractor Markup (G&A, fee)	21%			$6,780,000			$8,760,000			$4,101,804	6% Markup
SUBTOTAL			75%	$16,800,000			$21,700,000			$ 19,832,755	
Miscellaneous											
Institutional Controls and other Administrative Approvals	1	Constr Phases	$1,000,000	$1,000,000	1	$1,000,000	$1,000,000	1	$1,000,000	$1,000,000	
Biological Monitoring	1	Constr Yrs	$330,000	$330,000	1	$330,000	$330,000	1	$330,000	$330,000	
Cultural Monitoring	1	Constr Yrs	$330,000	$330,000	1	$330,000	$330,000	1	$330,000	$330,000	
Regulatory Oversight	1	Constr Yrs	$300,000	$300,000	1	$300,000	$300,000	1	$300,000	$300,000	
Soil Cuttings	1	Constr Phases	$200,000	$200,000	1	$200,000	$200,000	1	$200,000	$200,000	
										$2,160,000	
TOTAL CAPITAL COST LESS CONTINGENCY				$41,300,000			$52,700,000			$90,356,163	
Contingency	15%			$6,200,000			$7,910,000			$13,600,000	
TOTAL CAPITAL COST				**$47,500,000**			**$60,600,000**			**$103,956,163**	
ADDITIONAL CAPITAL COSTS NOT INCLUDED											
SITE RESTORATION COSTS										$20,800,000	
MW20 BENCH										included above	

Notes:
CMS/FS Estimate Values taken from Table D-6 CMS/FS (CH2M Hill, 2009)
a. USEPA costing guidance EPA-540-R-00-002

TABLE H-2
Summary of Scope Changes from Preliminary Design to Intermediate Design
Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Cost Element	Preliminary Design Change from CMS/FS	Rationale	Intermediate Design Change from Preliminary Design	Rationale
Wells	One additional remediation well (54 vs. 53 in CMS/FS), but they are larger and more costly (depth and diameter have increased). See Table H-3 below.	Larger diameter wells required to house all equipment needed especially backwashing pumps. EIR mandated limits on number of wells requires dual screens in a single borehole. Deeper wells needed based on results of groundwater modeling. No plastic casings were assumed because of the need for long well life.	Reduced number of new remedy wells from 54 to 47. Updated remedy well design to include dual-function flow control valve in freshwater injection wells and PLCs at each wellhead.	The well design approach evolved as part of the intermediate design. Reduction in number of remedy wells based on groundwater modeling. Added costs for labor to manage IDW, baseline logging, testing, packers, conductor casing, per diem, mobilization, rental support equipment (e.g., forklifts). All soil is stored for re-use on site.
			Reduced number of monitoring wells from 28 to 19.	Modified design of monitoring wells to accomplish monitoring objectives and be within EIR constraints on boreholes. This results in larger and deeper wells. Added costs for well development and labor to manage IDW. Assumed separate mobilization from remedy well installation. All soil is stored for re-use on site.
Piping, conduit and trenching	1. Total pipe length increased from about 24,000 to 61,000 feet, but all double contained piping (11,000 feet) was eliminated. 2. Conduit length increased from about 24,000 to almost 38,000 feet. 3. Trench length reduced slightly from 21,000 to 19,000 feet.	These changes are a result of the groundwater modeling and preliminary design work	1. Total pipe length adjusted to 69,000 feet. 560 feet double contained piping.	Changes made in routing to avoid putting pipes in Bat Cave Wash and reducing extent of piping along National Trails Highway. Provided secondary containment of contaminated groundwater or produced water.
			2. Conduit length increased to 73,000.	Design evolution to include spare conduit for future expansion or repair.
			3. Trench length increased slightly to	

TABLE H-2
Summary of Scope Changes from Preliminary Design to Intermediate Design
Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Cost Element	Preliminary Design Change from CMS/FS	Rationale	Intermediate Design Change from Preliminary Design	Rationale
			25,000 feet.	See above for item 1.
			4. Added 5,000 feet of pre-cast concrete trench in place of conventional excavated trench	Improves access for inspection, repair, and modification over life of remedy.
Trenchless crossing	3 trenchless crossings are included	To reach Arizona supply well and serve wells located west of Bat Cave Wash. The leg through Bat Cave Wash improved system reliability	6 new trenchless crossings in floodplain.	Designed to reduce effects on plants and other floodplain features.
Remedy produced water management	This involves additional equipment and structures to store and treat the produced water.	This was identified during PG&E team discussions before the design began and is considered an important part of effective remedy performance.	Split process equipment into two separate streams and added new conditioned water tank farm for second stream.	Segregate produced water streams for more effective treatment and flexible operations.
SCADA [a]	A central control system, not included in the CMS/FS estimate will be built at the Compressor Station.	This is important for proper remedy monitoring and control and evolved as part of the preliminary design.		
Electrical power distribution system	A distributed power system originating from TCS including local electrical transformers and equipment to supply power to remote remedy equipment and facilities.	This system and approach evolved as part of the preliminary design.	Reduced number of transformers from 7 to 6.	Reduction in number of wells and pipe route changes. Added PVC coated steel conduit for underground use per PG&E standard.
Electrical supply	A new natural gas fired generator in an enclosure will be installed to supply power in the event TCS generators are at maximum capacity	This was learned as part of the preliminary design effort in discussion with TCS gas operations personnel	Included a natural gas engine-driven 750 kVA generator (continuous duty) to the Station, removing the existing diesel engine-generator, installing a new unit on this location and extending the building to provide	Allows the plant to support the increased loads for the groundwater remediation project.

TABLE H-2
Summary of Scope Changes from Preliminary Design to Intermediate Design
Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Cost Element	Preliminary Design Change from CMS/FS	Rationale	Intermediate Design Change from Preliminary Design	Rationale
			cover to the new unit. In addition, the existing switchgear would be replaced with new switchgear with automation features to provide automatic synchronization of the various units.	
Central maintenance facility			10,000 square foot building located at the Transwestern Metering Station Bench with office space, meeting rooms, laboratory, restrooms, and maintenance areas.	Limited space available at TCS to accommodate PG&E remedy personnel and contractors. IM-3 facilities will be shut down, further reducing available facilities to support the remedy.
Groundwater, surface water monitoring and remedy performance reporting			Included varying frequencies of sampling and reporting over life of remedy.	Based on analysis of anticipated remedy performance and final number of monitoring wells shown in O&M Plan. See Attachment D.
Well decom-missioning			Included all Topock remediation and monitoring wells. Added field geology oversight of well decommissioning.	To fully estimate the project costs.
Freshwater Pre-injection Treatment System			Included a 2-story 1,500 square foot building with associated process tanks and expanded chemical storage area.	Based on the need to remove arsenic to concentrations less than 10 µg/L and fluoride to concentrations less than 2 mg/L to comply with California drinking water standards.

TABLE H-2
Summary of Scope Changes from Preliminary Design to Intermediate Design
Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Cost Element	Preliminary Design Change from CMS/FS	Rationale	Intermediate Design Change from Preliminary Design	Rationale
				The basis of design assumes that regenerable activated alumina will be used to accomplish the treatment goals. See Appendix M.
Power Distribution System			Included a natural gas engine-driven 750 kVA generator (continuous duty) to the Station, removing the existing diesel engine-generator, installing a new unit on this location and extending the building to provide cover to the new unit. In addition, the existing switchgear would be replaced with new switchgear with automation features to provide automatic synchronization of the various units.	Allows the plant to support the increased loads for the groundwater remediation project.

Attachment A – Basis of Estimate

PG&E Topock Compressor Station

Topock Groundwater Remediation Project

Needles, California

DRAFT BASIS OF ESTIMATE

Project Name:	Topock Groundwater Remediation Project
Estimated By:	Wally Kurzeja
Estimator Phone:	734.887.4393
Estimate Date:	1 April 2013

HALEY& ALDRICH

Purpose of Estimate

Haley & Aldrich, Inc., (Haley & Aldrich) was requested to perform a budgetary cost estimate on the 60% design for the Topock Compressor Station's final groundwater remedy. The estimate is intended to represent the budgetary cost at the 60% design stage and to assist the Pacific Gas and Electric Company (PG&E) to document the financial assurance required by the California Code of Regulations Title 22 §66264 and §66265.

General Project Description

The Groundwater Remediation Project is to remediate chromium in groundwater at the PG&E Topock Compressor Station in San Bernardino County, California. The existing chromium contamination in groundwater near the Compressor Station is largely attributable to historical wastewater discharge from Compressor Station operations to the Bat Cave Wash, and within the East Ravine, designated as AOC 10. Other cleanup actions that may be required due to other historical operations at the Compressor Station are not within the scope of this estimate.

PG&E is implementing the groundwater remedy at the Compressor Station in conformance with the requirements of the Resource Conservation and Recovery Act (RCRA) Corrective Action and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The California Environmental Protection Agency, Department of Toxic Substances Control (DTSC) is the state lead agency overseeing corrective actions at the Compressor Station in accordance with the RCRA Corrective Action. In February 1996, PG&E and DTSC entered into a Corrective Action Consent Agreement (CACA) pursuant to Section 25187 of the California Health and Safety Code (DTSC, 1996). The United States Department of the Interior (DOI) is the lead federal agency overseeing response actions on or emanating from land under its jurisdiction, custody, or control near the Compressor Station pursuant to CERCLA. In July 2005, PG&E and the federal agencies entered into an Administrative Consent Agreement (DOI, 2005).

The groundwater remedy uses in-situ remediation methods. The scope of the project includes 15 extraction and 32 injection wells including above and below ground piping (approximately 65,000 LF) which is either above ground single contained freshwater piping, below ground double contained, or below ground contained in a precast concrete trench. Also included are mechanical and electrical equipment, organic substrate amendment facilities, remedy produced water conditioning plant, operations building, natural gas generator, and supervisory control and data acquisition (SCADA) system.

The reference or comparison point for this estimate is the Corrective Measures Study/Feasibility Study[1] (CMS/FS).

[1] CH2M Hill, 2009. Final Groundwater Corrective Measure Study/Feasibility Study Report for SWMU 1/AOC 1 and AOC 10, Pacific Gas and Electric Company, Topock Compressor Station, Needles, California. Prepared for PG&E. December.

Overall Construction Costs

The estimated construction cost is $104,000,000 (excluding a 15% contingency). See reports in attachments to Appendix H for additional detailed information.

The estimate provided by Haley & Aldrich is representative of direct cost and does not include markups or contingency. Contingency and markup are included in Table H-1.

Markups and Contingency

Certain costs in the CMS/FS and 30% design estimate were estimated as percentages and are now estimated in detail as described below:

1. General Contractor Overhead and Profit (i.e., general and administrative costs plus fee) 35% on direct labor plus 20% on other direct costs.
2. Remedy Construction Cost Estimate Contingency 15%. Other contingencies are discussed in other attachments within Appendix H.

The contingency is applied after the miscellaneous costs are added to the subtotals.

Miscellaneous

The CMS/FS miscellaneous costs were carried forward to the construction estimate and include the following:

- Institutional Controls and Other Administrative Approvals;
- Biological Monitoring;
- Cultural Monitoring;
- Regulatory Oversight; and
- Soil Cuttings Management.

For additional description, see the CMS/FS (CH2M Hill, 2009).

Market Conditions

Current market conditions are very competitive given the state of the national and local economy. However, the large amount of anticipated gas pipeline construction work in California will probably have an opposite effect on this type of construction. Because of the slow economy, material prices have deflated considerably and vendors have expressed considerable interest in bidding this work. Despite the estimator's best practices and adjustments, bids are being driven by current market conditions. A detailed analysis of local market conditions should be made. This could be performed by reviewing similar and upcoming projects around the region of the Topock site. This market adjustment factor is above and beyond the typical contractor mark-ups, normal estimating contingency, and current but normal escalation factors. This estimate should be evaluated for market changes after 90 days of the issue date.

Estimate Classification

The Topock site is in its third estimating iteration. The initial estimated construction cost in the CMS/FS (2009 CH2M Hill) was $51,600,000, followed by the 30% design estimate of $65,900,000. The estimate classifications used by CH2M Hill represent widely accepted cost estimate classifications as developed by the Association for Advancement of Cost Engineering (AACE). The estimate classifications are found in the AACE's Recommended Practice (RP) No. 17R-97 and RP No. 18R-97). The five suggested generic cost estimate classifications are listed in Table 1 along with their primary characteristics.

Cost Estimate Classification	Primary Characteristics	
	Level of Definition (% of Complete Definition)	Cost Estimating Description (Techniques)
Class 5, Concept Screening	0% to 2%	Stochastic, most parametric, judgment (parametric, specific analogy, expert opinion, trend analysis)
Class 4, Study or Feasibility	1% to 15%	Various, more parametric (parametric, specific analogy, expert opinion, trend analysis)
Class 3, Preliminary, Budget Authorization	10% to 40%	Various, including combinations (detailed, unit-cost, or activity-based; parametric; specific analogy; expert opinion; trend analysis)
Class 2, Control or Bid/Tender	30% to 70%	Various, more definitive (detailed, unit-cost, or activity-based; expert opinion; learning curve)
Class 1, Check Estimate or Bid/Tender	50% to 100%	Deterministic, most definitive (detailed, unit-cost, or activity-based; expert opinion; learning curve)

Table 1. Generic Cost Estimate Classifications and Primary Characteristics

The cost estimate prepared by Haley & Aldrich is considered a budgetary or Class 3[2] estimate as defined by the AACE. It is considered accurate to -20% to +20%, based upon a 60% design deliverable provided to Haley & Aldrich.

The cost estimates shown have been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. The final cost of the project will depend upon the actual labor and material costs, competitive market conditions, final project costs, the implementation schedule, and other variable factors. As a result, the final project costs will vary from the estimates presented herein. Because of this, project feasibility and funding needs must be carefully reviewed prior to making specific financial decisions to help ensure proper project evaluation and adequate funding. Our estimate is based on material, equipment, and labor pricing as of October 2012 through December 2012. The client should be cautioned that such prices are highly subject to variation as a result of material shortages or installation resources due to market conditions or recent natural disasters.

[2] This cost estimate is a Class 3 estimate with the exception the Freshwater Pre-Injection Treatment System and Power Distribution System. Due to the late addition of these two systems, their estimates are Class 5 cost estimates.

Cost Resources

The following is a list of the various cost resources used to develop of the cost estimate.

- Labor costs – based on survey of local contractors, Haley & Aldrich internal costs, and discussions with local contractors. All labor pricing assumed that the project was non-union and non-prevailing wage;
- Construction Managers' and Engineers' judgment and professional experience;
- Equipment costs based on supplier quotes and previous estimates for similar equipment for other projects or proposals in California and other areas of the United States as required;
- Budgetary vendor quotations for major components such as piping, precast trench sections, well drilling, horizontal drilling, etc.[3];
- National Electrical Contractors Association - Labor Unit Manual and published list pricing discounted 30% for electrical materials;
- CH2M HILL and Haley & Aldrich historical data;
- Estimator judgment;
- R.S. Means;
- DC&D Technologies parametric cost models;
- AACE Parametric Cost Model for Structures escalated to 2012 costing; and
- CH2M Hill's Cost Report was used as a QA document to verify take off quantities.

Estimate Methodology

Haley & Aldrich performed an independent budgetary cost estimate of the 60% design prepared by CH2M Hill. A bottom-up[4] project cost estimate is a method of calculating the overall costs of the project by adding the individual costs of various project elements. This method of project estimating is considered the most accurate method for generating project estimates. It is typically used to develop budgets during the planning phase and at the start of each project stage. The method is intended to use the Work Breakdown Structure (WBS) developed during the planning stage of the project. Estimates are created for all tasks at the lowest level of the WBS and are then accumulated to develop the estimates for the whole project.

The objective of Haley & Aldrich's estimate is to provide a deterministic basis for project cost comparisons. The estimate performed is representative of the basis of design construction plan set dated 18 August 2012, 14 September 2012, and as amended on 15 February 2013. This and

[3] Oral quotes from vendors and contractors for major supplies as well as electrical and mechanical work. Due to the conditions of the specifications and drawings, most vendors would not provide a written quote.

[4] For this project, a bottom-up estimate is a fact driven estimate of the actual work effort from the project side of the balance sheet. The bottom-up estimate is a deterministic estimate that employs the concept of a three point estimate based up the degree of accuracy as defined for a Class 3 estimate by the AACE.

CH2M Hill's estimate were prepared to provide guidance in project evaluation and implementation available at the time the estimate was prepared.

Sales Tax

Sales tax of 8% is included in the estimate for the California portion of the work. A 7% environmental tax is included for the Arizona portion of the work.

Allowance Costs

The cost estimate includes the following allowances within the cost estimate:

- The costs of the new maintenance facility at the Transwestern Metering Station Bench the process building and the hazardous waste building have been parametrically estimated on a square foot basis.
- Work benches, tables and chairs, computers, printers and plotters, and laboratory equipment at the new maintenance facility are allowances.

Major Assumptions

The estimate is based on the assumption that the work will be done on a competitive bid basis and the contractor will have a reasonable amount of time to complete the work. All contractors are equally qualified, with a reasonable project schedule, overtime at 2 hours per day, constructed as under a single contract, no liquidated damages.

- It is assumed that much of the fabricated equipment will be manufactured locally.
- Temporary fencing such as tortoise fencing is not in the estimate.
- Except for work at the Transwestern Metering Station Bench and the Remedy Produced Water Conditioning System area, and new well access roads, there will be no substantial change in existing grade contours for work. Some access roads will require cut and fill.
- High density polyethylene (HDPE) pipe pricing is based on recent vendor quotations. Confined space work and/or requirements and training are excluded.
- Personal protective equipment will be Level D.
- HDPE pipe installation and fusing will be done at night for the next day of work.
- No high volume air sampling is required.
- Hydroseeding will be used as proxy for re-vegetation as those requirements haven't been defined.
- Only the 28 base IRZ wells are installed (i.e., no future provisional wells).
- Nineteen (non-IRZ) remediation wells are installed, including 11 extraction and 6 injection wells. Two freshwater injection wells will be installed. The freshwater supply well HNWR-1 is retrofitted to serve the remedy.

- Nineteen new monitoring wells will be installed. No additional infrastructure or equipment is included in the estimate.
- Startup is 6 weeks.
- Field drilling oversight is covered under the wells section of Table H-1.
- IM-3 deconstruction and site restoration costs are based on the CMS/FS, with some changes as stipulated by Attachment E of Appendix H.
- A single remedy produced water influent storage tank farm is built.
- The natural gas generator pricing was based on AECOM's, "Topock Compressor Station, Power Study for Chromium Remediation Program," dated 14 September 2012.
- Off-road and on-road fuel costs were based on the January 2013 fuel cost in California.

Description of Construction Work

Install Access Roads. Included in this item are: 1) construction of five assumed access roads for drillers, 2) construction of 800 feet (ft) of major access road, 3) Construction of 20,000 ft of scratch-graded contractor haul/access roads and removal at construction completion, 4) road maintenance during construction, and 5) installation of a water truck fill station.

Survey for New Wells. Layout survey for new wells is included.

Wellhead Work. Wellhead work at the existing well (HNWR-1) in Arizona, installation and development of 47 new remediation wells, and installation of electrical power to the 47 new wells is included.

Installation of New Pipeline. There are 11 named pipelines, each either of three types of construction: pipeline in underground trench (Direct burial), pipeline in precast concrete trench, and above ground pipeline on sleepers. The pipeline installation was estimated based upon the revised Table C-07-03 provided by CH2MHIll.

Pipelines in Precast Concrete Containment Trench. Activities include:

- Layout survey for vertical and horizontal alignment of precast trench;
- Pothole for existing utilities;
- Excavate trench and haul trench spoil to processing area;
- Process trench spoil, assuming 100% will be used as bedding/backfill (per PG&E);
- Place bedding using processed fines, grade;
- Furnish and place precast concrete containment system;
- Place processed backfill adjacent to precast sections;
- Furnish and place HDPE conveyance pipe;

- Place precast concrete trench covers;
- Pipeline A includes an elevated 200 ft long structural steel road crossing; and
- Pipeline C includes two underground directional drilling segments.

Pipelines in Underground Trench.

Activities include:

- Layout survey for vertical and horizontal alignment of pipeline;
- Pothole for existing utilities;
- Excavate trench and haul trench spoil to processing area;
- Process trench spoil, assuming 100% will be usable as bedding/backfill (per PG&E);
- Furnish and place HDPE conveyance pipe;
- Place pipe zone backfill using processed fines, grade;
- Place backfill to grade;
- Pipeline B has a 1,120 ft segment of above ground steel pipe on sleepers, a 495 ft bore and jack casing, a 50 ft directional drill casing, and an 816 ft steel pipe segment on the existing bridge across the Colorado River;
- Pipeline G has three directional drill casing segments; and
- Pipeline I has a 200 ft long structural steel road crossing.

Well Installation Install New Monitoring Wells. Cost to install 19 new monitoring wells.

Install Equipment & Controls System. This item includes installation of process, mechanical, and electrical equipment and controls for all non-well facilities (organic substrate amendment facilities at the MW-20 and Transwestern Benches, and Remedy Building located at the Compressor Station). Any site grading and other site work required is included here.

Start Up and Test. Cost to start up and test all process, electrical, and mechanical systems.

Well Removal/Destruction. Cost to decommission 47 remediation wells and 19 monitoring wells

Pipeline Equipment & Controls Removal. Used 30% Estimate.

Access Road Removal. Cost to remove major roads to well sites**.**

Area Wide Restoration. Used 30% estimate.

Install Power Station (Electrical Generator). An estimate was provided based on the costs for Option 1 as outlined in AECOM's, "Topock Compressor Station, Power Study for Chromium

Remediation Program," dated 14 September 2012. This should be maintained as an AACE Class 5 estimate until a larger portion of the design is complete.

General Conditions (Sub Mob, Sub GC). Estimated cost for mobilization, contractor facilities, and general conditions has been placed in the various sections of the bid.

Field Construction Management & Engineering SDC.
Cost of construction management and engineering services during construction for general engineering SDC, Well installation SDC, and SDC for removal of all 252 wells.

Project Management. Cost for project management of construction phase.

Contractor Markup (G&A, Fee) Markup for overall project contractor. Assumed to be PG&E Master Services Agreement holder, so approximately 5% of lower tier subs.

Transwestern Bench Maintenance Facility. Parametric estimate for a new building including finishes, furnishings, and laboratory equipment.

Waste Water Treatment Plant. Cost for operating and maintenance (O&M) of Remedy Produced Water Conditioning System for 12 months per year for 30 years. See Attachment C of Appendix H.

Freshwater Well Maintenance and Pumping. Cost of freshwater well maintenance and pumping for 12 months per year for 30 years. See Attachment C of Appendix H.

IRZ System Operation. Cost of operating the IRZ system for 12 months per year for 30 years. See Attachment C of Appendix H.

Remedy Well Replacement. Cost of Remedy well replacement over 30 years. See Attachment C of Appendix H.

Maintenance of Remedy Wells. Cost of Remedy well maintenance activities (rehabilitation) over 30 years. See Attachment C of Appendix H.

Miscellaneous. Miscellaneous O&M costs include road maintenance, permit compliance, groundwater ICs, biological surveys, cultural surveys, regulatory/stakeholder oversight, water rights, and 5-year reviews based on the values used in the CMS/FS. O&M project management is also included. O&M costs occur for 12 months per year for 30 years and long term monitoring costs occur for 12 months per year for 10 years. See Attachment C of Appendix H.

Excluded Costs

The cost estimate excludes the following items:

- Landscaping;
- Rock excavation;

- Escalation - costs are current dollars;
- Removal and disposal of concrete precast trenches;
- Permits, right-of-ways, and easements;
- Engineering design and project management; and
- Schedule effects caused by work limitations within the floodplain area due to bird nesting season.

The following mitigation measures are excluded from these estimates:

- Paleontological investigation;
- Preparing and implementing a tribal access plan;
- Preparing and implementing an outreach plan for Moabi Regional Park to limit off-road vehicle use within the project area;
- Supporting a technical review committee;
- Preparing and implementing a plant transplantation and monitoring plan;
- Preparing and implementing a Cultural Impact Mitigation Program;
- Preparing a project restoration plan;
- Preparing an IM-3 decommissioning plan;
- Sensitivity training documentation;
- Funding a disturbance coordinator;
- Noise mitigations during construction; and
- Aquifer testing, data analysis, and modeling.

Schedule

The construction schedule is assumed to last 18 months. Sequencing will be defined during the 90% design and the estimate will be revised accordingly.

Design Reference Documents

1. Drawings dated 14 September 2012.

Dwg. No.	Title
	ARCHITECTURAL
A-00-01	Legends & Abbreviations
A-12-01	Remedy Produced Water Conditioning Plant Code Summary Sheet
A-12-02	Remedy Produced Water Conditioning Plant Floor Plans

Dwg. No.	Title
A-12-03	Remedy Produced Water Conditioning Plant Roof Plan and Reflected Ceiling Plan
A-12-04	Remedy Produced Water Conditioning Plant Exterior Elevations
A-12-05	Remedy Produced Water Conditioning Plant Building Sections
A-12-06	Remedy Produced Water Conditioning Plant Wall Sections
A-12-07	Remedy Produced Water Conditioning Plant Enlarged Plans & Elevations
A-12-08	Remedy Produced Water Conditioning Plant Stairs & Details
A-12-09	Remedy Produced Water Conditioning Plant Details
A-12-10	Remedy Produced Water Conditioning Plant Schedules
	PIPING
C-07-01	Pipeline Key Map
C-07-02	Pipeline Segment Map
C-07-02	Pipe Schedule
C-07-03	Valve Details
C-07-08	Piping Details
C-07-09	Plan Profile – STA 12+31 to STA 020+50
C-07-10	Plan Profile – STA 20+50 to 28+75
C-07-11	Plan Profile – STA 28+75 to STA 36+50
C-07-12	Plan Profile – STA 36+50 to STA 45+00
C-07-13	Plan Profile – STA 45+00 STA 54+86
C-07-14	Plan Profile – STA 10+00 to STA 15+33
C-07-15	Plan Profile – STA 4+77 to STA 14+00
C-07-16	Plan Profile – STA 14+00 to 21+30
C-07-17	Plan Profile – STA 21+30 to 29+30
C-07-18	Plan Profile – STA 29+30 to 40+55
C-07-19	Plan Profile – STA 40+55 to 50+55
C-07-20	Plan Profile – STA 50+55 to 61+05
C-07-21	Plan Profile – STA 61+05 to 71+00
C-07-22	Plan and Profile –STA 71+00 to 80+49.06
C-07-23	Plan and Profile – STA 10+00 to 13+50
C-07-24	Plan and Profile – STA 13+50 to 19+60
C-07-25	Plan and Profile – STA 19+60 to 25+89
C-07-26	Plan and Profile – STA 10+00 to 13+60
C-07-27	Plan and Profile – STA 26+00 to 29+50
C-07-28	Plan and Profile – STA 26+50 to 35+60
C-07-29	Plan and Profile – STA 36+40 to 40+60
C-07-30	Plan and Profile – STA 40+60 to 44+00
C-07-31	Plan and Profile – STA 44+00 to 49+20
C-07-32	Plan and Profile – STA 49+20 to 53+30
C-07-33	Plan and Profile – STA 10+00 to 14+79

Dwg. No.	Title
C-07-34	Plan and Profile – STA 10+00 to 15+80
C-07-35	Plan and Profile – STA 10+00 to 12+50
C-07-36	Plan and Profile – STA 10+00 to 13+50
C-07-37	Plan and Profile – STA 10+00 to 14+60
C-07-38	Plan and Profile – STA 10+00 to 15+80
C-07-39	Plan and Profile – STA 10+00 to 12+60
C-07-40	Plan and Profile – STA 10+00 to 14+15
C-07-41	Plan and Profile – STA 10+00 to 12+85
C-07-42	Plan and Profile – STA 10+00 to 13+25
C-07-43	Trench Details
C-07-44	Trench Details
C-07-45	Trench Details
C-07-46	Trench Details
C-07-47	Intersection Details
C-07-48	Intersection Details
C-07-49	Intersection Details
C-07-50	Intersection Details
C-07-51	Electrical Trench Details
C-07-52	Electrical Trench Details
C-07-53	Electrical Trench Details
C-07-54	Plan and Profile – STA 10+04 to 15+83
C-07-55	Plan and Profile – STA 13+05 to 18+00
C-07-56	Plan and Profile – STA 18+00 to 23+00
C-07-57	Plan and Profile – STA 23+00 to 26+25
C-07-58	Plan and Profile – STA 90+00 to 91+04
C-07-59	Plan and Profile – STA 80+00 to 84+46
C-07-60	Plan and Profile – STA 60+00 to 65+00
C-07-61	Plan and Profile – STA 65+00 to 70+05
C-07-62	Plan and Profile – STA 85+00 to 86+38
C-07-63	Plan and Profile – STA 8+00 to 12+85
C-07-64	Pipeline D Plan and Profile
C-07-65	Trench Sections
C-07-66	Trench Sections
C-07-67	Above Ground Pipeline Sections
C-07-68	Pipeline Sections
C-07-69	Pipeline Sections
C-07-70	Pipeline Sections
C-07-71	Pipeline Sections
C-07-72	Pipeline Sections
C-07-86	Pipeline Intersection Details

Dwg. No.	Title
C-10-02	Pipe Layout Sheet 1 of 3
C-10-03	Pipe Layout Sheet 2 of 3
C-10-04	Pipe Layout Sheet 3 of 3
	Civil Site Plans
C-00-01	General Notes
C-00-02	Well Location Map
C-00-03	Well Schedule
C-00-04	Overall Civil Site Plan
C-00-06	Chain Link Fence and Gate
C-00-07	Chain Link Fence and Gate Details
C-01-01	HNWR Freshwater Supply Site Plan
C-02-01	Freshwater Injection Well – FW-1 Site Plan
C-02-02	Freshwater Injection Well – FW-2 Site Plan
C-05-01	IRL-4 Access Road Site Plan
C-05-02	IRL-4 Access Road Sections
C-05-03	IRL-2Access Road Plan and Section
C-05-04	Inner Recirculation Loop Injection Well IRL-1 Site Plan
C-05-05	Inner Recirculation Loop Injection Well IRL-2 Site Plan
C-05-06	Inner Recirculation Loop Injection Well IRL-3 Site Plan
C-05-07	Inner Recirculation Loop Injection Well IRL-4 Site Plan
C-06-01	MW-20 Bench Area Plan
C-06-02	MW-20 Bench Grading Plan
C-06-03	MW-20 Yard Piping Plan
C-08-01	TW Bench Carbon Amendment Area Plan
C-10-01	TCS Civil Site Plan 1
C-10-02	TCS Civil Site Plan 2
C-11-01	Influent Tank Farm Site Plan
C-11-02	Influent Tanks Site Plan No. 2
C-12-01	Water Conditioning Plant Site Plan
C-12-01	Remedy Produced Water Conditioning Plant Site Plan
C-13-01	Relocated Hazardous Waste Storage Site – Plan
C-14-01	Conditioned Water Storage Tank Site Plan
C-14-02	Conditioned Water Storage Tank Farm Site Plan
	Electrical and Controls
E-00-01	Electrical Symbols and Abbreviations
E-00-02	Remedy Water Treatment Overall Electrical – Siteplan
E-00-03	TCS Electrical Area Plan
E-00-04	Transwestern Bench Area Plan
E-00-05	MW-20 Bench Area Plan
E-00-06	North Riverbank Area Plan

Dwg. No.	Title
E-00-07	Uplands Area Plan
E-00-08	Typical Node Site Plan
E-00-09	Electrical Power One-Line Diagram
E-00-10	Load Calculations
E-00-11	Electrical Load Schedules
E-00-12	Conduit & Cable Schedules
E-00-13	Conduit & Cable Schedules
E-00-14	Conduit & Cable Schedules
E-00-15	One-Line Diagram Node 1
E-00-16	One Line Diagram Node 2
E-00-17	One Line Diagram Node 3
E-00-18	One Line Diagram Node 3
E-00-19	One Line Diagram Node 4
E-00-20	One Line Diagram Node 5
E-00-21	Remote Well Communication Panel 1 Elevation & Layout
E-00-22	Remote Well Communication Panel 1 Schematic
E-00-23	Remote Well Communication Panel 2 Elevation & Layout
E-00-24	Remote Well Communication Panel 2 Schematic
E-00-25	Remote Well Communication Panel 3 Elevation & Layout
E-00-26	Remote Well Communication Panel 3 Schematic
E-00-27	Remote Well Communication Panel 4 Elevation & Layout
E-00-28	Remote Well Communication Panel 4 Schematic
E-00-29	Remote Well Communication Panel 5 Elevation & Layout
E-00-30	Remote Well Communication Panel 5 Schematic
E-00-31	SCADA Block Diagram
E-00-32	Energy Use Calculations
E-00-51	Electrical Details 1
E-00-52	Electrical Details 2
E-01-01	Freshwater Well (HNWR-1) Electrical Site Plan
E-01-02	Freshwater Well (HNWR-1) PLC Control Panel Elevation & Backpan Layout
E-01-03	Freshwater Well (HNWR-1) Control Panel Power Distribution & PLC Diagram
E-01-04	Freshwater Well (HNWR-1) Pump Elementary Diagram
E-01-05	Freshwater Injection Well PLC Control Panel Elevation & Backpan Layout
E-01-06	Freshwater Injection Well Control Panel Power Distribution & PLC Diagram
E-01-07	Freshwater Injection Well Pump Elementary Diagram
E-01-08	Freshwater Well (Topock-2/3) PLC Control Panel Elevation & Backpan Layout
E-01-09	Freshwater Well (Topoc-2/3) Control Panel Power Distribution & PLC Diagram
E-12-01	Remedy Produced Water Conditioning Plant – Motor Control Center –Line & Elevation
E-12-02	Remedy Produced Water Conditioning Plant FVNR Elementary Diagram
E-12-03	Remedy Produced Water Conditioning Plant VFD Elementary Diagram

Dwg. No.	Title
E-12-04	Remedy Produced Water Conditioning Plant Control Panel Elevation
E-12-05	Remedy Produced Water Conditioning Plant Control Panel Backpan Layout
E-12-06	Remedy Produced Water Conditioning Plant Power Distribution Diagram
E-12-07	Remedy Produced Water Conditioning Plant Example PLC I/O Wiring Diagrams
E-12-08	TCS Remote Radio Panel
E-12-20	Remedy Produced Water Conditioning Plant 1st Floor Power & Control Plan
E-12-21	Remedy Produced Water Conditioning Plant 1st Floor Lighting and Receptacle Plan
E-12-22	Remedy Produced Water Conditioning Plant 2nd Floor Power & Control Plan
E-12-23	Remedy Produced Water Conditioning Plant 2nd Floor Lighting and Receptacle Plan
	Process
G-00-06	Process Schematic for Fresh Water Injection and Remedy-Produced Water
G-03-01	Process Flow Diagram for TCS Recirculation Loop
G-04-01	Process Flow Diagram for NTH IRZ Extraction Well Network
G-04-02	Process Flow Diagram for NTH Injection Well Network
G-05-01	Process Flow Diagram for Inner Recirculation Loop
G-06-01	Process Flow Diagram for Carbon Substrate Amendment and Clean-in-Place Systems
G-07-01	Hydraulic Profile Freshwater Injection System
G-07-02	Hydraulic Profile Remedy-Produced Water System
G-10-01	Process Schematic Secondary Containment for TCS/Remedy Produced Water
G-12-01	Process Flow Diagram Remedy Produced Water Conditioning Plant
G-12-02	Mass Balance Remedy Produced Water
I-00-01	P&ID Instrumentation Symbols and Abbreviations 1
I-00-02	P&ID Instrumentation Symbols and Abbreviations 2
I-00-03	Remedy Well ID Schedule
I-02-01	P&ID Freshwater Supply Well
I-02-02	P&ID Fresh Water Tanks
I-02-03	P&ID Injection Well
I-03-01	TCS Loop Extraction and Injection Wells P&ID
I-04-01	NTH IRZ Extraction Wells P&ID
I-04-02	South NTH IRZ Injection Wells P&ID
I-04-03	North NTH IRZ Injection Wells P&ID
I-04-04	North NTH IRZ Node 03 Fiber Optic Network
I-04-05	North NTH IRZ Node 03 MCP-03 Instrumentation Connection
I-04-06	North NTH IRZ Node 03 MCP-03 Instrumentation Connection
I-04-07	North NTH IRZ Node 03 CP-03-xx Instrumentation Connection
I-04-08	North NTH IRZ Node 03 CP-03-xx Instrumentation Connection
I-04-09	South NTH IRZ Node 04 Fiber Optic Network
I-04-10	South NTH IRZ Node 04 MCP-04 Instrumentation Connection
I-04-11	South NTH IRZ Node 04 CP-04-xx Instrumentation Connection
I-04-12	South NTH IRZ Node 04 CP-04-xx Instrumentation Connection

Dwg. No.	Title
I-05-01	River Bank Extraction and Upland Injection Wells P&ID
I-05-02	Inner Recirculation Loop Node 05 Fiber Optic Network
I-05-03	Inner Recirculation Loop MCP-05 Instrumentation Connection
I-05-04	Inner Recirculation Loop CP-05-xx Instrumentation Connection
I-06-01	IRZ Carbon Amendment Building P&ID Sheet 1 of 2
I-06-02	IRZ Carbon Amendment Building P&ID Sheet 2 of 2
I-06-03	MW-20 Bench Node 02 Fiber Optic Network
I-06-04	MW-20 Bench Node 02 MCP-02 Instrumentation Calibration
I-06-05	MW-20 Bench Node 02 CP-02-xx Instrumentation Calibration
I-08-01	TW Bench Carbon Amendment Building P&ID
I-08-02	TW Bench Node 01 Fiber Optic Network
I-08-03	TW Bench Node 01 MCP-01 Instrumentation Connection
I-08-04	TW Bench Node 01 CP-01-xx Instrumentation Connection
I-08-05	TW Bench Node 01 TCS-1&2 CP-01-xx Instrumentation Connection
I-11-01	P&ID Influent Tank 1
I-11-02	P&ID Influent Tank 2
I-11-03	P&ID Influent Tank 3
I-11-04	P&ID Influent Tank 4
I-12-01	P&ID Filter System – A Side
I-12-02	P&ID Filter System – B Side
I-12-03	P&ID Caustic and Coagulant System
I-12-04	P&ID Acid and Dewatering Aid Systems
I-12-05	P&ID Liquid Phase Separator & Air Compressor
I-14-01	P&ID Conditioned Water Storage Tank Farm - A Side
I-14-02	P&ID Conditioned Water – B Side
	Mechanical Drawings
M-01-01	HW NR-1 – Well Head Piping and Electrical Pad Plan and Section
M-02-01	Freshwater Injection Well and Meter Vault Plan and Section
M-02-02	Freshwater Injection Well Construction Details
M-03-01	TCS Loop Extraction Well Construction Details
M-03-02	TCS Loop Injection Well Construction Details
M-03-03	TCS Loop Extraction Well Vault Mechanical Details
M-03-04	TCS Loop Extraction Well Vault Mechanical Sections
M-03-05	TCS Loop Injection Well Vaults Mechanical Details
M-03-06	TCS Loop Injection Well Vaults Mechanical Sections
M-04-01	IRZ Extraction Well Construction Details
M-04-02	IRZ Injection Well Construction Details
M-04-03	IRZ Extraction Well Vault Mechanical Details
M-04-04	IRZ Extraction Well Vault Mechanical Sections
M-04-05	IRZ Single Screen Injection Well Vaults Mechanical Details and Sections

Dwg. No.	Title
M-04-06	IRZ Dual Screen Injection Well Vaults Mechanical Details
M-04-07	IRZ Dual Screen Injection Well Vaults Mechanical Sections
M-04-08	IRZ Dual Screen Cluster Injection Well Vaults Mechanical Details
M-04-09	IRZ Dual Screen Cluster Injection Well Vaults Mechanical Sections
M-05-01	Inner Recirculation Loop Extraction Well Construction Details
M-05-02	Inner Recirculation Loop Injection Well Construction Details
M-05-03	Riverbank Extraction Well Vault Mechanical Details
M-05-04	Riverbank Extraction Well Vault Mechanical Sections
M-05-05	Inner Recirculation Loop Injection Well Vaults Mechanical Details
M-05-06	Inner Recirculation Loop Injection Well Vaults Mechanical Sections
M-06-01	IRZ Carbon Amendment Building Mechanical Layout
M-06-02	IRZ Carbon Amendment Building Sections and Details Sheet 1 of 2
M-06-03	IRZ Carbon Amendment Building Sections and Details Sheet 2 of 2
M-06-04	IRZ Carbon Substrate Storage Tank Mechanical Details
M-08-01	TW Bench Carbon Amendment Building Mechanical Layout
M-08-02	TW Bench Carbon Amendment Building Sections and Details Sheet 1 of 2
M-08-04	TW Bench Carbon Substrate Storage Tank Mechanical Details
M-11-01	Influent Tank Farm Plan
M-11-02	Influent Tank Eductor Mounting Detail
M-12-01	Remedy Produced Water Conditioning Plant First Floor Plan
M-12-02	Remedy Produced Water Conditioning Plant Second Floor Plan
M-12-04	Remedy Produced Water Conditioning Plant HVAC & Plumbing Details
M-12-05	Remedy Produced Water Conditioning Plant HVAC & Plumbing Details 1st Floor Plan
M-12-06	Remedy Produced Water Conditioning Plant HVAC & Plumbing Details 2nd Floor Plan
M-12-07	Remedy Produced Water Conditioning Plant Potable Water
M-14-01	Conditioned Water Tank Farm Plan
	Structural Drawings
S-00-05	Well Vault Schedule
S-01-01	HNWR Freshwater Well Foundation Plan and Section
S-01-02	HNWR Freshwater Well Electrical Pad Floor & Roof Plan and Section
S-01-03	HNWR Freshwater Well Electrical Pad Sections and Details
S-02-01	Injection Well – Meter & Valve Vault – Top & Bottom Plans
S-02-02	Injection Well – Meter & Valve Vault – Sections
S-03-01	TCS Loop Injection Well Vaults – Type 1 - Plan
S-03-02	TCS Loop Injection Well Vaults – Type 2 - Plan
S-03-03	TCS Loop Injection Well Vaults – Foundation Plan
S-03-04	TCS Loop Injection Well Vaults – Sections
S-03-05	TCS Loop Injection Well Vaults – Sections
S-03-06	TCS Loop Extraction Well Vaults – Type 2 Plan
S-03-07	TCS Loop Extraction Well Vaults – Foundation Plan

Dwg. No.	Title
S-03-08	TCS Loop Extraction Well Vaults – Sections
S-04-01	IRZ Injection Well Vaults – Type 1 - Plan
S-04-02	IRZ Injection Well Vaults – Type 2 - Plan
S-04-03	IRZ Injection Well Vaults – Foundation Plan
S-04-04	IRZ Injection Well Vaults - Sections
S-04-05	IRZ Injection Well Vaults - Sections
S-04-06	IRZ Extraction Well Vaults – Type 1 - Plan
S-04-07	IRZ Extractions Well Vaults – Type 2 - Plan
S-04-08	IRZ Extraction Well Vaults – Foundation Plan
S-04-09	IRZ Extraction Well Vaults - Sections
S-04-10	IRZ Extraction Well Vaults - Sections
S-05-01	Inner Recirculation Loop Injection Well Vaults – Type 1 - Plan
S-05-02	Inner Recirculation Loop Injection Well Vaults – Type 2 - Plan
S-05-03	Inner Recirculation Loop Injection Well Vaults – Foundation Plan
S-05-04	Inner Recirculation Loop Injection Well Vaults - Sections
S-05-05	Inner Recirculation Loop Injection Well Vaults - Sections
S-05-06	Inner Recirculation Loop Extraction Well Vaults – Type 1 - Plan
S-05-07	Inner Recirculation Loop Extraction Well Vaults – Foundation Plan
S-05-08	Inner Recirculation Loop Extraction Well Vaults - Sections
S-06-01	IRZ Carbon Substrate Storage Tank Foundation
S-06-03	IRZ Unloading Pad
S-07-01	Aerial Crossing Pipeline “A”
S-07-02	Aerial Crossing Pipeline “I”
S-07-03	Aerial Crossing Pipeline “A” Sections and Details
S-07-04	Aerial Crossing Pipeline “I” Sections and Details
S-08-01	TW Bench Storage Tank Foundation
S-11-01	Influent Tank Farm Foundation Plan
S-11-02	Influent Tank Farm Floor Plan
S-11-03	Influent Tank Farm Sections and Details
S-12.01	Remedy Produced Water Conditioning Plant – Foundation Plan
S-12-02	Remedy Produced Water Conditioning Plant First Floor Plan
S-12-03	Remedy Produced Water Conditioning Plant Second Floor Plan
S-12-04	Remedy Produced Water Conditioning Plant Roof Framing Plan
S-12-05	Remedy Produced Water Conditioning Plant Wall Framing Elevations
S-12-06	Remedy Produced Water Conditioning Plant Wall Framing Elevations
S-12-07	Remedy Produced Water Conditioning Plant Building Section
S-12-08	Remedy Produced Water Conditioning Plant Building Section
S-12-09	Remedy Produced Water Conditioning Plant Building Section
S-14-01	Conditioned Water Storage Tank – Mechanical Plan and Details
S-14-02	Conditioned Water Storage Tank – Sections and Details

Dwg. No.	Title
S-14-03	Conditioned Water Storage Tank – Sections and Details
S-14-04	Conditioned Water Storage Tank – Sections and Details
S-14-05	Conditioned Water Storage Tank – Sections and Details
S-14-06	Conditioned Water Storage Tank Cathodic Protection
S-14-07	Conditioned Water Storage Tank Cathodic Protection
S-14-08	Conditioned Water Storage Tank Farm Foundation Plan
S-14-09	Conditioned Water Storage Tank Farm Floor Plan
S-14-10	Conditioned Water Storage Tank Farm Sections and Details

Attachment B – Well Installation Cost Estimate

TECHNICAL MEMORANDUM

Final Groundwater Remedy – Well Installation and Testing Basis of Cost Estimate

PREPARED FOR: Pacific Gas & Electric Company

PREPARED BY: Beth Breitenbach, P.G., Haley & Aldrich, Inc.

DATE: April 2, 2013

This memorandum presents the basis of cost estimate for the Pacific Gas & Electric Company (PG&E) Topock Compressor Station well installation and testing associated with the final groundwater remedy. Table 1 summarizes the costs for each item included in this basis of cost estimate. This memorandum is a companion document to the Final Groundwater Remedy Project cost estimate for the intermediate (60%) design. The costs used to develop this estimate are based on the attached drawing set, scope of work statements from CH2MHill and Arcadis, discussions with contractors, initial discussions with agencies and project stakeholders, and professional judgment.

Remediation Wells

The term "remediation well" includes injection, extraction and in-situ reactive zone (IRZ) wells. The estimated cost to install and test all the primary remediation wells defined in the 60% basis of design report is $17,930,000. Secondary remediation wells, which are included in the design but will not be part of the initial groundwater remedy construction and startup are not included in this cost estimate. The estimated cost for remediation well installation and testing is based on the following major assumptions:

- Forty-seven (47) primary remediation wells will be installed and tested. Forty-one (41) of the wells will be drilled in unconsolidated deposits; four (4) wells will be drilled in bedrock and two remaining freshwater wells.
- Wells will be constructed in accordance with the design details included in the 60% basis of design report.
- Each well will be developed prior to initial testing to remove fluids introduced during installation and establish proper hydraulic connection between the well screen, filter material, and surrounding geologic material.
- Drilling equipment will not be decontaminated between well locations.
- All drill cuttings will be retained on site for subsequent return, reuse, or restoration purposes. The protocol for managing and disposing of displaced site material, which includes drill cuttings, is currently being developed by a subgroup that includes PG&E, DTSC, DOI, and Interested Tribes. Therefore, the assumptions used to develop this cost basis will need to be revised as the protocol and associated technical details are established.
- Remediation wells will be tested following installation and development to evaluate performance. Based on the designed purpose of a given remediation well, well tests will be performed to assess well capacity and efficiency, injectivity, and assess aquifer hydraulic properties, as determined necessary. Other baseline measures of post-installation well condition, including video logging and well plumbness, are included in the cost.
- All groundwater extracted during well development and testing will either be reused for injectivity testing or disposed on site through the IM-3 treatment plant or remedy produced water conditioning facility associated with the final groundwater remedy.

- Field oversight will occur for the duration of installation with full-time office support by a lead hydrogeologist.

Monitoring Wells

Monitoring wells will be installed as part of the final groundwater remedy to supplement the existing monitoring well network at the site. The estimated cost to install monitoring wells at all of the locations defined in the 60% basis of design report is $2,949,750 The estimated cost for monitoring well installation is based on the following major assumptions:

- Monitoring well(s) will be installed at 19 new locations.
- A 15% contingency is included for drilling downtime, false starts, and equipment malfunctions.
- Monitoring well construction details are based on the existing monitoring well network at the site; however, it is assumed that the actual design of the new monitoring wells will be based on the data collected during the construction of the final groundwater remedy, and may therefore vary.
- The pre-drilling field program will consist of pilot boring with vertical aquifer sampling at approximately 100 intervals distributed across 10 locations and grain-size analysis at three intervals per well for screen design and assessment of formation characteristics.
- Each well will be developed to remove fluids introduced during installation and establish proper hydraulic connection between the well screen, filter material, and surrounding geologic material.
- All drill cuttings will be retained on site for subsequent return, reuse, or restoration purposes. The protocol for managing and disposing displaced site material, which includes drill cuttings, is currently being developed by a subgroup that includes PG&E, DTSC, DOI, and Interested Tribes. Therefore, the assumptions used to develop this cost basis will need to be revised as the protocol and associated technical details are established.
- All groundwater extracted during well development will either be reused for injectivity testing at remediation wells or disposed on site through the IM-3 treatment plant or remedy produced water conditioning facility associated with the final groundwater remedy.
- Field oversight will occur for the duration of installation with full-time office support by a lead hydrogeologist.

TABLE 1

Well Installation and Testing Costs

Intermediate (60%) Design

PG&E Topock Compressor Station, Needles, California

Description	Qty	Unit	Unit Cost	Total
Initial Mobilization	1	LS	$7,500.00	$7,500.00
Relocation and Decontamination (66 Locations x 3 hrs/loc)	198	HR	$500.00	$99,000.00
Weekly Shift Travels	49	WK	$930.00	$45,570.00
Per Diem - Assume 3.5 MD/Day	345	MD	$125.00	$150,937.50
Well Development	345	MD	$1,650.00	$569,250.00
Drilling				
Drilling 16 inch Borehole	7580	VF	$125.00	$947,500.00
Approx. 1,550 feet of 12-inch borehole drilling (riverbank extraction wells)	1550	VF	$115.00	$178,250.00
Approx. 230 feet of 8-inch borehole drilling (bedrock carrier casings – East ravine wells	230	VF	$55.00	$12,650.00
Approx. 360 feet of 4-inch air rotary drilling (open hole portion of bedrock wells)	360	VF	$45.00	$16,200.00
45 remediation wells (41 in unconsolidated deposits, 4 in bedrock)				
Well Screen - Approx. 2,825 feet of 12-inch, wire-wound, 316L SS	2825	VF	$325.00	$918,125.00
Well Screen - Approx. 400 feet of 8-inch, wire-wound, 316L SS screen	400	VF	$225.00	$90,000.00
Well Casing - Carbon Steel/12 inch Casing 0.250 wall thickness	1250	VF	$175.00	$218,750.00
12 inch casing Approx. 4,800 feet of 12-inch casing 316L SS = $375/ft – LCS	4800	VF	$175.00	$840,000.00
Approx. 1,150 feet of 8-inch casing 316L SS = $275/ft – LCS	1150	VF	$125.00	$143,750.00
Approx. 230 feet of 6-inch casing 316L SS = $195/ft – LCS	230	VF	$85.00	$19,550.00
12 inch 316SS Casing	1250	VF	$375.00	$468,750.00
12 inch Dielectric couplings	8	EA	$8,500.00	$68,000.00
Post Construction Sampling				-
Hydraulic testing: 10-hour duration stepped rate aquifer test at 5 Riverbank Extraction Wells and up to 5 other well locations (10 locations total)	100	HR	$175.00	$17,500.00
Specific injectability testing: 10-hour duration stepped rate injection test at 4 IRL injection wells and 2 fresh water injection wells (6 locations total)	60	HR	$175.00	$10,500.00

TABLE 1

Well Installation and Testing Costs

Intermediate (60%) Design

PG&E Topock Compressor Station, Needles, California

Down Hole TV Logging	47	EA	$1,850.00	$86,950.00
Well Plumbness Test	10	hr	$550.00	$5,500.00
Vertical Aquifer Samples	250	EA	$775.00	$193,750.00
Geophysical Logging of 20 wells	20	EA	$4,250.00	$85,000.00
Install 19 Monitoring Wells	5700	VF	517.50	$2,949,750.00
Cr(VI) Samples	250	EA	$45.00	$11,250.00
Water Quality Analysis	10	Ea	$2,000.00	$20,000.00
Total				$8,200,982

Attachment C –O&M and Startup Cost Estimate Update

Final Groundwater Remedy - Preliminary Design O&M and Post-Remediation Cost Estimate Update

PREPARED FOR: Pacific Gas & Electric Company

PREPARED BY: Beth Breitenbach, P.G. , Haley & Aldrich, Inc.

DATE: April 2, 2013

This memorandum presents the updated operations and maintenance (O&M) costs for the Pacific Gas & Electric Company, Topock Compressor Station, Final Groundwater Remedy Project. The site is located in San Bernardino County, near Needles, California. This memorandum is a companion document to the project cost estimate. See the report for a more detailed description of the project.

The reference or comparison point for this estimate is the Corrective Measures Study/Feasibility Study (CMS/FS) (CH2M Hill, 2009) and a copy of Table D-6 is included as Attachment 1. For brevity, the reader is referred to the CMS/FS for a detailed discussion of assumptions and design basis. Exceptions to the assumptions and design basis are discussed below. The initial annual O&M cost in the CMS/FS was $4.0 million, followed by the 30% design annual O&M cost estimate of $5.1 million.

Operations and Maintenance Costs

O&M costs in the CMS/FS primarily included in situ reduction system O&M and monitoring and reporting costs. The duration of the project is assumed to be 30 years, plus 10 years of post-remediation monitoring. Changes to the O&M portion of the costs are discussed below.

- In situ reduction O&M costs were revised based on changes in flow rates, uptime for carbon injection, and target carbon concentrations. The original estimate shown on Table D-14 of the CMS/FS is revised and included as Attachment 3 to this memorandum. The annual cost is $1,016,500 before applying the contingency.
- A remedy produced water conditioning system will be built and operated to treat remedy well maintenance fluids from well backwashing and rehabilitation. The estimated cost for operating the system is $490,000 per year. This assumes all remedy produced water is disposed of or re-used or re-injected on-site. Labor staffing includes a project manager and a technician (Attachment 2).
- Two line items covered well maintenance and replacement. These two items were updated based on the cost of the well installation. For remedy wells, the cost was assumed to be 2% of installation costs (see Table 1).
- Well rehabilitations are shown on Table 1. The estimated costs are based on experience at the Interim Measures Number 3 injection wells. Rehabilitation frequencies are assumed to be every 1.5 years for IRZ wells, every 2 years for injection wells, and every 4 years for extraction wells.
- Freshwater extraction well electricity costs for pumping were based on a rate of 450 gpm, the nominal freshwater injection rate.
- Groundwater and surface water and remedy performance monitoring costs are included here. Detailed descriptions of the cost basis are included in Attachment D of Appendix H.
- Access road maintenance was updated to reflect the change in length from 3,000 to 800 linear feet.
- The cost for water rights was adjusted based on the assumption that all 7.6 million gallons of remedy produced water are used consumptively.

- Project management is included at ½ full time equivalent with 12 annual trips to Topock.
- A freshwater pre-injection treatment system will be built and operated to remove arsenic to concentrations less than 10 µg/L and fluoride to concentrations less than 2 mg/L to comply with California drinking water standards. The basis of design assumes that regenerable activated alumina will be used to accomplish the treatment goals. If fluoride removal is not required, this treatment process may use granular ferric hydroxide adsorption to remove arsenic only (based on preliminary data provided CH2MHIll).

Table 1 shows the estimated O&M costs and identifies any scope changes from the 30% cost estimate (under the Comments column). This estimate will be updated in future design submittals. The annual O&M cost is $6.78 million and the annual long-term maintenance (LTM) cost is $0.88 million (including a 15 percent contingency). No escalation or allowance for regulatory or technology changes are included.

References

CH2M Hill, 2009. *Final Groundwater Corrective Measure Study/Feasibility Study Report for SWMU 1/AOC 1 and AOC 10, Pacific Gas and Electric Company, Topock Compressor Station, Needles, California*. Prepared for PG&E. December.

CH2M Hill, 2011. *Draft Basis of Design Report / Preliminary (30%) Design Submittal for the Final Groundwater Remedy, Pacific Gas and Electric Company, Topock Compressor Station, Needles, California*. Prepared for PG&E. November.

ATTACHMENT C - TABLE 1
ANNUAL OPERATION AND MAINTENANCE COST ESTIMATE
INTERMEDIATE (60%) DESIGN
PG&E TOPOCK COMPRESSOR STATION, NEEDLES, CALIFORNIA

			CMS/FS Estimate Values			Preliminary (30%) Design Cost			Intermediate 60%) Updated Cost		
Description	**Units**	**Unit Cost**	**O&M**	**Long Term Monitoring**	**CMS/FS Source Notes**	**O&M**	**Long Term Monitoring**	**Comments**	**Annual O&M**	**Annual Long Term Monitoring**	**Comments**
		Duration	**29 years**	**10 years**		**29 years**	**10 years**		**30 years**	**10 years**	
Ex-Situ Treatment Plant O&M	Yr					$340,420	$0	Remedy Produced Water	$490,000	$0	Remedy WWTP. Updated labor rates - Electricity not included. - Assume local employees. - Coagulants not included. - Assume 2 FTEs for O&M.
Freshwater well maintenance & pumping	100 gpm	$ 11,108	$55,542	$0	500 gpm of freshwater. Cost is for electricity for pumping, and maintaining the well.	$66,650	$0	600 gpm	$49,988	$0	450 gpm of freshwater. Cost is for electricity for pumping, and maintaining the well (no well rehabilitation).
IRZ	YR	See note	$1,031,500	$0	Labor, materials, maintenance, well cleaning, reagents, reporting. Cost based on site experience in California and adjusted for flow and carbon demand. See Table D-14.	$977,500	$0	Updated estimate	$809,200	$0	Updated estimate - see Attachment 2
Remedy Well Replacement	10%	Capital cost of wells	$106,596	$0	Replacement based on 10% of capital cost of wells.	$546,390	$0	Based on replacing 32 IRZ wells	$398,000	$0	Based on replacing 28 IRZ wells and 8 injection/12 extraction at a cost of 2% of well installation and development cost. No allowance for monitoring wells.
Maintenance of Wells	See note		$1,023,251	$393,341	Assume maintenance as percent of capital cost of wells. 10% for extraction and monitoring wells; 20% for injections wells.	$1,168,791	$393,341	28 MWs, 9 injection/13 extraction wells plus 110 existing MWs	$1,406,635	$0	28 IRZ wells, 8 injection rehabilitated every other year and 12 extraction wells rehabilitated every 4 years. Aquagard costs are not included. Does not include costs for treating backwash water, redeveloping/ rehabbing wells or replacing wells.
Groundwater/Surface Water Monitoring	YR	See note	$158,276	$67,500	$135,000/event for S&A, data management. 6 events in first yr. of a Phase, then 1 event/yr. Based on cost for recent similar activities at Topock. Every 2 years during Alt B or LTM.	$158,276	$67,500	Assume no change	$840,684	$413,032	Combined monitoring program with reporting
Reporting - Site-wide groundwater monitoring	YR	See note	$121,241	$60,000	$156,000 for first sampling event in a Phase, then $120,000/year. Assume once per 2 years during LTM. Based on cost for recent similar activities at Topock.	$121,241	$60,000	Assume no change	$0	$60,000	See above
Reporting - Performance	YR	See note	$50,000	$25,000	Allowance of $50,000/report in years remedy operating. Assume once per 2 years during LTM.	$50,000	$25,000	Assume no change	$0	$25,000	See above
Other facilities - road maintenance	3x1,000 LF	$700	$2,126	$0		$560	$0	800 LF	$4,000	$0	Assume $5/LF of road maintenance, including aggregate.
Other O&M Costs											
Project Management	0	-	$0	$0		$0	$0	$0	$115,000	$115,000	Assume 1/2 FTE with 12 annual trips to Topock
Permit Compliance	YR	See note	$360,000	$72,000	$360,000/year based on IM3 compliance costs. 20% assented during LTM.	$360,000	$72,000	Assume no change	$360,000	$72,000	Assume no change
Groundwater ICs	YR	$20,000	$20,000	$20,000	Allowance	$20,000	$20,000	Assume no change	$20,000	$20,000	Assume no change
Biological Surveys	YR	See note	$100,000	$20,000	$100,000/year from recent site costs for monitoring per PBA document. Spring DETO and SWFL surveys. 20% assumed during LTM.	$100,000	$20,000	Assume no change	$100,000	$20,000	Assume no change
Cultural Surveys	YR	See note	$50,000	$10,000	Annual allowance. 20% assumed during LTM.	$50,000	$10,000	Assume no change	$16,667	$10,000	Annual allowance for years 1-5 is $50,000/yr. 20% assumed for years 6 through 30.
Reg/stakeholder oversight	YR	See note	$100,000	$20,000	Annual allowance. 20% assumed during LTM.	$100,000	$20,000	Assume no change	$100,000	$20,000	Assume no change
Water Rights	$/ac-ft.	27	$8,694	$0	Based on current invoices from the City of Needles.	$605	$0	Assume 7.3 MG/year are used	$630	$0	Assume 7.6 MG/year are used
5-year reviews	YR	$15,000	$15,000	$15,000	$75,000/review based on cost at other sites; done once per 5 years.	$15,000	$15,000	Assume no change	$15,000	$15,000	$75,000/review based on cost at other sites; done once per 5 years.
Power Supply O&M									$10,000	$0	Per AECOM, assume $10,000/yr
Arsenic and Fluoride Treatment Plant	YR								$1,160,000	$0	Facility O&M and assumes minimal waste need to be transported off-site.
SUBTOTAL			$3,202,226	$702,841		$4,075,433	$702,841		$5,895,804	$770,032	
Contingency		25%	$800,557	$175,710		$1,018,858	$175,710		$884,371	$115,505	15% contingency
TOTAL			$4,002,783	$878,551		$5,094,291	$878,551		$6,780,174	$885,537	

Assumptions:
CMS/FS Estimate Values taken from Table D-6 CMS/FS (CH2M Hill, 2009).
All remedy produced water is reused or disposed of on-site.
No additional mitigation measures are included in these estimates.
30 years of active remediation followed by 10 years of post-remediation long term monitoring.

Attachment 1 – Table D-6, Final CMS/FS

TABLE D-6

Alternative E

Remedial Alternative Cost Summary - In-Situ Treatment with Freshwater Flushing

Site: Topock
Date: 12/13/2009

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Wells					
Injection & Extraction Wells	1	See Note	$5,701,860	$5,700,000	See Table D-12. Does not include freshwater extraction wells.
Monitoring	28	WELL	$60,800	$1,700,000	28 new wells assumed
SUBTOTAL				$7,400,000	
In Situ Systems					
IRZ	1	LS	$4,034,500	$4,030,000	See Table D-13c
SUBTOTAL				$4,030,000	
Ex Situ Treatment					
Treatment plant	0			$0	
SUBTOTAL				$0	
Infrastructure					
Pipelines & Conduit / Wire & Trench	1	See Note	$8,860,766	$8,860,000	See Table D-16
Access Roads	3	1,000 LF	$16,200	$50,000	
Fresh water					
Wells	1	LS	$158,700	$160,000	Assumed one 10" diameter well (shown on Table D-12)
Pipeline	1.6	1,000 LF	$100,000	$160,000	1,600 feet of 10" steel pipe running across existing pipe bridge and supports.
SUBTOTAL				$9,230,000	
Remove IM3 Treatment Plant					
IM3 treatment - restoration and deconstruction	1	LS	$1,600,000	$1,600,000	See Table D-17
SUBTOTAL				$1,600,000	
SUBTOTAL				$22,300,000	
Prime Contractor Cost Factors[1]					
General Conditions (sub mob, sub GC)	10%			$2,230,000	
Field Construction Management and Engineer SDC	10%			$2,450,000	
Pre-construction (work plans, design, as-builts)	14%			$3,780,000	USEPA costing guidance EPA-540-R-00-002
Project Management	5%			$1,540,000	
Contractor Markup (G&A, fee)	21%			$6,780,000	
SUBTOTAL			75%	$16,800,000	
Miscellaneous					
Institutional Controls and other Administrative Approvals	1	CONSTR PHASES	$1,000,000	$1,000,000	Allowance
Biological Monitoring	1	CONSTR YRS	$330,000	$330,000	Allowance
Cultural Monitoring	1	CONSTR YRS	$330,000	$330,000	Allowance
Regulatory Oversight	1	CONSTR YRS	$300,000	$300,000	Allowance
Soil Cuttings	1	CONSTR PHASES	$200,000	$200,000	Allowance - see also Section D.2.1.7 for description of this line item.
SUBTOTAL				$41,300,000	
Contingency	25%			$10,300,000	
TOTAL CAPITAL COST				**$51,600,000**	

Low Range	High Range
$36,100,000	**$77,400,000**

Attachment 2 – Remedy Produced Water Conditioning System O&M Cost Estimate

Topock Groundwater Remediation Project
Pacific Gas and Electric Company

Produced Water Conditioning System O&M Cost Estimate

Labor

Description	*No.*	*$/hr*	*hr/year*		*$/year*	
PM	1	100	2080	$	208,000	
Technician	1	85	2080	$	176,800	
			Subtotal	$	384,800	

Chemicals

	lbs/year	*$/lb*		*$/year*	
Caustic	13840	0.49	$	6,782	
Acid	1000	0.49	$	490	Allowance
		Subtotal	$	7,272	

Maintenance

Replacement Filters	*No.*	*$/unit*	*$/month*		*$/year*
Housing 1	29	217.04		$	6,236
Housing 2	62	217.04		$	13,512
O-Rings	20	190		$	3,800
Vehicle Rental	1		1000	$	12,000
Other Maintenance	Assume 3% Total Equipment Cost			$	6,000
			Subtotal	$	41,548

Solids Disposal

	No.	*$/day*	*$/ton*		*$/year*
Phase Separator Bin Rental	2	45		$	32,850
Solids Disposal	2		$ 1,057	$	2,114
			Subtotal	$	34,964

Electrical- Assume costs will be incurred directly by PG&E, not included in estimate

Markup on Subs & Materials	5%	$	4,789	
	Sub-Total	**$**	**485,373**	$ 490,000
15%	**Contingency**	$	72,806	
	Total	$	558,179	$ 560,000

Assumptions

One PM and one technician needed for operations of plant.
Operations only during business hours, M-F, 8 hrs/day (1 shift per day).
Based on model effort, 1850 L of 25% caustic needed to neutralize 1 million gallons of wastewater.
Annual number of replacement filters based on influent TSS.
One vehicle (truck) required for operations, monthly rental option is quoted based on current IM3 pricing.
Assume other annual maintenance and analytical is approximately 3% of total equipment cost.
Assume costs for electrical will be incurred directly by PG&E and are not included within this estimate.
Two bins rented per year for phase separator.
Two tons of solids generated per year based on influent TSS and precipitation from caustic addition.
Assume $0.49/lb for caustic and acid based on current pricing for IM3.
Assume costs for solids disposal based on current pricing for IM3.

Attachment 3 - Estimate of Probable Cost - IRZ Yearly O&M

PG&E Topock Compressor Station
Estimate of Probable Cost - Annual O&M
NTH IRZ, IRL, and Transwestern Injection and Extraction Systems
Needles, CA
Revision 5
Revision Date: September 14, 2012

Annual O&M Costs - Active IRZ Operations	QTY	Unit	Unit Cost	Extension	Notes
Labor - IRZ	34	WK	$ 11,000	$374,000	Operations and office support for operations. No PM, data evaluation, or reporting. Assumes 4 weeks pre- and post-IRZ operations for cleaning, major maintenance.
Labor - IRL, Transwestern, Freshwater Treatment Components	0	WK	$ 8,000	$0	Assumes operator costs included with Remedy Produced Water Conditioning Plant O&M costs.
Carbon	38,304	Gallons	$ 7	$268,128	Based on 672 gpm maximum flow @ 100 mg/L TOC for 26 weeks of operation.
Miscellaneous Materials/Equipment and Subs	52	WK	$ 7,200	$374,400	Spare parts, maintenance, well redevelopment, pipe cleaning.
		Annual O&M Subtotal (O&M):		***$1,016,500***	

Annual O&M Costs - Inactive IRZ Operations	QTY	Unit	Unit Cost	Extension	Notes
Labor - IRZ	0	WK	$ 11,000	$0	Operations and office support for operations. No PM, data evaluation, or reporting.
Labor - IRL, Transwestern, Freshwater Treatment Components	0	WK	$ 8,000	$0	Assumes operator costs included with Remedy Produced Water Conditioning Plant O&M costs.
Carbon	-	Gallons	$ 7	$0	
Miscellaneous Materials/Equipment and Subs	52	WK	$ 7,200	$374,400	Spare parts, maintenance, well redevelopment, pipe cleaning.
		Annual O&M Subtotal (O&M):		***$374,400***	

Attachment D – Monitoring Program Cost Estimate Update

Final Groundwater Remedy – Intermediate Design - Remedy Monitoring

PREPARED FOR: Pacific Gas & Electric Company

PREPARED BY: Jay Piper

DATE: August 12, 2012

PROJECT NUMBER: 435062.01.06.01

This memorandum presents the updated remedy monitoring cost estimate for the Pacific Gas & Electric Company, Topock Compressor Station (TCS), Final Groundwater Remedy Project. The site is located in San Bernardino County, California near Needles. This memorandum is a companion document to the project cost estimate which is appended to the Intermediate (60%) Basis of Design Report issued for the project. For a more detailed description of the project, see the report.

Specific assumptions related to the groundwater and surface water monitoring cost estimate are explained below.

Final Remedy Groundwater and Surface Water Monitoring

Groundwater remedy monitoring costs are based on the Table 4.3.1 "Process Control Monitoring Program"[1] provided by ARCADIS. Final remedy monitoring will make use of 159 existing monitoring wells, up to 72 proposed new monitoring wells, and surface water monitoring locations.

The primary objectives of the remedy monitoring program are:

1. Compliance monitoring at monitoring wells inside and outside of the chromium plume and at 17 surface water sampling locations, and
2. Performance monitoring of the final remedy elements: the National Trails Highway (NTH) in-situ reduction zone (IRZ); the inner recirculation loop; the TCS IRZ recirculation loop; and freshwater injection. This data would also be used with process control of the remedy elements.

Cost Estimating Approach

The Draft "Process Control Monitoring Program" table assigned sampling frequencies for each of the listed analytes to the existing and proposed monitoring wells. In the first year of the remedy monthly sampling was specified for many locations, becoming quarterly or semi-annual frequency in the second and continuing years of remedy operation. Several specific additions were made to the table for cost estimating purposes:

- The frequency for wells identified in the table with "as-needed" sampling was assumed to be one sample per well in the first year, and 0.5 samples per well in the second and later years.
- For 19 new monitoring wells A thru S it was assumed that all each well has 3 screens per well, sampled at the same frequency
- For 11 proposed remedy extraction well locations not shown on the table, quarterly sampling was assumed for all analytes, for 44 annual samples from this set of wells.
- A quarterly frequency was assumed for surface water sampling at 16 locations, for Cr(VI), Cr, TOC, As, Mn . These locations had no assigned analytes or frequency in the table.

[1] Table 4.3.1, "DRAFT Process Control Monitoring Program" Operations and Maintenance Manual. Intermediate (60%) Design Submittal for the Final Groundwater Remedy, PG&E Topock Compressor Station, Needles, California

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- No sampling frequency is included for the 8 Arizona monitoring wells
- No markup or contingency costs are included.
- Primary reference is the Draft Process Control Monitoring Program table; since this draft program is subject to change, the final sampling frequencies and analytical will determine actual cost.

Sampling Frequency and Analytical Costs

The annual number of samples collected was totaled for each analyte from the Draft table with those added assumptions. The annual number of samples for each analyte is shown in the table below. The annual quantity of Cr(VI) samples was used for estimating purposes for the field and office level of effort discussed below.

The current negotiated discount laboratory unit costs were used for each analyte, which include electronic data delivery at no added cost. These unit costs are also summarized below, without markup.

Analyte	Unit Cost	Quantity (Year 1)	Quantity (Year 2)
Cr(VI)	$110	965	755
Cr	$30	489	479
TOC	$35	801	569
As	$30	879	647
Mn	$10*	813	581
Se	$30	31	31
Fe	$10*	749	517
Ba	$30	749	517
NO3	$30	387	308
SO4	$30	534**	244**
TDS	$15	185**	115**
Alkalinity	$20	185**	115**
Cations/Anions	$130	185**	115**
Laboratory Courier trips	$600	30	20

Note
* cost when analyzed with As
** indicates “as-needed” sampling frequency assumption
Courier cost is based on TLI.

Sample Collection Costs

The field effort for sample collection was based on these assumptions:

- A 3-person sampling team will consist of 2 on-site technicians plus oversight/sample manager.
- Field sampling costs are based on 4.5 hours per well per Cr(VI) sample for the on-site technicians, including loading, purge water management and equipment decontamination, calibration and maintenance; and 1.5 hours per well for on-site oversight/sample manager. A portion of the groundwater sampling will require an off-site alternate for the oversight/sample management role, and 0.5 hour per

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well is included for this, with $25 travel expense per well. Finally, consumables and sampling equipment upkeep are estimated at $75 per well per sampling event.

- Monitoring well sampling purge water will be disposed of on-site via the final remedy carbon amendment system.
- Boat charter costs of up to $1,400 total per event for all surface water sampling locations are included, offset by 2-person (not 3-person as in per-well assumption) team used for surface water sampling.
- $100,000 per year is included for on-site UTV and truck lease and maintenance
- Pricing assumes 3-volume purge at each well sampling event. LOE per well may be reduced with agency approval of alternative groundwater sampling approaches for some types of data collection.

Costs are shown for the first year of remedy operation and for subsequent years, assuming that the 2nd year sampling frequency continues for longer term remedy monitoring.

Data Validation, Management and Reporting Costs

This portion of the cost estimate includes primarily office-based efforts. The following assumptions are the basis for estimating this effort:

- Laboratory data will be validated by chemistry staff.
- A chemistry database (including field measured parameters) will be maintained.
- Compliance and process monitoring results and review against compliance metrics will undergo senior review.
- Quarterly reports will be prepared in a format based on and streamlined from the present Performance Monitoring Report/Groundwater Monitoring Program (PMR/GMP) report, and Compliance Monitoring Program report. The reports will present tables, maps and cross sections, and trend plots from water chemistry and water level monitoring data.
- Groundwater, surface water, water level and operation status will be delivered as simplified quarterly reports. More detailed annual reports will be prepared, with data interpretation and recommendations presented in the annual reports.
- Simple monthly 'data dump' reports with limited interpretation and recommendations of monthly data focused on process adjustments are also assumed for the first year of operation, delivered between the quarterly reports.
- A simplified reporting structure is assumed with a single unified remedy reporting deliverable, similar to the previous consolidation of formerly separate GMP, RMP and PMP reporting programs. Remedy operational reporting is also assumed to consolidate with all remedy compliance reporting.
- The Cr(VI) sampling frequency was used to estimate these costs based on the following level of effort per well per sampling event: 0.1 hours from senior reviewer; 1 hour from project chemist and data manager, and 1 hour from staff scientist/GIS/Technical editor.
- Limited postage and report materials are included as shown in the cost estimate table.

Project Management Costs

This portion of the cost estimate includes primarily office-based efforts. The following assumptions are the basis for estimating this effort:

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- 32 hours of senior staff and 36 hours of junior and administrative staff will be the level of effort for event planning and coordination, contract and subcontract administration, and invoicing and planning with PG&E.
- This task will be used for cost saving or innovation presentations or proposals with PG&E
- Input for the Green Remediation Evaluation Matrix will be tracked under this task

Groundwater Elevation Data Collection

The cost for groundwater elevation data collection and management are estimated separately from groundwater and surface water sampling. These costs assume that water level elevations will be monitored to verify hydraulic gradient and groundwater flow during the final remedy operations. Key assumptions are listed below.

- 80 wells (or approximately 40-50% of total remedy monitoring wells) will be instrumented with in-well pressure transducers or multi-parameter sensor 'sondes' (80 wells is an increase from present 2012 network of approximately 70 wells with transducers currently used for PMP, CMP, and short-term hydraulic testing data collection).
- Multi-parameter probes will be used in place of water level transducers if practical, for in-well measurement of dissolved oxygen (DO), oxidation/reduction potential (ORP), and specific conductivity (SC), in addition to pressure and temperature measurements. It is possible that single ion electrodes can be added to monitor directly for additional parameters.
- 20 multi-parameter probes and 60 pressure transducers are assumed as the instrumentation for the 100 wells in this program.
- Second year and ongoing year equipment costs will be 50% of first year costs, for replacement and repair after first year purchase costs.
- Water level transducer data will be transmitted to remedy operation control either hardwired in utility trenches or via telemetry nodes; manual downloads and well access would only be performed for maintenance reasons, bi-monthly manual water level calibration, and quarterly salinity profiling.
- At least 10 transducers or multi-parameter probes will be connected to one telemetry sending unit.
- For each well there will be 6 visits per year for manual water levels and /or salinity profiling, 2 visits for maintenance, and in the office, monthly data management and minimum bimonthly calibration and database maintenance with senior review and QC, totaling 18 hours of annual field effort and 10 hours of office effort per well.

Summary of Cost Estimate

The summary of all costs for data collection, data validation, data management and reporting is shown on Table 1 below. No markups are included.

TABLE 1
Summary of Monitoring Program Costs

Item	Cost
Year 1 Analytical Cost	$292,380
Year 1 Sampling Cost	$563,803
Year 1 Reporting Cost	$274,696
Year 1 Project Management	$71,520

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TABLE 1
Summary of Monitoring Program Costs

Item	Cost
Year 1 Telemetry/Transducer Cost	$419,600
YEAR 1 TOTAL	$1,621,999
Year 2 Analytical Cost	$213,513
Year 2 Sampling Cost	$462,632
Year 2 Reporting Cost	$218,440
Year 2 Project Management	$64,368
Year 2 Telemetry/Transducer Cost	$303,600
YEAR 2 TOTAL	$1,262,552
Year 3-5 Analytical Cost	$161,866
Year 3-5 Sampling Cost	$389,265
Year 3-5 Reporting Cost	$128,135
Year 3-5 Project Management Cost	$57,216
Year 3-5 Telemetry/Transducer Cost	$303,600
YEAR 3-5 TOTAL	$1,040,082
Year 6-20 Analytical Cost	$170,315
Year 6-20 Sampling Cost	$330,742
Year 6-20 Reporting Cost	$76,881
Year 6-20 Project Management Cost	$42,912
Year 6-20 Telemetry/Transducer Cost	$242,880
Year 6-20 TOTAL	$863,730
Year 21-30 Analytical Cost	$135,858
Year 21-30 Sampling Cost	$215,351
Year 21-30 Reporting Cost	$46,129
Year 21-30 Project Management Cost	$28,320
Year 21-30 Telemetry/Transducer Cost	$200,376
Year 21-30 TOTAL	$626,033
Year 31-40 Analytical Cost	$111,274
Year 31-40 Sampling Cost	$161,513
Year 31-40 Reporting Cost	$23,064
Year 31-40 Project Management Cost	$16,992
Year 31-40 Telemetry/Transducer Cost	$100,188
Year 31-40 TOTAL	$413,032

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TABLE 1
Summary of Monitoring Program Costs

Item	Cost

Opportunities for Cost Reduction

The following are all opportunities to reduce monitoring costs from the assumptions included with this estimate, and are recommended for pursuit before or during final remedy implementation:

- Reduce the number of telemetry units transmitting some wells' data via wires to a central "historian" if feasible, instead of wireless telemetry.
- Reduce the scope of general chemistry analyses performed at off-site laboratories by performing at on-site wet lab, or relying on multi-parameter sensor measurements from the transducer/telemetry system.
- For some or all wells and sample requirements, use alternative sampling approaches that reduce field level of effort compared to the standard 3-volume purge that is assumed. These could include HydraSleeve no-purge sampling, or minimal-drawdown, reduced purge volume techniques.
- Reduce overall sampling analytical scope and frequency in follow-on years.
- Reduce the transducer monitoring network extent
- Reduce follow-on year reporting frequency to semi-annual and then annual as the remedy progresses.

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Attachment E - Post-Remediation Cost Estimate Update

Final Groundwater Remedy - Decommissioning, Removal, and Restoration Basis of Cost Estimate

PREPARED FOR: Pacific Gas & Electric Company

PREPARED BY: Courtney Rhymer/CH2M HILL

DATE: August 11, 2012

PROJECT NUMBER: 435062.01.06.01

This memorandum presents the basis of cost estimate for Pacific Gas & Electric Company final groundwater remedy decommissioning, removal, and restoration which includes well decommissioning, pipeline, equipment, and controls removal, access road removal, and area wide restoration. Table 1 summaries the costs for each item included in this basis of cost estimate. This memorandum is a companion document to the Pacific Gas & Electric Company Topock Compressor Station Final Groundwater Remedy Project Cost Estimate to be submitted as a part of the intermediate (60%) design.

Project Management and Services During Construction

Project management will include project administration services, health and safety plan development for onsite staff, and quality management for oversight of services during construction (SDC) services. SDC will include requests for information (RFI) response, submittal review, site inspections by either a resident engineer or a project engineer, assistance with change order scope development, and attendance of project meetings. The cost breakdown for these services is presented in Table 2.

Well Deconstruction/Removal

All wells associated with the implementation of the final groundwater remedy, including the associated monitoring wells, will be decommissioned either at some point during remedy implementation or at the completion of the project. The estimated cost to decommission all wells is $12,700,000. The technical approach for decommissioning these wells is currently being developed by a subgroup that includes PG&E, DTSC, DOI, and Interested Tribes. Therefore, the assumptions used to develop this cost basis will need to be revised as the general approach and associated technical details are established. The costs used to develop this estimate are based on costs from previous phases of work at Topock, discussions with contractors, initial discussions with agencies and project stakeholders, and professional judgment. The estimated cost for well decommissioning is based on the following major assumptions:

- Wells to be decommissioned include all those existing prior to the construction of the final groundwater remedy (excluding the six injection/extraction wells associated with the IM-3 treatment plant) and primary injection/extraction wells (referred to as remediation wells) and monitoring wells identified in the 60% basis of design report. This includes:
    - Approximately 56 remediation wells.
    - Approximately 207 monitoring wells.
- The condition of all wells will be evaluated using an in-well video survey prior to decommissioning.
- All remediation wells will be decommissioned in place, which involves the filling of the well casing and filter pack with sealing material and removal of the upper 5 feet of the well.
- Among the total number of monitoring wells, approximately half will be decommissioned in place and half will be decommissioned by removal. Well removal will involve the over-drilling and removal of the well casing and annular construction materials.

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- Wastes generated during well decommissioning activities will include liquids (e.g., groundwater and drilling fluids) and construction materials (e.g. well casing and annular materials). All liquids will be managed and disposed on site. All construction materials will be transported off-site for disposal at an appropriate facility.

Pipeline, Equipment, and Controls Removal

The cost estimate of $2,800,000 for the removal of Final Remedy pipeline, equipment and controls will remain the same as the estimate listed in the CMS/FS because the Final Remedy design is still in the intermediate design phase and also because the IM-3 Decommissioning, Removal and Restoration Work Plan is still under development. A revised cost estimate will be provided with the 90% design cost estimate because a revised cost estimate for the decommissioning and removal of the IM-3 Groundwater Extraction and Treatment System will be available and can be used as a basis for estimate for the Final Remedy removal.

Access Road Removal

Per the 60% Final Remedy Design, two access roads will be constructed to facilitate the construction and operation of the Final Remedy. One access road is a green field construction to give access to injection well, IRL-2, and the other road is a reconstruction of an old, significantly damaged road to give access to injection well, IRL-4. After the Final Remedy is shutdown, decommissioned, and removed, one or both of these roads will need to be removed and returned to pre-construction conditions based on consultation with the land owners and managers. The new access roads will be gravel roads. This cost estimate will be based on the access road design submitted with the Final Remedy 60% design.

The following major assumptions are included in this basis of cost estimate:

- Only the new access road to injection well, IRL-2, will be removed and returned to pre-construction conditions to the extent practicable.
- The reconstructed access road to injection well, IRL-4, will be left in place as it provides additional access to the existing natural gas pipelines in the area. If this road is damaged as a result well or pipeline removal work, then it will be returned to pre-mobilization conditions.
- Removal work will include removing base course aggregate and subbase materials and earthwork to reestablish existing grade in the area of the road construction.
- A grading, drainage, and erosion control plan will need to be developed to assure proper drainage and erosion control when the area is returned to pre-construction grade.

Area Wide Restoration

Area wide restoration is assumed to include the restoration of areas originally affected by Final Remedy construction and operations. Since the Final Remedy is currently in the 60% design phase, the basis of cost estimate for area wide restoration is based on the total acreage of the areas likely to be originally affected or disturbed by Final Remedy construction assuming it is constructed as exactly shown in the 60% design. If an area within the footprint of the Final Remedy is documented as previously significantly disturbed, then it is not included in the total acreage to be restored. The estimated total acreage of land to be restored in the floodplain is 4.0 acres and in the upland is 0.75 acres for a total of 4.75 acres to be restored. A restoration plan will be developed in consultation with the land owners and managers and will be implemented after the Final Remedy site has been completely decommissioned per direction of the regulatory agencies, and the land has been left in a safe condition.

The following major assumptions are included in this basis of cost estimate:

- Existing roads within the footprint of the Final Remedy will not be restored upon Final Remedy decommissioning and removal because these areas contain no vegetation. Therefore, any Final Remedy components or infrastructure within the boundaries of existing roads is not included in the total acreage

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estimate of 4.75 acres. If existing roads are damaged as a result of area wide restoration work, then they will be returned to pre-mobilization conditions.

- The basis of estimate submitted with the 30% design lists the following major assumption, "It is assumed that there will be no change in existing contours for work. Existing grades will be final grades." Based on this major assumption, no earthwork cost is included the estimate for restoration. (Minor earthwork will be required as a part of the pipeline, equipment, and controls removal to backfill holes or trenches created during the removal of Final Remedy infrastructure and components to make the area safe prior to restoration. Following backfill, minor grading, contouring, and compacting may also be required).
- The identified 4.75 acres will be restored to conditions existing prior to the construction of the Final Remedy to the extent practicable by revegetating the site.
- Revegetating the site will likely include transplanting indigenous plants, planting native bare root stock or container seedlings, or reseeding with a generalized seed mix for the vegetation community within the specific restoration area. A minimum of 75% survivorship for indigenous plant species transplanted or planted within the restoration area will be required.
- The restoration area will be maintained and monitored for five years following planting by a qualified biologist or restoration specialist to assure minimum growth requirements are met.

Restoring 4.75 acres of land given the major assumptions listed above, the total cost for area wide restoration was calculated to be within the original allowance of $1,000,000 included in the 30% cost estimate, so the 60% cost estimate for area wide restoration will remain at $1,000,000. Restoration costs were based on a cost estimate prepared in 2006 by PG&E for the restoration of a half acre of floodplain. The cost estimate prepared in 2006 was based on similar assumptions as listed above. The area wide restoration will include restoring land primarily in the floodplain.

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TABLE 1

Post-Remediation Deconstruction Costs

Intermediate (60%) Design

PG&E Topock Compressor Station, Needles, California

Description	Qty	Unit	Unit Cost	Total	Notes
Well Decommissioning	263	WELL	$48,300	$12,700,000	
Pipeline, Equipment, and Controls Removal (Deconstruct Remedy WW treatment plant + IRZ Facilities)	1	LS	$2,800,000	$2,800,000	Use IM-3 deconstruction estimate for Remedy WWTP, and carbon amendment facilities at MW-20 and Transwestern Metering Station Benches.
Access Road Removal	1	LS	$40,000	$40,000	
Area Wide Restoration	1	LS	$1,000,000	$1,000,000	Same as CMS/FS
Subtotal				$16,540,000	
Contingency on Subtotal of Tasks	25%			$4,135,000	
Services During Construction for All Deconstruction/Removal and Restoration Tasks	1	LS	$110,000	$110,000	Based on 18 month project duration.
Total Post-Remediation Deconstruction Cost				$20,800,000	

Note – All costs are rounded to $100,000

TABLE 2

Project Management and Services During Construction Costs

Intermediate (60%) Design

PG&E Topock Compressor Station, Needles, California

	Senior Project Manager	Resident Engineer	Senior Project Engineer	Chemist	Biologist	CADD Technician	Project Controls/Office Clerical	TOTAL LABOR	TOTAL LABOR COST
1 Project Management									
- Project Administration	80						40	80	$ 16,000
- Health & Safety	6						2	8	$ 2,000
- Quality Management	8		4	4			4	20	$ 4,000
2 Services During Construction									
- RFIs/Clarifications		60	10	20	32		32	154	$ 18,000
- Submittal Review		80	20	40	60		40	240	$ 28,000
- Site Inspections		60	24	8	16			108	$ 14,000
- Change Orders		24						24	$ 3,000
- Construction Meetings		40						40	$ 5,000
3. Close Out Services		24	16	16		80	20	156	$ 20,000
TOTAL	54	288	74	88	108	80	138	830	$ 110,000

*Duration of SDC is 18 months.

Appendix I
Response to Comments on Draft Basis of Design Report/ Preliminary (30%) Design

APPENDIX I

Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design

Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design

PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
General Comments									
1	DOI-1	General Comment		The 30% design package meets the substantive requirements of the 2009 Model Consent Decree as shown in Table 8-1. It represents a considerable level of effort.	Comment noted.				
2	DOI-2	General Comment		The Basis of Design (BOD) references the CERCLA Model Remedial Design/Remedial Action (RD/RA) Consent Decree throughout. PG&E and DOI have negotiated a Consent Decree and the document is going through the final approval process. It is DOI's expectation that future design documents reference the final Consent Decree rather than the model.	Comment noted. The final Consent Decree will be referenced when it is available.			Comment resolved.	The Consent Decree executed in 2012 and lodged with the court in January 2013 was referenced throughout this BOD Report.
3	DOI-3	General Comment		The text should identify specific wells by number in the discussions of well extraction and injection. It appears there are inconsistencies in understanding which wells are used for each particular purpose. For example, discussions in the modeling appendix indicate that wells UPGRAD-INJ-3 and -4 will be used for fresh water injection and wells UPGRAD-1 and -2 will be used for injection of carbon-amended water from the riverbank wells. This is not consistent with DOI's understanding, which is that all UPGRAD-INJ wells will be used for carbon-amended water injection. However, it was not possible to verify which wells were being used for what purpose because the discussion in the design basis sections (Section 3 of the main report) does not identify the wells by number, nor do the design drawings resolve this question.	The design and model presented in the 30% design uses UPGRAD-INJ-3 and -4 for fresh water injection and UPGRAD-INJ-1 and -2 for un-amended Riverbank well water. However, Riverbank well water will be amended with carbon if Cr(VI) exceeds 32ug/L, prior to injection into UPGRAD-INJ-1 and -2. In the 60% design the well references will be clarified and be more specific than in the 30% to minimize confusion. It should be noted that alternative injection scenarios involving these injection wells will be considered as part of the 60% design and flexibility has already been designed into the system to accommodate alternative flow scenarios. Additional detail will be included in the 60% design.		Okay pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Section 3.2 and Appendix B of the BOD Report.
4	DOI-4	General Comment		There appear to be some inconsistencies in pipeline cross references between related P&ID drawings. It is recommended that all cross references be verified for the 60% design submittal.	Comment noted. All cross references will be verified for the 60% design submittal.		Okay pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Appendix D of this BOD Report.
5	DOI-5	General Comment		The BOD does not address green and sustainable remediation practices. It is the expectation of DOI that PG&E evaluate the current design and employ strategies for the Topock Remediation Project that uses natural resources and energy efficiently, including the use of renewable energy sources where practical, reduces negative impacts on the environment, minimizes or eliminates pollution at its source, protects and benefits the community at large, and reduces waste to the greatest extent possible. The BOD should include a specific section that references these practices.	The 30% BOD addressed green and sustainable remediation practices in many ways. As requested, the 60% design document will include a separate section to enumerate and discuss application of green and sustainable remediation practices. Examples where the 30% BOD addressed these issues include: **Energy Use** – a) design criteria included energy efficient architectural elements (see Appendix C.7), energy efficient equipment and lighting (see Appendix C.5.2), b) EPANET water supply program was used to design the piping network and minimize energy consumption. **Materials/Recycling/Reuse** – the concepts of reuse, shared use, and recycling of existing facilities and infrastructure were incorporated into the design (e.g., shared		Okay pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Section 4 – Application of Green Remediation Practices of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
					use of existing storage tanks, repurposing of existing buildings); the concept of using native materials sourced from the site was included in Section 3.5.4 (this will be further detailed in the 60% design as the strategy for handling of displaced materials is further developed by agencies, Tribes, and PG&E); the design criteria included the International Green Building Code (see Appendix C.7). **Protection of Sensitive Resources** – Surveys and mapping are underway to document baseline conditions (e.g., mature plants, vegetation conditions, wetlands delineation, protocol surveys for sensitive bird species); and results have been and will continue to be used to guide the design to protect, avoid, and minimize potential impact to resources. Furthermore, plans such as the bird avoidance and minimization plan are being prepared that will include best management practices for remedy activities. **Waste Minimization** – operational experience with well backwash/ rehabilitation at Topock and the ongoing pilot test of backwash frequency at Hinkley have been and will continue to be incorporated into the design of the remedy produced water management system to minimize waste (see Appendix F). **Water Management** – most water needs for the remedy will be taken from and returned to the target IRZ barrier thereby maintaining the aquifer's net water balance; optimizing recirculation flowrates and careful carbon dosing will minimize generation and migration of by-products, while maintaining the required carbon distribution. **Airborne NOx and SOx, Greenhouse gas emissions, and Airborne particulates** - Careful dosing of carbon will reduce carbon substrate needs and thereby reduce air emissions associated with transportation of materials to the site. In addition, the timeframe for site remediation is reduced through the use of freshwater flushing, which induces a hydraulic gradient that is essential to creating more efficient and effective treatment. Any reduction in treatment time results in reductions to water use, materials use, waste generation, energy use, air emissions generated, health and safety hazards, and adverse effects on biological resources, stakeholders, and local economy.				

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
					Furthermore, Table 8-3 lists a host of forthcoming plans and documents including the Access Plan and the Security Plan, as well as signage and information kiosk that are designed to protect public health and safety and to reduce potential damage to environmental resources.				
6	DTSC-GC4	General Comment: Green / Sustainable Remediation		Green Sustainability Factors need to be identified in the beginning stages of the design and factored in to the goals and objectives for minimizing impacts to the environment.	Comment noted. As discussed in response to comment #5 DOI-5, the 60% design submittal will include a separate section on application of green and sustainable remediation practices. PG&E's approach to green and sustainable remediation is aligned with the DTSC Interim Advisory for Green Remediation, and include the following steps: 1. Identify the green sustainability factors (e.g., energy use, materials, greenhouse gas emissions, etc.); 2. Identify sustainability best management practices (BMPs) to address each factor (e.g., reducing the number of site mobilizations, utilizing low-emitting technologies, etc.); 3. Evaluate the sustainability impacts and to assess the benefits of the implemented BMPs.	Okay pending review of 60% submittal		Comment resolved.	See Section 4 – Application of Green Remediation Practices of this BOD Report.
7	DOI-6	General Comment		Treatment and disposal of remedy-produced water is seemingly very complex and labor intensive to implement. This is a result of multiple types of remedy produced water (various sources of backwash water, rehab water [first and second flush], and other sources); options for both trucking and pipeline conveyance of wastewater; each type of wastewater requiring different degrees of treatment; and each potentially having a different final disposition. Although the O&M Plan is expected to flesh out the operational procedures in great detail, the 30% design package should offer further discussion on how wastewater conveyance, treatment, and disposal will be accomplished in practice.	The management plan and proposed facilities for remedy-produced water have been designed with flexibility to support, and not constrain the remedy over the anticipated multiple decades of operation. Figures 1 and 2 are simplified schematics to illustrate the management of the various streams of produced water as proposed in the preliminary (30%) design. Additional details will be included in the draft O&M plan.		Okay pending review of future documents.	Comment resolved.	See Section 3.4 and Appendix F of this BOD Report. Also see the draft O&M Manual (Volume 1 – O&M Plan and Volume 3 – Contingency Plan).
8	DOI-7	General Comment		Selection of the initial carbon source (ethanol or lactate) is still not finalized. As the upland and floodplain ISPTs have been completed, and Hinkley treatment system has been in operation for many years, it is not clear what data or analysis is pending to permit selection of the carbon source.	Based on the past success and level of experience with ethanol, it is currently planned for use in the final remedy, as will be stated in the 60% design. Substrate selection may change over the lifetime of the project as substrate costing varies. In addition, other substrates, such as longer lasting substrates, could be useful for certain situations that arise over the life of the project, and as such documents written to date have preserved the option of using additional substrates.		Okay pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Section 3.2.1.2 (Design Basis) under the heading Organic Carbon Substrate Selection.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
9	DOI-8	General Comment		Suggest adding a figure that includes the approximate chromium (VI) plume boundary, groundwater flow direction, and the remedy design components for reference.	PG&E proposes to add the approx. Cr(VI) plume boundary and groundwater flow direction to Figure 3-1 in the forthcoming BOD Report for intermediate (60%) design submittal.		Okay pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Figure 2.1-1 of this BOD Report.
10	DOI-9	General Comment		The recent findings of high flow rates and elevated contamination levels at Site H must be considered in the discussions of East Ravine bedrock flow and contamination conditions, as well as the remedy design. Although early investigation results for the East Ravine resulted in a preliminary conceptual model by PG&E that fracture flow in the bedrock was of limited rate and radius of influence, and provided the basis for the 30% design, recent findings at Site H raise questions about whether higher flow conditions and fracture interconnectivity may exist within the bedrock. Investigations of the hydrogeologic conditions in the East Ravine bedrock are ongoing, and substantial revision of the conceptual flow and contamination model of the East Ravine may prove to be warranted. The 30% design document must acknowledge the uncertainties in the conceptual model at this time and the possibility for substantial revision of the East Ravine bedrock remedy design at the 60% stage. PG&E should refrain from statements in the 30% design document regarding the bedrock generally having limited fracture interconnectivity, flow rates at wells, and radius of influence.	The 60% design submittal will include an update of the conceptual site model for the East Ravine that addresses conditions observed at Site H.	Okay pending review of 60% design submittal.	Okay pending review of 60% design submittal.	Comment resolved.	Results of the East Ravine groundwater investigation were summarized in a technical memorandum entitled *Addendum to the Summary of Findings Associated with the East Ravine Groundwater Investigation, Pacific Gas and Electronic Company, Topock Compressor Station, Needles, California*. The Addendum was submitted to agencies on November 12, 2012 and results were discussed at the January 17, 2013 TWG meeting in Henderson, NV. Comments were received from DTSC and DOI on February 15, 2013. The Addendum is currently being revised to incorporate comments.
11	DOI-10	General Comment		Given the holidays and time allotment for review of the 30% design package, a detailed evaluation of many of the design elements could not be done to the desired level. DOI has identified some errors and included those in our comments, however we believe there may be others. Due to the aforementioned, we anticipate that an extended review period may be needed at the 60% design to flesh out design details such as piping networks, valving and controls, hydraulic profiles, water mass balance calculations as well as others.	Comment noted. PG&E defers decision on extension of review period to DTSC and DOI.	DTSC agrees that additional review time would be necessary for the review of the 60% design document.			See Exhibit 1.0-1 of this BOD Report, which reflects an extended 60-day review period of CWG/TWG and Tribes and a 75-day review period for DTSC and DOI.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
12	DTSC-GC1	General: Report organization and structure		Current organization of the document is fragmented and makes it difficult to follow a cohesive discussion of design elements. ***Example** IRZ Component*: Section 3.2.1 discusses the component of the IRZ, but one must flip to Fig 1-2 to see the proposed layout, then Section 4.4.1 of Appendix B to review the discussion on modeling and resulting well spacing, but the reported differences between the two scenarios were not discussed in that section and was not mentioned until the Section 6 under sensitivity analysis which then points to the corresponding figures in B-39 and B-40. Add to that, the model Figures 27 – 30 did not provide a legend or any notable area of focus, leaving the reviewer to interpret the modeling results. DTSC suggests that the report be reorganized so that each component of the remedy is evaluated from beginning to end with corresponding tables and figures before moving into another component. The report can be tied together with an executive summary, introduction and conclusion.	Comment noted. Each section will be reviewed to ensure report text, figures, tables, conclusions, and supporting materials are tied together well. Figures and tables will be included at the end of each section (instead of at the end of text)	Okay pending review of 60% review		Comment resolved.	See new Executive Summary, as well as locations of figures and tables after each section of this BOD Report.
13	DTSC-GC2	General: Report organization and structure		Design basis/criteria can also be presented in a table format for ease of reference to the rationale to assist review. *For example*: The IRZ injection well backwash pump for IRZ-11 is designed for 40 gpm (shown on design drawings) which is based on 2 times (discussed in Section 3, with no rationale) the maximum injection flow rate of 20 gpm (shown in Table 3-1). This maximum flow rate is found within Appendix B modeling discussion. An example table is already in the document (Page 3-31, Exhibit 3-9 Remedy-Produced Water Conditioning System Design Criteria). It would much easier to review if a similar table is provided for each remedial component.	Comment noted. Design basis/ criteria will be presented in table format (similar to Exhibit 3-9) for ease of reference.	Okay pending review of table		Comment resolved.	See BOD Section 3.2.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
14	DTSC-GC3	General Comment Design Dependencies		Design dependencies are not clear. Do not begin sections by referring readers to other sections. Make a summary, synopsis or substantive argument for the category. Move references at the end of the section as they relate to supporting arguments or summaries. PG&E should develop a risk probability and impact assessment. A probability and impact matrix will provide an understanding of the probability of risks and costs or rewards in taking certain risks. Focus on opportunities and risks and identifies those risks and places values to the risks and response planning, monitoring and control to those risks. PG&E has the opportunity to discuss strategies for negative risks – avoid, transfer or mitigate certain risks, and to discuss strategies for positive risks in order to enhance, expand and ultimately share with stakeholders those inherent risks to get a shared understanding of priorities and responses for contingencies. Such a matrix will allow stakeholders to understand operational constraints and weigh them with other values, costs or risks that may not be associated with PG&E.	See response to comment #12 DTSC-GC1 (Report Organization/ Structure). PG&E intends to use a recognized and established tool (used in industry and government) called Failure Modes and Effects Analysis (FMEA), for preparation of the contingency plans. The FMEA tool provides an analytical and systematic approach to reviewing potential failure modes and their associated causes, and therefore, will help to assess which risks have the greatest concern and to prioritize risk management in order to prevent problems before they arise. Failure modes are any errors or defects in a process, design, or item and can be potential or actual. Effects analysis refers to studying the consequences of those failures.	Okay pending review of 60% design submittal.		Comment resolved.	See draft O&M Manual, Volume 3 – Contingency Plan.
15	DTSC-GC5	General Comment: Communications Management Plan		Identify methods and criteria to use to inform, resolve issues, approve change requests and corrective actions to unexpected occurrences. It should cover the regular periodic communication that needs to occur as well as when the project experiences unexpected changes. Define what the unexpected changes/risks that may occur and present a risk analysis describe the weekly or monthly status reports and list the chain of communication when a change occurs. Define who should be notified in the case of a significant change – determine factors for what is a significant change (Cr6, byproducts concentrations? other parameters?)	Comment noted. Communications framework, procedures, and protocols will be included in the Draft O&M Plan and the Draft Construction/Remedial Action Work Plan.	Okay pending review of future documents, DTSC, however, recommends that an outline of those reporting frameworks and procedures be provided as early as possible so that stakeholders can begin the evaluation process and develop consensus on framework where applicable.		Comment resolved.	See draft O&M Manual Main text, Section L.2 for communications framework, and O&M Volume 2 (Sampling and Monitoring Plan) for decision rules/ operational framework.
16	DTSC-GC6	General Comment: Scheduling		Identify general process steps, an activity list that includes sequencing of activities and estimated durations for construction and then for operations. Sequencing will describe how activities are interdependent or related. Critical path scheduling will demonstrate what drivers or dependencies are anticipated and assist in the development of contingencies for drivers that we cannot afford to fail. Discussing dependencies and whether they are mandatory or discretionary allows us to agree on importance of issues that may be incidental or critical to all stakeholders whether they are technical, cultural, budgetary or other elements.	Comment noted. An updated project schedule will be provided in the 60% design submittal.	Okay pending review of 60% submittal		Comment resolved.	See BOD Section 7 – Project Delivery Strategy/ Updated Schedule.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
17	DTSC-GC7	General Comment: Contingency Planning		For the 60% design, PG&E should develop in the contingency plan some criteria that may require contingencies to be executed. PG&E should also define measurable short term remedial goals with criteria for the contingencies. This may include contamination (define unacceptable levels Chrome VI or byproducts) increasing or not decreasing as anticipated for a certain period of time, or if the water resources are no longer available (river water vs. HNRW-1 water), etc.	Comment noted.	Okay		Comment resolved.	See draft O&M Manual, Volume 3 – Contingency Plan.
18	DTSC-GC8	General Comment: Progress Reports		PG&E should discuss a method or progress reporting and the parameters to determine progress. Cost, contaminant removal, GSR factors, time, and schedule using methods such as Schedule or Cost performance indices or forecasting techniques.	Comment noted. A discussion on progress reporting will be included in the Draft O&M Manual.	Okay pending review of O&M plan		Comment resolved.	See draft O&M Manual (Main text, Section L.2).
19	HA-GC1	General Comment		As you are aware, the draft 30% BOD is a voluminous compilation of information on the Topock groundwater remedy design basis, design criteria, drawings, and specifications. Additionally, the document reflects the limited information available for presentation at a preliminary (30%) level of design, with the understanding that additional detail, representing a 60% and 90% level of design, will be provided for Tribal review and comment over the next several months. Moreover, as discussed in the *Revised Corrective Measure Implementation/ Remedial Design (CMI/RD) Work Plan for Solid Waste Management Unit (SWMU) 1/ Area of Concern (AOC) 1 and AOC 10* (the "CMI/RD WP"), there are several more items needed to support the design and implementation of the groundwater remedy. Accordingly, the comments issued by the Tribe at this time in review of this 30% BOD necessarily are not to be considered as comprehensive or complete. Essential parts of the plan are missing, for example the monitoring plan and a contingency plan. Thus this review process requires that comments provided at each stage be reconsidered in the context of the newer information so every commenter is afforded an opportunity to reconsider the continuing applicability of earlier comments and/or the need to refine and/or add to those prior comments.	Comment noted. PG&E is committed to deliver the design documents and plans as presented in the CMI/RD Work Plan.	Comment noted.	Comment noted.	Noted.	See draft O&M Manual Volume 2 (Sampling and Monitoring Plan) and Volume 3 (Contingency Plan).

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
20	HA-GC2	General Comment		As has been emphasized many times in the past by the Tribe, this remedial project as well as the existing compressor facility and other man-made constructions are present on hallowed grounds and are of deep cultural value to the Tribe. Desecration of the purity and sanctity of these sacred grounds is significant and ongoing as a result of the continuing presence and operation of the compressor station in addition to the impacts associated with the remedial actions. In particular regard to the 30% BOD, the Tribe has concerns over the process leading to the transition from the Interim Measure No. 3 ("IM3") to the final remedy. Specifically, the IM3 water treatment plant (WTP), which is located within and operating within the footprint of the Topock Maze, and is a continuing adverse effect, must be decommissioned as expeditiously as practicable to minimize that adverse effect. The presence of this facility on the sacred Tribal grounds is spiritually harmful and distressing to members of FMIT and other tribes having cultural affinity to this area. Certainly, this situation is not unknown to PG&E, the California Department of Toxic Substances Control ("DTSC"), or the U.S. Department of the Interior ("DOI") ("the Agencies"), to whom this offense has been made known since the start of the IM3 operations. According to DTSC decision documents, the purpose of IM3 is to protect human health and the environment by preventing seepage of groundwater contaminated with hexavalent chromium ("Cr(VI)") into the Colorado River. However, as set forth in the 30% BOD and accompanying materials, upon implementation of the final groundwater remedy, the IM3 will necessarily be shut off and thus will be providing no further protection unless (1) some event were to occur that would result in shutting down the final remedy extraction wells, and (2) the IM3 WTP could handle the volume and chemistry of water then needed to be extracted. There is no discussion in the 30% BOD as to any foreseeable scenario under which the final remedy extraction wells would be shut down (to allow IM3 extraction wells to come back on line) or whether under such a scenario the water extracted by IM3 could even be treated by the IM3 WTP. Given that the hydraulic regime associated with IM3 operation are concededly inconsistent (and to a large extent directly opposite) the hydraulic regime associated with the final remedy design, there does not appear to be any reasonably foreseeable scenario under which IM3 would be reactivated. If IM3 is not to be immediately decommissioned upon the completion of startup of the final remedy, which would remove its	PG&E acknowledges the Tribe's statement of its position regarding the decommissioning of IM-3. These topics are currently being addressed in confidential settlement discussions between the Tribe, DTSC and PG&E, and PG&E defers any response on these issues to those settlement discussions.	Comment noted. DTSC agrees that the IM3 Treatment Plant will be decommissioned when the remedy is operating properly and successfully based the remedy decision documentation. IM3 decommissioning is currently a subject of litigation filed by the FMIT. Therefore, additional discussion is deferred.	Defer response.		See BOD Section 7.4 (Criteria for Approval of IM-3 Decommissioning)

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
				continuing adverse effect, the agencies must explain what conditions are reasonably foreseeable that support continuing this adverse effect. Additionally, even if there were a scenario under which restarting IM3 would be indicated, the IM3 WTP technology would be incapable of managing the type of chemical treatment and volume that the final remedy would have established in situ. There is presently no technical basis to support continuing the presence of the IM3 WTP following the completion of final remedy startup. While the draft 30% BOD discusses an IM3 transition process broadly in Section 8.3, it is not clear that the criteria listed for this evaluation are those that would necessarily be acceptable to the agencies or to FMIT, nor that the transition process described by PG&E will meet the criteria anticipated by the Agencies. That transition process (including the timing and criteria for directing decommissioning) must be more clearly defined and supported by a reasonable factual foundation.					
21	Hualapai-GC	General Comment		With the assistance of the TRC Committee Hualapai's review focused on the groundwater flow and solute transport modeling described in Appendix B and the estimated 30-year time frame for completion of the remediation. As the Topock modeling incorporated parameters generated from the two In-Situ Pilot Tests (ISPTs) conducted in the upland and flood plain areas, attention was also given to 1) the data generated from these pilot tests, 2) how those data were incorporated into the groundwater model, and 3) the potential impact on estimates of the actual clean-up time frame. We appreciate that the work has been done in a professional and through manner and that the regional model seems to have been developed with appropriate, standard practice and care. Our comments herein are prepared to provide additional, constructive input which we hope will provide positive contributions to the continued design of the remedial system, and to continue to incorporate the concerns and interests of the Tribes. The TRC Committee has been invaluable throughout this review and they welcome the opportunity to discuss any of these points with any technical consultants for the project, and appreciate the opportunity to contribute to a successful and effective remediation.	PG&E appreciates the Tribe's comment and welcomes the TRC's review and inputs.	Comment noted.	Comment noted.		

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
Section 1 Comments – Introduction									
22	DOI-12	Section 1.0, Paragraph 2, Sentence 3		Please change the text to "The DOI is the lead federal agency overseeing response actions for land under its jurisdiction, custody, or control …", removing "on or emanating from" for consistency with previous documents.	The text will be changed as suggested.		Okay pending review of text in 60% design submittal.	Resolved pending review of 60% design submittal.	See Section 1.0 of this BOD Report.
23	HA-1a	p. 1-1, para. 3		This paragraph establishes that the scope of this document pertains to the "final groundwater remedy" and distinguishes its purpose "… from other future actions that may be selected for the *soil media* at the Compressor Station." [Emphasis added]. In the past, the Tribe has commented about its concern regarding the project's separation of the groundwater and soils components of this project. Fundamentally, the remedial program makes this distinction, but in reality the potential interrelationship between soil and groundwater contamination is quite evident from various actions and decisions, such as parts of the soils remedial investigation that are designed to test the potential for downward migration of soil contaminants to act as continuing sources of groundwater contamination. See comment #2 below.	The intent of this paragraph is to provide additional information about the decision documents for the groundwater remedy and clarification on terminology to be used in the design document. If helpful, the following text in the last sentence of the third paragraph can be deleted in the 60% design submittal: "…~~to distinguish it from other future actions that may be selected for the soil media at the Compressor Station~~".	Proposed changes are okay.	Proposed changes are okay.		See Section 1.0 of this BOD Report.
24	HA-1b	p. 1-1, para. 4		This paragraph acknowledges that further refinement to the groundwater remedy will result from input provided by "stakeholders, Agencies, and Tribes" throughout the review process that will continue through November of 2012. The obligation of the Agencies to timely and meaningfully consult with the Tribes should be expressly acknowledged. Considering the complex and voluminous nature of these documents, sufficient time for Tribal review should be allocated, which may be greater than 30 to 45 days. The obligation of the agencies to consult with the Tribes should be added to the project's "Rainbow Schedule."	Comment noted. The project's "Rainbow Schedule" includes step and duration for Tribal Consultation, as set forth in the Programmatic Agreement, for each design document (30/60/90%). See Consultation Protocol of the PA (Appendix B).	Comment and response noted. DTSC has requested that additional time be allocated for the review of the 60% design document.	DOI acknowledges the complexity of design documents and have suggested an extension to the review period as well (See DOI Comment 10). We suggest a 60-day review period for the Tribes and stakeholders with an additional 15 calendar days for the agencies to review those comments prior to our comment submittal.		See Exhibit 1.0-1 of this BOD Report, which reflects an extended 60-day review period of CWG/TWG and Tribes and a 75-day review period for DTSC and DOI.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
25	HA-2	Ex.1-1, p. 1-2		This schedule indicates that the East Ravine/Topock Compressor Station Groundwater Investigation is ongoing through January 2012. Again, this is an example of where the schedules for the groundwater and soils investigations overlap but are not in sync. This is an example of where the ultimate impacts of this project may have not been fully and properly assessed. The East Ravine may be an area where groundwater risks have not been fully accounted for thereby adding to uncertainty related to the design and may therefore result in further disturbances in attempting to resolve the uncertainty. The details of the groundwater remedy design for this area will need to be addressed in the forthcoming design reports as indicated on the schedule.	Legal counsel for the Tribe has confirmed in discussions with PG&E counsel that this comment was intended to refer to the status of the East Ravine investigation and not the adequacy of the analysis in the EIR. To date, the East Ravine-Compressor Station Groundwater Investigation has focused on collecting the most important data for the design first and those data (groundwater quality and subsurface lithology) have been and will continue to be incorporated into the design as efficiently as possible, following validation and QA. Information and data from the investigation have been and will continue to be shared and discussed with agencies, stakeholders, and Tribes on screen calls to ensure opportunities for inputs. As mentioned at the January 18, 2012 CWG meeting, the East Ravine-Compressor Station groundwater investigation report will be included as an appendix to the 60% design submittal.	Comment and response noted.	Comment and response noted.		Results of the East Ravine groundwater investigation were summarized in a technical memorandum entitled *Addendum to the Summary of Findings Associated with the East Ravine Groundwater Investigation, Pacific Gas and Electronic Company, Topock Compressor Station, Needles, California*. The Addendum was submitted to agencies on November 12, 2012 and results were discussed at the January 17, 2013 TWG meeting in Henderson, NV. Comments were received from DTSC and DOI on February 15, 2013. The Addendum is currently being revised to incorporate comments.
26	HA-3a	p. 1-3, para. 2		In the first sentence delete the word “considered.” The area is indeed sacred to the FMIT. Also, after the words “adjacent lands” add “... are the aboriginal homelands and such lands ...” Delete the next sentence that begins with “The Tribes believe ...” This area is a holy place to the Fort Mojave People. It is hallowed ground based on the religious beliefs of the FMIT and other Native American Tribes.	PG&E acknowledges the FMIT’s statement of its beliefs regarding the sacred nature of the area. The text appropriately refers to these statements as statements of belief; this terminology was used in the EIR including the Tribe’s comments on the EIR. PG&E also believes that the last sentence of the paragraph should be clarified to more accurately state BLM’s findings in the Programmatic Agreement. Accordingly, the last sentence should be revised to state that “….and the BLM has also determined that a traditional cultural property or property of traditional religious and cultural significance that is eligible for listing on the National Register of Historic Places exists in the area of the Topock project within the APE.”	Comment and response noted pending review of text in 60% design submittal	Comment and response noted pending review of text in 60% design submittal		See Section 1.1 of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

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27	DOI-13	Section 1.1, Paragraphs 2 & 3		This section is entitled “Background” however the information primarily pertains to the cultural significance of the area. This is misleading. One would expect a background section to provide project history. It is recommended that this section be revised to discuss project history and a new section or subsection be added to address the cultural significance, cultural and historic resources and ecological resources, including the ACEC and HNWR. It is the agencies intent to minimize, to the extent practicable, impacts to the cultural significance of the area and to protect cultural, historic and ecological resources.	The following changes will be made to Section 1.1 (Background) (inserted verbiage shown in underline typeface, deleted text shown in ~~strikethrough~~ typeface): **1.1 Background** The Compressor Station is located adjacent to the Colorado River in eastern San Bernardino County, California, approximately 12 miles southeast of Needles, California, south of Interstate 40 (I-40), in the north end of the Chemehuevi Mountains (see Figure 1-1~~; all figures are located at the end of this document~~). The selected groundwater remedy addresses existing chromium contamination from past discharges of wastewater into the Former Percolation Bed (SWMU1) and the area around the Former Percolation Bed (AOC1) within Bat Cave Wash near the Compressor Station. The groundwater remedy also addresses groundwater within the East Ravine (AOC10) and under the Compressor Station. The following presents a description and history of SWMU1/AOC1 and AOC10 (CH2M HILL 2009d), and description of the cultural, historical, and ecological resources in the project area. **Description and History of SWMU1/AOC1 and AOC10** SWMU1 was formerly the site of wastewater percolation within Bat Cave Wash. AOC1 is defined as areas affected by flow of wastewater from the percolation bed, including the floor of Bat Cave Wash in the area surrounding the location of the discharge area (SWMU1) and the floor of Bat Cave Wash downstream from the discharge area towards the Colorado River. From 1951 to 1970, facility wastewater was discharged to this area and was allowed to percolate into the ground and/or evaporate. In addition, there have been several incidentals releases of facility wastewater, a few of which have resulted in wastewater released to Bat Cave Wash. Wastewater discharged to Bat Cave Wash consisted primarily of cooling tower blowdown (about 95 percent) and a minor volume of effluent from an oil/water separator (OWS) and other facility maintenance operation (about 5 percent). From 1951 to 1964, cooling tower blowdown was not treated prior to being released to the wash. During that period, the cooling tower blowdown contained Cr(VI). From 1964 to 1969, the cooling		Response/additional text are okay pending review of text in 60% design submittal		See Section 1.1 of this BOD Report. Please note that the sentences in italicized typeface under the PG&E Response to 30% Design Comment column of this comment have been added for completeness and accuracy.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

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					tower blowdown was treated with a one-step system to reduce Cr(VI) in the wastewater to Cr(III) prior to discharge to the wash. Beginning in late 1969, cooling tower blowdown was treated with a two-step system to reduce Cr(VI) to Cr(III) and then to remove Cr(III) from the wastewater prior to discharge to Bat Cave Wash. The continuous discharge of wastewater to Bat Cave Wash ceased in May 1970 when injection well PGE-08 was brought online. From May 1970 to September 1971, however, some treated wastewater may have been temporarily discharged to the percolation bed in Bat Cave Wash when injected well PGE-08 was offline for repairs or maintenance. All wastewater discharges to the percolation bed in Bat Cave Wash stopped when the first of four single-lined evaporation ponds was installed in September 1971. Since 1989, industrial wastewater from the Compressor Station has been disposed at Class II (double-lined) evaporation ponds. AOC10 (East Ravine) is located southeast of the Compressor Station, and includes four subareas, designated as AOC10a, 10b, 10c, and 10d. Subarea 10a is the location of the termination of a storm drain leading from the southeastern portion of the Compressor Station. The remaining subareas are locations within the East Ravine where water and sediment have collected within low areas or behind one of three earthen embankments. Two historical aerial photographs of this portion of the site show a low area within the AOC10c subarea that apparently contained liquids behind the largest embankment. While the composition of such liquids is not known, it is noted that this is the location of some of the highest chromium concentrations detected in soil sampling. Thin layers of white powdery materials have also been identified in the East Ravine area. Drainage to this ravine includes minor runoff from the access road to the facility, runoff from the mountains to the south, and some runoff from the compressor station. **Cultural and Historical Resources** The Topock site and adjacent lands are contained within a larger geographic area that is considered sacred by the Fort Mojave Indian Tribe and by other Native American Tribes. The Tribes believe that the environmental, cultural, and spiritual resources may not be physically				

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

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					perceptible. DTSC has concluded within the January 2011 certified EIR that the project site "appears to qualify as a historic resource under CEQA [California Environmental Quality Act] as an area that is significant in the social and cultural annals of California," and the BLM also has determined that a traditional cultural property or property of traditional religious and cultural significance that is eligible for listing on the National Register of Historic Places exists in the area of the Topock project within the APE (AECOM 2011). *The Topock site is also located in a Riparian and Cultural Area of Critical Environmental Concern (ACEC), designated under the BLM Resources Management Plan (BLM 2007).* Thousands of years of human history are evident in the area surrounding the Compressor Station. Among the larger and better known cultural resources on the site is an expansive desert geoglyph or intaglio known as the Topock Maze. Although the Maze is viewed as one contiguous element of a larger area having unique value to some Tribes, archaeological documents refer to three geographically-distinct parts, two of which overlie the groundwater plume. Prominent historic-era features in the landscape, several of which intrude upon the Maze and also overlie the groundwater plume, include segments of historic United Stated Route 66, the National Old Trails Highway, and the right-of0way of the Atlantic and Pacific/Atchison, Topeka, and Santa Fe Railroad. A broad spectrum of archaeological resources is also present within the project area and on adjacent lands. Properties on and near the Topock site that are eligible for or listed on the National Register of Historic Places include Native American cultural resources and elements of the historic "built environment". **Ecological Resources** A large portion of the site and surrounding area is the Havasu National Wildlife Refuge (HNWR). The Lower Colorado River National Wildlife Refuges Comprehensive Management Plan 1994-2014 (USFWS and BOR 1994), adopted in 1994, currently guides land management at the HNWR. The Comprehensive Management Plan emphasizes that the HNWR should be used in a manner that will facilitate protection of (1) the endangered and threatened species found in the Refuge, (2) marsh and wetland				

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
					habitat for both endangered and threatened species, and (3) habitat for migratory, wintering, and nongame avian species and their habitat. *Portions of the Topock site are also located in an Riparian and Cultural ACEC and the Topock-Needles Special Cultural Resource Management Area (SCRMA),* designated under the BLM Resources Management Plan (BLM 2007). In recognition of this, all remedial activities are planned in such a way as to minimize impact to this area. Specifically, impacts to cultural resources will be minimized by implementing the mitigation measures required by the EIR and the Programmatic Agreement. The work will be conducted in a manner that recognizes and respects these resources and the spiritual values of the area. ~~Practices that will be implemented with this objective in mind include: minimizing additional disturbance to the area by installing facilities in previously disturbed areas where possible; minimizing the size of drilling pads and staging areas; use of all-terrain drilling and sampling equipment in areas not served by existing roadways; constructing wells with multiple well screens at different depths in a single boring where possible rather than drilling individual borings for each well depth; minimizing the amount of equipment and duration that equipment is present on site; and providing training to all site employees to ensure that they are aware of and respectful of the spiritual value of this area that is considered sacred by certain Tribes.~~				
28	DOI-14	Section 1.1, Paragraph 3, Sentence 2		The text states that "impacts to cultural resources will be minimized by implementing the mitigation measures required by the EIR." Although it is further discussed in Section 1.2.2, this paragraph should acknowledge that mitigation measures will be developed in accordance with the BLM PA and the CHPMP and in consultation with the Tribes throughout the design process.	The following text will be added to this paragraph in the 60% design submittal: "In addition, mitigation measures will be implemented in accordance with the PA and the CHPMP and in consultation with the Tribes throughout the design process".		OK pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Section 1.1 of this BOD Report.
29	HA-3b	p. 1-3, para. 3		The Final Environmental Impact Report[1] ("FEIR" or "EIR") concluded that "... even with the implementation of mitigation ... significant impacts to the Topock Cultural Area ... within the project area are expected to be significant and unavoidable." This paragraph should reiterate this conclusion. [1] DTSC, 2011. *Final Environmental Impact Report for the Topock Compressor Station Groundwater Remediation Project.* SCH #2008051003. p. 6-33.	PG&E acknowledges the comment and the conclusion in the EIR. It is not necessary, however, for the basis of design report to reiterate conclusions set forth in the EIR.	The draft EIR is a record in itself. The resulting potential project impacts are used for the project decision. Restating a conclusion in the EIR in the design is not necessary.	Defer response.		

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
30	HA-3c	p.1-3, para. 3		Consultation with the Tribe is ongoing, so this list of mitigating measures is incomplete. Each step of the remedial project will require consideration of further mitigation to address potentially different and additional impacts of the particular action. Among the mitigating measures required by the EIR, the list should also include a commitment to continue working with the tribes to establish work implementation policies that are acceptable to the tribes, such as the ongoing effort to establish a disturbed soils policy and a well decommissioning policy or procedure. There should also be a mechanism established so that the effectiveness of the adopted mitigation measures is regularly assessed and mechanisms to improve mitigation performance established.	Counsel for the Tribe, in discussions with PG&E counsel, has confirmed that the reference to further mitigation in this comment refers to consideration of further mitigation measures already specified in the EIR. The summary of measures on page 1-3 is a short list of the measures in Table 7-1, which provides a summary of how the 30% design complies with the EIR. If helpful, the following text can be deleted in response to this portion of comment: " ~~Practices that will be implemented with this objective in mind include: minimizing additional disturbance to the area by installing facilities in previously disturbed areas where possible; minimizing the size of drilling pads and staging areas; use of all-terrain drilling and sampling equipment in areas not served by existing roadways; constructing wells with multiple well screens at different depths in a single boring where possible rather than drilling individual borings for each well depth; minimizing the amount of equipment and duration that equipment is present on site; and providing training to all site employees to ensure that they are aware of and respectful of the spiritual value of this area that is considered sacred by certain Tribes~~." Regarding the request to include a commitment to continue working with the tribes, PG&E re-iterates here our commitment to work with Tribes through our ongoing processes, our MOUs, and implementation of numerous EIR mitigation measures (e.g. CUL-1a provides for tribal input to the final design. (Final EIR at 4.4-62).) Specifically, PG&E has convened a Technical Review Committee that includes technical representatives of the Interested Tribes to review project-related documents, participate in project-related meetings, and advise interested tribal members on technical matters relating to the final design and remedy. (Final EIR at 4.4-64.) Tribal representatives on the Technical Review Committee have input into work implementation policies, including the disturbed soils policy and the well decommissioning procedure. Further, the mitigation monitoring and reporting program (MMRP) as implemented by a Qualified Cultural Resource Consultant ensures that the effectiveness of adopted mitigation measures is regularly assessed and that if necessary, mechanisms to improve	The evaluation of mitigation measures is a subject of litigation. DTSC is committed to continue dialogue with all interested tribes during the design, construction and implementation of the remedy.	Defer response.		See Section 1.1 of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
					mitigation performance will be established. (Final EIR at 4.4-63.) Finally, the Cultural Impact Mitigation Program (CIMP) is being developed in coordination with Interested Tribes and shows PG&E's commitment to working with the Tribes. (Final EIR at 4.4-65-4.4-66.) Through the development of the CIMP, the Tribes will have the opportunity to participate in the creation of many design specific protocols and methods, including, among others, protocols to for continued communication between PG&E and the interested Tribes, protocols for the appropriate treatment of archaeological materials that may be disturbed, protocols for the review of cultural resource-related documents, protocols for the review of project design documents, protocols for the appropriate methods to be used to restore the environment on decommissioning individual groundwater remedy facilities, a plan for decommissioning and removing the IM-3 facility, protocols for the repatriation of clean soil cuttings generated during Project activities, and provisions affording sufficient tribal monitors to observe ground-disturbing activities and/or other scientific surveying that may occur in preparation for construction activities. (Id.) Tribal consultation is also ongoing pursuant to the Programmatic Agreement's Consultation Protocol. Additionally, the mitigation measures under the Programmatic Agreement and the Cultural and Historic Properties Management Plan are also being followed in order to minimize impacts to cultural resources.				

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
31	HA-4a	p. 1-4, Section 1.2.1 (Remedial Action Objectives)		The Tribe has previously commented on the fact that these RAOs do not include goals for minimizing cultural impacts in the course of implementing this list of technical objectives. The impacts to the cultural setting have and continue to affect the health and well being of the Mojave people mentally, emotionally, and spiritually. It should be noted that the American Society for Testing and Materials (ASTM) has recognized the need for non-risk RAOs in addition to risk-based corrective action measures.[2] Non-risk criteria are typically non-numeric narratives. Among the non-risk criteria listed in the ASTM standard are property use requirements and community concern, both of which may relate to concerns of the Tribe. [2] ASTM, 2012. ASTM E2616 - 09 *Standard Guide for Remedy Selection Integrating Risk-Based Corrective Action and Non-Risk Considerations.* Accessed at: http://www.astm.org/Standards/E2616.htm	Comment noted. As the RAOs for the groundwater remedy are established in the decision documents, PG&E defers to DTSC and DOI.	The RAOs were identified and established during the CMS/FS documentation. The RAOs were developed by following the USEPA guidance to define RAOs by media, and specific for each receptor group. The RAOs are consistent with the National Contingency Plan for measurable objectives. In reviewing the scope established by the ASTM standards, the non-risk remedial action objectives are stated as objectives which "may include resource protection standards and the prevention of aesthetic or nuisance impacts in addition to protection of human health and the environment" The scope of the ASTM E2616 further states that "other non-risk criteria are typically non-numeric and may include: remediation timeframe, implementability, cost effectiveness, regulatory compliance, property use requirements, liability control, and community concern." Although the Tribe may object to the conclusions, DTSC believes that through our remedy selection process, including the certified EIR, these goals have been considered,	The RAOs provided in the CMS/FS are based on CERCLA guidance. The National Contingency Plan specifies that "In developing and, as appropriate, screening the alternatives, the lead agency shall: Establish remedial action objectives specifying contaminants and media of concern, potential exposure pathways, and remediation goals. Initially, preliminary remediation goals are developed based on readily available information, such as chemical-specific ARARs or other reliable information." The RAOs for the Topock Groundwater remedy were established during the development of the CMS/FS and finalized in the DOI ROD and the DTSC FEIR and Decision Package. DOI will consider the ASTM guidance in the development of the soil CMS/FS and future decision documents.		

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
32	HA-4b	p. 1-4, Section 1.2.2 (Incorporation of ARARs ...)		This section states that the Bureau of Land Management's (BLM) Programmatic Agreement (PA) has helped "... to guide the BLM's planning and decision-making as it affects cultural and historic properties specific to the groundwater remedy." Please provide an example as to how this process has served to properly protect the Topock Cultural Area. Furthermore, only one tribe, the Hualapai, signed the PA. Other affected tribes did not based on the fact that the PA failed to address a number of their concerns. The Tribes are requiring that formal consultation be carried out on a government-to-government basis with non-signatory tribes pursuant to Section 106 of the National Historic Preservation Act. The language in this section does not portray this situation accurately. The language should reflect the process being used to engage Tribal perspectives on this project	PG&E defers to BLM/DOI.		Comment noted. The BLM, the CA and AZ SHPO's, and the Advisory Council for Historic Preservation executed the Programmatic Agreement (PA) on October 26, 2010. The execution of the PA streamlines the consultation process, and allows the implementation of the Selected Remedy in a timely manner. All further consultations with the nine federally-recognized American Indian tribes affiliated with the PG&E Topock Remediation Project are to be conducted in furtherance of BLM's compliance under Section 106 and pursuant to the PA Consultation Protocol (Appendix B). The BLM made a reasonable and good faith effort to gain and incorporate the views of the FMIT and other consulted tribes into the PA for this Undertaking. The provisions of the PA will be followed as the Topock Remediation Project proceeds. The Cultural and Historic Properties Management Plan (CHPMP) is the treatment plan for how effects to historic properties and cultural values will be taken into account given approval and implementation of the Selected Remedy. The PA also stipulates how consultation under the National Historic Preservation Act (NHPA) will occur as the selected Remedy is implemented. Initially, none of the consulted Tribes signed the PA as Invited Signatories and two tribes (FMIT and the Hualapai Tribe) expressly declined to do so. Later, the Hualapai Tribe changed their position and signed the PA on July 20, 2011. Tribal views regarding the significance of the cultural resources and values adversely		

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
							affected and the importance of mitigating adverse effects on those resources and values will continue to be solicited through government to government and face to face consultations under the Consultation Protocol of the PA (Appendix B) and incorporated into the decision-making process.		
33	HA-4c	p. 1-4, same section, last para. – (refer to earlier comment # 3)		Again, this paragraph understates the fact that mitigating measures "... capable of reducing these impacts to less-than-significant levels" could not be enacted for several cultural impacts important to the Tribe. The Tribes have throughout this process stated that anything that transpires on the hallowed ground is an impact of irreversible and damaging effect and further desecrates the area. No mitigation can resolve such impacts to the spiritual cleaning area we know as present-day Topock.	As this statement is from the EIR, PG&E defers to DTSC.	Comment noted.	Comment noted.		
34	DOI-15	Section 1.3, Paragraph 1		Please ensure that the text is updated, as appropriate, and refers to the Consent Decree between DOI and PG&E when it becomes available.	Comment noted. The final Consent Decree will be referenced when it is available.		Response noted.	Comment resolved.	The Consent Decree executed in 2012 and lodged with the court in January 2013 was referenced throughout this BOD Report.
35	DOI-11	Section 1		A Section 1.4 should be added that summarizes the specific elements of the design that will be included in the 60% design package and are either not included in the 30% design package or will be extensively refined. This refers to design details only, not plans and other submittals as shown in Table 8-1.	PG&E proposes to add a table, instead of a separate section, into the 60% design submittal that meets the substantive requirements of DOI's request.		Okay pending review of 60% design submittal	Resolved pending review of 60% design submittal.	See Exhibit 1.3-1 of this BOD Report.
Section 2 Comments — Baseline Site Conditions and Pre-Design Work									
36	HA-5	p. 2-1, Section 2.1.1 (Hydrogeologic Setting), para. 3		This paragraph attributes the fluctuations in the Colorado River primarily due to regulation at Davis Dam. Does Parker Dam also play a significant role in affecting River stage?	Parker Dam does play a role in the river fluctuation pattern, mainly during heavy rain/higher river flow conditions. Our river level predictions are tied to the Davis Dam release rates and Lake Havasu level. Most of the time, the Davis Dam releases are the dominant factor in determining river levels at Topock. This text will be added to the 60% design submittal.	Noted pending review of text in 60% design submittal	Noted pending review of text in 60% design submittal		See Section 2.1 of this BOD Report.
37	HA-6	p. 2-1, Section 2.1.1 (Hydrogeologic Properties)		Please provide an approximate value or range of values for the magnitude of the landward hydraulic gradient imposed by the IM.	The hydraulic gradient imposed by IM-3 pumping is measured in three pairs of monitoring wells. Over the period from August 2007 through December, 2011, the average landward gradient in these three wells pairs has been approximately 0.005 ft/ft. This information will be added to the first bullet under Section 2.1.2 (Hydrogeologic Properties).	OK	Okay.		See Section 2.1 of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
38	Hualapai-31			<u>*Further considerations for the 60% Design Evaluation*</u> The CMS-FS reported, and DTSC confirmed, that there will be "recalcitrant" areas that may be difficult to remediate. 5.3.6 Alternative E – In-situ Treatment with Fresh Water Flushing (starting p. 5-30). Note that, on page 5-31: *The estimated time for five pore volumes to be flushed with this alternative is approximately 29 years. The actual cleanup time will be dependent on the rate at which organic carbon can be distributed to all areas of contaminated groundwater in the flood-plain and/or contaminated groundwater in recalcitrant zones in the upland areas can be flushed to the IRZ treatment line where it will be treated by injected organic carbon. These factors are subject to considerable uncertainty. It is estimated that the range of cleanup time is from 10 (based on two pore volumes) to 110 years (based on 20 pore volumes). The estimated time for this alternative is derived based on the assumed configuration described above. The estimated time for this alternative could be adjusted by modifying the number and location of wells and/or by modifying the flow rates. Under this alternative, an institutional control would be maintained during the remediation period to restrict use of groundwater in the plume area until the cleanup goals are attained, thereby eliminating the pathway for human health risk from direct exposure to groundwater. The area subject to the institutional control would include a buffer area surrounding the plume to prevent the consumption of water that potentially could migrate from the plume in other directions as a result of pumping from hypothetical future local water supply wells.* Note that the concept of "recalcitrant" zones is mentioned in several of the remedies that were discussed in this document. So it is a concept that was included in the evaluation of each of these remedies prior to the selection of the current remedy. There are data gaps in the understanding of these recalcitrant areas. If these could be mapped by examination of core logs, for example, then these areas could be stimulated either with higher TOC concentrations or introduction of Cr-reducing microbes.	The range of cleanup times of alternatives presented in the CMS/FS was based on a pore-volume flushing approach which was based on observed data from in situ pilot study tracer data and floodplain stable isotope data. In those cases, the approximate range of pore volume flushing required to replace initial groundwater concentration with final concentration was 2-20 pore volumes. This was considered a reasonable screening tool for comparison of alternatives. The current model uses reactive solute transport parameters to estimate concentration changes over time. Recalcitrant zones in groundwater cleanup projects may be caused by several factors. The most common is probably high concentrations of contaminants in low permeability silt or clay zones. Other causes can be stagnation points in the groundwater flow field, or in the case of in-situ remediation, geochemical heterogeneities that adversely affect the chemistry of the in-situ process. Examination of core logs would not be expected to yield useful data on the location of recalcitrant zones. In the complex alluvial fan depositional environment of the Topock site, there is often very little correlation in lithology even between adjacent wells, so the core logs do not provide a clear picture of where sizable silt or clay inclusions may exist. Even if it were possible to identify sizable clay inclusions from the core logs, there is no data from which to determine the concentration of Cr(VI) in the clays. A clay inclusion that is not contaminated does not represent a recalcitrant zone, so there would be no need to apply additional remedial effort to it. Recalcitrant zones typically become apparent after a few years of remediation. At that time, optimization measures can be implemented as necessary to speed the cleanup in recalcitrant zones.	Response noted.	Comment and response noted.		
39	DOI-16	Section 2.1.2/2-2/1st Paragraph/last sentence		It should be mentioned that a borehole in the East Ravine encountered a flowing bedrock fracture.	A full discussion of the ramifications of the conditions encountered at Site H will be provided in the 60% design submittal.	OK pending review of 60% design submittal.	Okay pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Section 2.1 of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

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40	DOI-17	Section 2.2/2-2/ 1st Paragraph/last sentence		There should be some discussion of the mechanism by which bedrock groundwater is contaminated if there are upward gradients from the bedrock to the alluvium.	Below are some potential mechanisms: 1) There is photographic evidence of surface water ponding in East Ravine. During the time the ponds were present, there could have been sufficient head in alluvial aquifer at the ponds to overwhelm the slight upward gradients we see today between bedrock and alluvium. 2) The discharge of cooling water in Bat Cave Wash may have elevated groundwater levels in the alluvium relative to the bedrock, producing downward gradients under the compressor station and along alluvial bedrock contact at the north edge of East Ravine. There are insufficient data to identify to what extent these or other potential mechanisms may be responsible for Cr(VI) in East Ravine bedrock.		Okay.	Resolved	
41	DOI-18	Section 2.2, Last Paragraph, Sentence 5		The statement that “bedrock in East Ravine has relatively few conductive fractures” is broad and not well supported as evidenced by the extent of the plume and conductivity of some of the wells. For example, a borehole in the East Ravine (Site H) encountered a flowing bedrock fracture. This information should be added to support the discussion of conductive fractures.	As noted in response to comment #10 DOI-9, the 60% design submittal will include an update of the conceptual site model for the East Ravine that addresses conditions observed at Site H.		Okay pending review of 60% design submittal.	Comment resolved.	See Section 2.2 of this BOD Report. Results of the East Ravine groundwater investigation were summarized in a technical memorandum entitled *Addendum to the Summary of Findings Associated with the East Ravine Groundwater Investigation, Pacific Gas and Electronic Company, Topock Compressor Station, Needles, California*. The Addendum was submitted to agencies on November 12, 2012 and results were discussed at the January 17, 2013 TWG meeting in Henderson, NV. Comments were received from DTSC and DOI on February 15, 2013. The Addendum is currently being revised to incorporate comments.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

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42	DTSC-1	Page 2-3, 3rd Paragraph	Though the interpretation of the southern extent of the chromium plume has expanded slightly due to new wells being installed since the CMS/FS (CH2M HILL 2009d), other parts of the plume have shrunk since that time, resulting in a slightly smaller extent overall.	What basis is PG&E using to state that the resulting plume is slightly smaller overall when the Eastern extent of East Ravine is still unknown?	The shallow plume was drawn around all East Ravine wells, similar to what was done for the CMS/FS. It is acknowledged that the ER has not been fully characterized, and the southern boundary of the plume remains an approximation. The 60% submittal will provide updated plume dimensions. For clarification, the sentence will be deleted in the 60% design report,	Okay		Comment resolved.	See Section 2.2 of this BOD Report.
43	DTSC-2	Section 2.3, Baseline Distribution of Other Compounds		Generally this section needs to include a design discussion on how the baseline distribution of each constituent discussed has a capacity or probability [or not] of impacting the proposed design. While the discussion on the distribution brings out salient qualities of the COPC, a direct statement on the design impact or lack thereof is missing.	Text will be added to clarify that the COPCs (selenium, molybdenum, and nitrate) and other general geochemical indicators parameters (TDS and sulfate) are not expected to impact remedy performance and therefore do not impact the design. With regards to TDS and sulfate, pilot test data indicates that Cr(VI) treatment is not affected by the presence of TDS and sulfate, as presented at the January 6 and January 19, 2012 TWG meetings. These findings will be discussed in the text. With regards to in-situ byproducts, the remedy is already designed to control the generation and migration of these compounds.	Okay		Comment resolved.	See Section 2.3 of this BOD Report.
44	DTSC-3	Page 2-3, 2.3 Baseline Distributions of Other Compounds		The document will need to expand the list of baseline constituents to the full title 22 metals list as well as a full suite of general minerals, etc., as DTSC will require these analyses during early startup of certain remedial facilities. For injection wells, the program will be very similar to that previously used at IM-3 injection wells.	Comment noted. A statistical summary table (similar to Table 2-1) will be included in the Draft O&M Manual for the full Title 22 metals list and available general minerals information, This will serve as a point of comparison for remedy monitoring data in the future.	Okay		Comment resolved.	See Table 2.2-2 of this BOD Report that includes a statistical summary of the full Title 22 metals and available general minerals information.
45	DTSC-4	Section 2.3.1, Page 2-3, Constituents of Potential Concern		Each section should include a discussion of the level of concern of the COPC existing presently and evolving during the remediation, and qualitatively discuss whether the COPC is a design driver or significant/insignificant risk factor to consider in the remedy and why. Then summarize how contingencies can be developed or alternatives to address those factors.	Text will be added to clarify that the COPCs (selenium, molybdenum, and nitrate) are not expected to impact remedy performance and therefore do not impact the design. The 2009 Groundwater Risk Assessment (ARCADIS 2009) concluded that selenium, molybdenum, and nitrate do not represent a significant health risk too future hypothetical users of the groundwater.	Okay		Comment resolved.	See Section 2.3 of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

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46	DTSC-5	Page 2-3/2-4, Section 2.3.1.1 Selenium		The section should be revised to indicate that elevated selenium almost exclusively occurs within or immediately adjacent to the boundary of the chromium plume. Well MW-17 is the only exception out of the eleven elevated wells as evidenced in Figure 2-4. Revise the section to indicate that elevated selenium is not discontinuous across the site as illustrated by the cluster of orange and magenta dots on Figure 2-4. Figure 2-4 can be interpreted to indicate that elevated selenium occurs within the general core of the chromium plume with the highest concentrations under the compressor station proper. Revise the section to indicate that significantly elevated selenium occurs at wells TW-1, MW-67-225, and MW-66-165 which are all located within the fence line of the compressor station, and therefore, suggestive of a compressor station source. The basis for elevated selenium levels related to colloidal breakthrough mentioned on page 2-4 should be discussed and supported. If not supported, the reference should be deleted. Would all metals exhibit similar levels of colloidal breakthrough? The section indicates that reducing conditions resulting from the remedy will likely limit selenium mobility. This assertion will need to be verified via selenium groundwater monitoring within the plume during the operation of the remedy. Text should be modified to indicate that the regional background concentrations mentioned on these figures (e.g., Figure 2-4) are background concentrations for the regional alluvial aquifer, and are not applicable to bedrock.	The 60% design submittal will honor the text used to describe selenium, molybdenum, nitrate, and TDS in the RFI/RI Vol 2 Addendum (CH2M HILL, 2009x), while accounting for any changes in distribution of these constituents since the RFI/RI was completed. Colloidal breakthrough in the samples will yield variable results based on the amount and composition of the colloids. Language used to describe this concept will be consistent with that used in the RFI/RI. Text will be added to stress that groundwater monitoring will be conducted to verify. Text will be added to indicate that Background Study UTLs listed for selenium, molybdenum, and nitrate were based on unconsolidated aquifer samples and not bedrock aquifer samples.	Okay pending review of the 60% design submittal		Comment resolved.	See Section 2.3 of this BOD Report.
47	DTSC-6	Page 2-4, Section 2.3.1.2 Molybdenum		Groundwater risk values associated with molybdenum should be mentioned, as an MCL does not exist, to assist in evaluating the significance of this constituent. The sentence on discontinuous distribution of molybdenum in the shallow zone wells should be modified to indicate that elevated concentrations (orange and magenta dots on Figure 2-5 – Shallow Wells) cluster to the south similar to the non-discontinuous Mid-Depth Zone. Text should clarify that the elevated molybdenum detected in groundwater is likely related to releases from the compressor station based on historical and current molybdenum use and documented releases. The section should indicate if reducing conditions resulting from the remedy will or will not likely limit molybdenum mobility (as stated in the document previously for selenium – see above).	See response to comment #46 DTSC-5.	Okay pending review of the 60% design submittal		Comment resolved.	See Section 2.3 of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

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48	DTSC-7	Page 2-4, Section 2.3.1.3 Nitrate		The section discussing the distribution of nitrate should be rewritten to indicate that Figure 2-6 clearly shows that almost all elevated nitrate (including values greater than the MCL) occurs within the confines of the chromium plume, suggesting that nitrate is a contaminant related to PG&E compressor station activities.	The 60% design submittal will honor the text used to describe nitrate in the RFI/RI Vol 2 Addendum (CH2M HILL, 2009x), while accounting for any changes in distribution of these constituents since the RFI/RI was completed.	Okay pending review of the 60% design submittal		Comment resolved.	See Section 2.3 of this BOD Report.
49	DTSC-8	Section 2.3.2, In-situ By-products	Citation of Table 2-2	Should be Table 2-1	This will be corrected in the 60% submittal.	Okay		Comment resolved.	See Section 2.3 of this BOD Report.
50	DTSC-9	Section 2.3.2, In-situ By Products, Page 2-4, paragraph 2,		In the opening statement, qualitatively summarize the important elements of Table 2-2 and do not depend on the reader to review the Table to interpret your sampling trend or results. This critical flaw is throughout the core document. Move first sentence identifying the COPC distribution Figures' locations to the end of the sections. Begin each sentence for each COPC with a qualitative or design statement relating the COPC impact on the design.	Discussion in text will be shifted in the 60% design submittal to emphasize the key points that may be concluded from the statistical summary in Table 2-1.	Okay pending review of 60% language.		Comment resolved.	See Section 2.3 of this BOD Report.
51	HA-7	p. 2-4, Section 2.3.2 (In-Situ By-Products)		It would be helpful to provide further details as to the anticipated behavior of these by-products in the subsurface environment, particularly at the anticipated geochemical interfaces along the flowpaths. While this information has been studied as part of the in-situ testing, geochemical and transport modeling, etc., it would be helpful to provide further discussion to facilitate the understanding of the anticipated behavior of these chemicals and the remedy processes that will control their migration as was discussed during recent TWG exchanges.	A detailed discussion of the generation and attenuation mechanisms at geochemical interfaces along flowpaths was provided in Section 8 of Appendix G in the CMS. The following text will be included in the 60% design submittal: Arsenic is primarily in the As(V) form in most areas of site groundwater. In the pH range of site groundwater, its form in solution is dominated by $HAsO_4^{2-}$. This anion tends to adsorb to the positively-charged surface of iron oxide minerals, which are present in the more oxidizing areas of the aquifer. This adsorption reaction maintains arsenic at concentrations below the UTL in most areas of the site. During the remedy operation of the IRZ, reducing conditions produced by the injection of organic carbon will dissolve iron oxide minerals in the surrounding matrix by reducing the Fe(III) in the oxide to Fe(II), which is soluble. The half-cell redox reaction may be written as: $Fe(OH)_3(s) + 3H^+ + e^- \rightarrow Fe^{2+} + 3H_2O$ with e^- representing electron, $Fe(OH)_3(s)$ as iron oxide (many variations on this formula exist in nature), and Fe^{2+} representing reduced iron or Fe(II). Coupled with this reaction would be another half-cell reaction showing equal oxidation of an electron donor, in this case ethanol going to carbon dioxide: $1/12\ C_2H_6O + 1/4\ H_2O \rightarrow 1/6\ CO_2 + H^+ + e^-$ where C_2H_6O is ethanol, the form of	Noted. Further evaluation will occur during review of the 60% design.	Noted. Further evaluation will occur during review of the 60% design.		See Section 2.3 of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
					organic carbon to be injected in the IRZ. The combination of organic carbon oxidation and iron reduction is a simplified model version of the family of reactions that occur in the IRZ, but effectively illustrates how iron and arsenic associated with iron minerals get released under these conditions. As the liberated Fe(II) and arsenic move downgradient from the IRZ into more oxidizing conditions, the iron will undergo the reverse reaction of that shown above, and the arsenic will either coprecipitate with the iron or adsorb onto the surface of the newly-formed solid, or both. The representation of these mechanisms in the numerical transport model was described in Appendix B of the 30 percent design Manganese is present in the matrix in the form of various oxides, similar to those of iron. Manganese is liberated around the IRZ in a similar reductive dissolution reaction to that of iron, with Mn(IV) and Mn(III) in the oxide reduced to Mn(II) and released into solution. Manganese is slower to reoxidize than iron, so it will travel further downgradient before the reverse reaction occurs to remove it from groundwater. During transport, Mn(II) is also attenuated by adsorption onto mineral surfaces. The representation of these mechanisms in the numerical transport model was described in Appendix B of the 30 percent design Additional geochemical processes affecting the behavior of dissolved metals occur within the hyporheic zone, the interface between the groundwater and the river. A conceptual level figure detailing these processes was included as Figure G8 in Appendix G of the CMS and discussed at the January 19, 2012 TWG meeting. A model is currently being constructed to evaluate geochemical/hydrological processes governing manganese behavior in the hyporheic zone (groundwater-river interface) as groundwater flows toward the river. This model focuses on Mn, as As is not expected to reach the hyporheic zone. The results of this model will be described in the 60% design and as such will include a more detailed discussion of the geochemical processes governing byproduct fate and transport.				

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

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52	DTSC-10	Page 2-5, Section 2.3.3 General Geochemical Indicator Parameters		The section emphasizes the natural occurrence of TDS and sulfate, yet makes no mention of anthropogenic sources. Some text should be dedicated to clarify that the large releases from the PG&E Compressor Station facility would have exhibited elevated TDS and general minerals (e.g., concentrated blow down water from the cooling towers) and that those releases would have mixed with unaffected waters. Please note that salts (Electrical Conductivity) were listed as hazardous waste constituents of concern in the 1996 DTSC Consent Agreement, and were sampled during various phases of PG&E compressor station site characterization and closure activities.	The 60% design submittal will honor the text used to describe sulfate and TDS in the RFI/RI Vol 2 Addendum (CH2M HILL, 2009x), while accounting for any changes in distribution of these constituents since the RFI/RI was completed.	Okay pending review of the 60% design submittal		Comment resolved.	See Section 2.3 of this BOD Report.
53	HA-8a	p. 2-6, Section 2.3.3.1 (Total Dissolved Solids)		As was discussed during recent TWG meetings and conferences, further discussion is needed as to the significance of the variably high concentrations of TDS within the aquifer as this may relate to the efficacy and operation of the groundwater remedy. Is there any component (*e.g.,* chloride, sulfate, etc.) of the TDS that may pose particular concern to remedy effectiveness? Was there any sensitivity analysis performed on the potential effects of density heterogeneity?	The composition of the groundwater has been taken into account in designing the remedy, and information was collected during the two pilot studies to examine effects of water chemistry on the in situ remedy. There are no constituents that posed concern in the design. In particular, Cr(VI) reduction was observed in the presence of elevated TDS concentrations, as presented at the January 19, 2012 TWG meeting. A discussion of this data will be included in the detailed response to comment in the 60 percent design. Variations in density were not applied in modeling the design. The main reason for this is that the vast majority of the groundwater is between about 500 and about 16,000 mg/L TDS, with an average around 5,000 mg/L. The density difference over this range is about one percent, which is not considered significant enough to evaluate density gradients. The areas with TDS greater than 16,000 mg/L are isolated portions of the shallow floodplain and a few deep wells. These areas are limited in extent and none have detectable chromium.	Comment noted. DTSC continues to be concerned with the efficacy of the remedy. However, to date, PG&E has been able to provide reasonable logic to all concerns raised. DTSC will continue to carefully evaluate and monitor PG&E's proposal throughout the design, construction and implementation process.	Comment and response noted.		See Section 2.3 of this BOD Report.
54	Hualapai-33			<u>Additional Technical Considerations</u> It is known that pH affects adsorption rates. Has it been determined how pH varies laterally and vertically within the Topock hydro-geologic system, and is this an issue? Will pH be monitored as part of the system monitoring program?	Average pH values in the remedy area are between 6.5 and 8.5. Most of the pH values that fall between 6.5 and 7.5 are in shallow- and mid-depth floodplain wells, and the remainder are predominantly 7.5 to 8.5, regardless of depth (see Figure 6-1 in the RFI Volume 2 Report). Given these relatively narrow pH ranges, adsorption rates are not expected to be significantly variable on the basis of pH alone. All sampled wells are monitored for pH, and will be monitored for pH throughout the remedy. The effect of pH on Mn sorption will be considered in an expanded discussion on the geochemical parameter sensitivity analyses.	Noted	Comment and response noted.		See Section 2.3 of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

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55	DOI-19	Section 2.4.1, Paragraph 5, Bullet 1		A summary statement of the findings of the EPNG evaluation of the structural and physical space capacity of the arched bridge should be included in this bullet.	The following text will be added to this paragraph in the 60% design submittal: "In its evaluation report, EPNG concluded that the proposed 12-inch freshwater line load is within the acceptable design loads for the bridge. EPNG recommended that equipment larger than 16 kips not be used in any 18.5 ft long deck section and the bridge deck supports be visually inspected prior to construction".	Okay	Okay pending review of 60% design submittal.	Comment resolved.	See Section 2.4.1 and Appendix G of this BOD Report.
56	HA-8b	p. 2-6, Section 2.4.1 (Land Ownership, Disturbance, and Development)		The Tribe requests further details regarding the proposed types of facilities and activities that will be performed on its property for construction and during remedy operation. As a general principle, the Tribe's preference is for as little remediation infrastructure to be placed on its property as possible. The Tribe and PG&E should consider this in the design phase. FMIT requests a meeting to discuss such potential facilities (i.e., the need for, proposed types, longevity, etc.).	The Tribe's preference is recognized and will be further considered during the development of the 60% design, consistent with the 2006 Easement Agreement and the 2006 Settlement Agreement between the Fort Mojave Indian Tribe and PG&E. A statement to this effect will be included in the 60% design submittal.	Comment noted	Comment and response noted.		See Sections 2.4.1 and 5.3.2 of this BOD Report.
57	HA-9	p. 2.7, Section 2.4.1 (Land Ownership, Disturbance, and Development) & Appendix A-2		PG&E has been discussing with the FMIT the preparation of an aerial map of disturbed areas pursuant to EIR Mitigation Measure CUL-1a-9. In particular, H+A transmitted comments to PG&E on July 5, 2011, expressing concerns on behalf of the Tribe.[3] Among the various concerns discussed was the potential for misuse of such a mapping. Specifically, the classification of lands as "disturbed" could lead to the impression that such areas would be "fair game" for further and additional disturbances, whereas there are other factors that the Tribe believes must be taken under consideration. Accordingly, consultation with the Tribe should always be a prerequisite for such planning regardless of whether the land has suffered disturbance in the past. [3] H+A, 2011. Letter from Dr. L.S. Leonhart, H+A, to Dr. Y.J. Meeks, PG&E, re "FMIT Comments on Mitigation Measure CUL-1a-9, Aerial Map of Disturbed Areas."	Comment noted. Existing mitigation measures require communication/ consultation with the Tribes throughout the design process, as reflected on the project's "Rainbow Schedule."	DTSC understands that the tribe does not believe in the generalization that disturbed areas are less significant to other undisturbed area. DTSC agrees that tribal input throughout the design, construction and implementation phrases of the project is important to the collaborative success of the remedy.	Comment noted. Tribal views regarding the significance of the cultural resources and values adversely affected and the importance of mitigating adverse effects on those resources and values will continue to be solicited through government to government and Section 106 consultations under the Consultation Protocol of the PA (Appendix B) and considered in the decision-making process.		See Section 2.4.1 of this BOD Report.

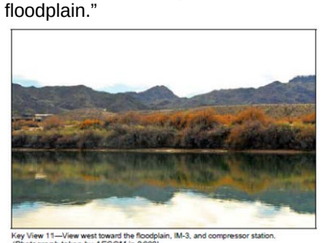
APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

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58	DTSC-11	Page 2-6/2-7, Section 2.4.1 Land Ownership, Disturbance, and Development		The Topock 66 Resort and Spa at the Topock Marina is identified as a planned development. DTSC had heard that it had been cancelled, but did recently check the resort website and noted plans for continuing the development as of July 2011. Based on current plans, a source of water for the development (hotel, brewery, pool, water features, greenscape) would be needed and could influence hydraulics in the area. PG&E must acknowledge this issue and evaluate potential impacts of the development on the remedy (e.g., What are potential effects on the remedy if groundwater is pumped from a well located in the Topock Marina area?) and the remedy on the development. PG&E needs to prepare a comprehensive list of all water wells in the Topock area including historical, current, and potential future pumping rates. DTSC had heard that SoCal Gas had requested pumping rights in the area that should be discussed in this section as well as other applicable sections.	As indicated in the response to comment #136 Hualapai-24, the EIR evaluated water use during construction, during operation, and during decommissioning of the remedy, and in each instance, the EIR concluded that the existing entitlement was more than sufficient to serve the remedy project needs. The basin is adjudicated and pumping is controlled by the Colorado River Board. PG&E will request information on the pumping allocations for water users in the Topock area from the Colorado River Board. These would be the maximum allowable pumping rates under the current water rights. Simulations could be conducted to determine if these maximum pumping rates would have any adverse effects on the remedial action. As requested, PG&E will prepare a list of wells in the Topock Area based on available data, and include the list in the forthcoming freshwater evaluation technical memorandum. According to information from BLM (early 2011), SoCal Gas had planned for a well near the water tanks between I-40 and Moabi Regional Park. The well could be up to 500 feet deep and was intended for cathodic protection, and not for pumping of groundwater.	Okay		Comment resolved.	See Appendix J of this BOD Report.
59	HA-10	p. 2-8, Section 2.4.2 (Site Topography and Surface Geology)		On a recent site walk, Tribal members expressed an interest in developing a three-dimensional (3D) physical model of the Site terrain for the purpose of explaining topographic and physical relationships of project facilities to the general Tribal Membership. In turn, PG&E requested the assistance of the Tribe in facilitating this request. It is hereby reasserted that the Tribe is interested in moving forward with this project. In a recent meeting with the Tribal Community, plastic raised-relief maps created by an impression process were displayed for the Needles and Kingman quadrangles. These products were welcomed and characterized as potentially useful if they could be produced on a larger scale, such as for the project area.	PG&E appreciates the Tribe's facilitation and its assertion in this comment. PG&E has initiated work and is coordinating with the Clearinghouse Task Force (CTF) members to deliver on this project.	Comment noted.	Comment and response noted.		Work on the physical model is underway. No changes were made to this BOD report (text/figures/ tables) as a result of this comment.
60	HA-11	p. 2-8, Section 2.4.3 (Soil Contamination Areas)		See previous comment No. 1 regarding soils.	See response to comment #23 HA-1a.	Comment noted.	Comment and response noted.		See Section 1.0 of this BOD Report.
61	DTSC-12	Page 2-8, Section 2.4.3, Soil Contamination Areas		Figure 2-15 is presented to acknowledge soil/groundwater infrastructure overlap. Greater detail, including detailed figures and sampling and soil management plans, will need to be prepared to evaluate how best to proceed.	Additional details will be provided in the 60% design submittal. Also see response to comment #62.	Okay, pending review of 60% design submittal.		Comment resolved.	See Figure 2.4-4 of this BOD Report and draft O&M Manual, Volume 4- Soil Management Plan.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
62	DOI-20	Section 2.4.3.1, Paragraph 2, Bullet 2		In reference to this bullet, please provide a figure or table of areas where remedy facilities will intersect soil contamination areas.	Comment noted. Figure 2-15 will be updated to include a table to list the overlapping areas in the 60% design submittal to address this comment.	Okay pending review of 60% design submittal.	Okay pending review of 60% design submittal.	Comment resolved.	See Figure 2.4-4 of this BOD Report.
63	DTSC-13	Section 2.4.3.1, Coordination of RFI/RI Soil Investigation with Remedy Design and Construction		This section did not mention coordination between the soil investigation and the possible use of an infiltration gallery mentioned in Appendix F. DTSC notes that PG&E has reserved this option for future use pending soil RFI results. If PG&E is maintaining this option as stated, the soil RFI work plan should reflect this proposal. In addition, this section mentions that additional soil investigations and opportunistic sampling are independent of design activities for the final groundwater remedy, but that the soil data would be used as it becomes available. PG&E must, as part of the O&M Plan, provide a soil management plan and sampling analysis plan that describes the logic and processes to follow as part of the remedial construction and soil disturbance (e.g., how to sample and handle trenched soils in a potentially contaminated area).	The Soil RFI/RI Work Plan will incorporate the possible use of an infiltration gallery in Bat Cave Wash for disposal of treated remedy produced water into the sampling plan, and will include collection of relevant and adequate data to support the CMS/FS design. The O&M Manual will include sampling protocols and analysis for soil and plan for managing soils during O&M, consistent with the ongoing discussions about displaced material handling protocols between PG&E, agencies, and Tribes (also see response to comment #64 DTSC-14).	DTSC did not note any proposal in the RFI/RI work plan for soil that incorporated the investigation and development for the infiltration gallery in Bat Cave Wash. However, if PG&E is considering such a proposal, DTSC agrees that it can be coordinated through the soil investigation phase.		Comment resolved.	See Section 2.4.3.1 of this BOD Report. Also see draft O&M Manual, Volume 4 – Soil Management Plan.
64	DTSC-14	Page 2-9, Section 2.4.3.1 Coordination of RFI/RI Soil Investigation with Remedy Design and Construction		A bullet should also be included that addresses maximizing retention of soils to address Tribal concerns. The document should clarify and/or provide examples for the following bullets currently included in the text: • Where appropriate, the timing and scope of soil investigation activities will be coordinated to minimize interference with groundwater remedy implementation. • Access restrictions established to protect groundwater remedy infrastructure will consider the need to access soil investigation areas for additional investigation or remediation.	Consistent with response to comment #181 HA-36, a bullet will be added in the 60% design submittal to mention the ongoing discussions about displaced soils handling protocols between PG&E, agencies, and Tribes. The approach and general protocols discussed to date are intended to minimize the amount of displaced material that leaves the site. Specific topics include handling and storage, contamination assessment, long-term disposition of displaced soil, etc. First bullet – an example is if the timing of the soil investigation and groundwater remedy construction coincides, the work will be carefully synchronized so as to minimize interference/obstruction. Second bullet – an example is when access restrictions are established for the protection of groundwater remedy infrastructure (i.e., Category 2 ICs) in certain areas, consideration will also be given to the potential need to access the same area for additional soil investigation or remediation.	Okay		Comment resolved.	Section 2.4.3.1 of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
65	DTSC-15	Page 2-9, Section 2.4.4 Surface Water and Wetlands		Figure 2-17: Will the OHWM need to be identified and documented for any Arizona remedy infrastructure (e.g., pipeline) or for the California river bank south of that pictured in Figure 2-17 (e.g., freshwater intake structure). The figure only evaluates a segment of the California floodplain area.	Figure 2-17 is intended to demonstrate compliance with EIR Mitigation Measure AES-2a which states the following: "A minimum setback requirement of 20 feet from the water (ordinary high water mark) shall be enforced, except with regard to any required river intake facilities, to prevent substantial vegetation removal along the riverbank" The requirement for the 20-foot setback from the OHWM is relevant to the aesthetic value from Key View 11. A Key View, according to the EIR, is a vantage point offering a view of some or all of the Project Area from one of the specified points. Each Key View vantage point is located and described in Volume II, Section 4, of the Final EIR. Key View 11 is defined in Table 4.1-1 as "View looking southwest toward the floodplain, IM-3 Facility, and compressor station from Colorado River. View is approximately 300 feet from the floodplain."  Key View 11—View west toward the floodplain, IM-3, and compressor station. *(Photograph taken by AECOM in 2009)* Given the above mitigation directives for AES-2a, the 20-foot setback requirement (hence the need to map OHWM) does not apply to Arizona remedy infrastructure. Further, AES-2a specifically excludes any required river intake facilities. However, it should be noted that the OHWM was identified and mapped (within the project area, in California and Arizona) during the recent wetlands delineation field survey conducted for compliance with EIR mitigation measure BIO-1.	Okay		Comment resolved.	
66	DTSC-16	Page 2-10, Section 2.4.5, 3rd paragraph	This alliance takes many forms and in the Project Area it is form that lacks ironwood (Olneya tesota).	This sentence seems incomplete.	The letter "a" will be inserted between the word "is" and the word form".	okay		Comment resolved.	See Section 2.4.5 of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
67	DOI-21	Section 2.4.7		Please update the activities required by the Programmatic Agreement to reflect current status of the stipulations (Access Plan and CHPMP) and reflect that a treatment plan will be developed throughout the design to address any mitigation measures.	The Access Plan and the CHPMP will be updated to reflect their current status in the 60% design submittal.		Okay pending review of 60% design submittal.	Comment resolved.	See Section 2.4.7 of this BOD Report.
68	DOI-22	Section 2.4.7, Last Bullet		Please clarify if a draft paleontological report is under review. It is unclear from the discussion. Also, please verify that the report will be available for review by the agencies.	The paleontological report will be submitted to DTSC once complete. A copy will be provided to DOI at that time.		Response noted.	Comment resolved.	See Section 2.4.7 of this BOD Report. A paleontological report was prepared and submitted to DTSC on December 21, 2012; this report is currently being revised to incorporate comments.
69	HA-12a	p. 2-12, Section 2.4.7 (Cultural Resources)		1st sentence, “Cultural resources occur in areas near some groundwater remedial facilities and will affect design, construction and implementation of the final groundwater remedy.” - First, the entire area has been recognized by both DTSC and the state as a tribal cultural property; the issue is not just about some areas near some facilities, but rather impacts to the whole of the area. Second, where and how does this occur? Please provide a map of where design, construction and implementation of these remedial facilities will be located. Third, please give examples of how cultural resource survey information is being used to guide siting and design.	Comment noted. PG&E will continue to outreach and work with the tribes during the design process. The first sentence will be revised to state:“Cultural resources in the area will affect design, construction and implementation of the final groundwater remedy.” A map indicating where both remedial facilities and archaeological/historical sites are located will be submitted to the tribes concurrent with the 60% design. Results of the cultural resources survey of archaeological and historical properties (sites) have been uploaded into the Project GIS database. Utilizing GIS, facilities are located with avoidance of historic properties as a primary goal.	Comment and response noted. DTSC will continue to outreach and work with the tribes during the design process.	Comment and response noted. Tribal views regarding the significance of the cultural resources and values adversely affected and the importance of mitigating adverse effects on those resources and values will continue to be solicited through government to government and Section 106 consultations under the Consultation Protocol of the PA (Appendix B) and considered in the decision-making process.		See Section 2.4.7 of this BOD Report. The map indicating where both remedial facilities and archaeological/ historical sites are located was submitted to the Tribes concurrent with the 60% design, but under a separate cover.
70	HA-12b	p. 2-12, Section 2.4.7 (Cultural Resources)		Activities required by the Programmatic Agreement (PA) First bullet – The Fort Mojave Tribe and other tribes (with the exception of Hualapai Tribe) did not sign the PA document as their concerns were not adequately reflected in the PA document. Fort Mojave and other non-signatory tribes have requested of BLM to be consulted under the government–to-government trust relationship that each tribe has directly with the United States as authorized under Executive Order 13175, and numerous Federal and State law, such as National Historic Preservation Act (NHPA), American Indian Religious Freedom Act (AIRFA), etc.	PG&E defers to BLM/DOI.		Comment noted. The 36 CFR 800 regulations (implementing Section 106 of National Historic Preservation Act) are not the only basis for BLM’s responsibility to consult with tribes about the actions proposed at Topock. BLM’s consultation responsibilities are grounded in the trust responsibility that the federal government bears toward Indian tribes as sovereign governments, which goes back to a variety of treaties, and many laws, executive orders, regulations, presidential memoranda and judicial decisions. Recent examples include the American Indian		

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
							Religious Freedom Act, the Native American Graves Protection and Repatriation Act, the Archaeological Resources Protection Act, Executive Orders 13007 and 13175, and memoranda to the executive branch issued by Presidents Clinton, Bush, and Obama. The NHPA is only one piece of the whole corpus of law and policy that drives federal agencies to consult with tribes about a wide range of tribal concerns, notably including tribal religious, spiritual and cultural values they attach to the Traditional Cultural Property/Place (TCP) in the Topock area. The BLM can only determine if an effect is adverse by consulting the tribes that ascribe significance to the TCP. It follows then, in furtherance of BLM's NHPA Section 106 responsibilities and government –to-government trust relationship, that, BLM will conduct its consultations under the Programmatic Agreement's Consultation Protocol (Appendix B) and through the implementation of the Cultural and Historic Properties Management Plan (CHPMP). Consultation will move forward with the tribes to determine if an adverse effect is anticipated for historic properties (i.e., bounded archaeological sites), as well as, for the cultural, religious, and spiritual (intangible) values tribes hold for the TCP within the APE.		

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
71	HA-12c	p. 2-12, Section 2.4.7 (Cultural Resources)		Second bullet – The description of implementation of the Cultural and Historic Properties Management Plan (CHPMP) fails to mention that the document is admittedly incomplete. Many of document's sections related to tribal views/perspectives currently are either blank or do not consider or protect the interests of those tribes who ascribe concern to the Area of Potential Effects (APE), referenced in the PA and CHPMP documents. Instead the document has solely an archaeological resource focus. Even through the many years of trying to address this missing link in the Topock process with the agencies and PG&E and the many promises by the decision makers to address this flaw, sadly this remains unchanged and unresolved as this process moves forward,. The final remedy will have many effects on the Mojave people, its aboriginal lands, religious and spiritual values and continued desecration of our Holy Place, surely this significant impact should have risen to the level of grave importance in the design and eventual construction of the final remedy. Only through a complete and knowledge-based understanding from the People who continue their religion and current day practices can such a document help and guide this process in this unique and sacred area. Financial resources were not provided by or to the BLM to adequately capture and reflect these religious and cultural values associated with the cumulative and imminent effects that will be undertaken by the cleanup project. The remedy design documents should acknowledge and provide a framework to solve these missing analytical pieces in such as way as these values can be adequately and timely considered within the design process.	PG&E defers to BLM/DOI.		Comment noted. The comment made that the CHPMP has solely an archaeological resource focus is not correct, nor is the assumption that two remedy design documents (PA and CHPMP) dealing with the implementation of the NHPA Section 106 process do not provide a framework to solve missing analytical pieces in such a way as these values held for the TCP within the APE can be adequately and timely considered within the design process. Additional consultation under the Programmatic Agreement's Consultation Protocol (Appendix B) provides the framework needed to address cultural values of religious and spiritual significance. The Tribes play a pivotal role in this process as only the Tribes can define the cultural values associated with the TCP within the APE. By design the CHPMP is a "living document" that can be modified and updated, as needed, to address new information and ongoing activities related to the Undertaking. Refer to page 33 of the CHPMP, under Section 3.3 Cultural Values/ Ethnographies; see the statement, "BLM will continue to seek additional input regarding cultural values from the Tribes. A contracted study may be undertaken to gather this information and, if provided, will be included in future iterations of the CHPMP. In Section 7.2 on page 77 of the CHPMP is a statement titled, "Accommodation of Tribal Activities and Ceremonies Involving the Topock Maze/TCP that states, "The BLM will continue to work with the Tribes to identify tribal activities and ceremonies that are associated with the Topock TCP. When such activities and ceremonies are identified, BLM will consult		

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
							with the Tribes and PG&E to develop treatment measures to accommodate them. Treatment measures may address scheduling of Undertaking work to accommodate ceremonial activities and to mitigate audible and visual impacts." The crux of the matter is that BLM can only determine if an effect is adverse by consulting the tribes that ascribe significance to the TCP. It follows then, in furtherance of BLM's Section 106 responsibilities that BLM can only complete its consultation under the Programmatic Agreement's Consultation Protocol by consulting with the concerned tribes to determine if an adverse effect is anticipated upon the cultural, religious, and spiritual values they hold for the TCP within the APE. If a place is determined to be a traditional cultural place, then all or part of the significance of that place is based on the intangible cultural values of the people whose traditions define the importance. Hence, the BLM, in order to determine if there is an effect to the TCP, must analyze how any given Undertaking affects intangible cultural values associated with that place. The Tribes possess this knowledge and BLM has on several occasions requested that the tribes share this knowledge to the extent that they feel comfortable in doing so, so that their cultural, religious, and spiritual intangible values associated with the TCP within the APE can be protected in a culturally appropriate manner to the maximum extent practicable given federal and state mandates to protect human health and environmental concerns.		

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
72	HA-12d	p. 2-12, Section 2.4.7 (Cultural Resources)		Activities required by the Environmental Impact Report Mitigation Monitoring and Reporting Program (EIR MMRP) – As a general statement, the design document must acknowledge that FMIT was not consulted on any of the Mitigation Measures described in the reference bulleted items, nor do we understand the intent of several of the Mitigation Measures and how they are to be implemented. Regardless, the Tribe does appreciate the opportunity to be involved early on in the implementation and refinement of these measures and request to have copies of all the draft reports currently under review (i.e., the Cultural Impact Mitigation Plan (CIMP), Cultural Resources Study, Paleontological Investigation and any others to be developed in the future) provided to the Tribe. This section should be corrected to note that the Tribes, to date, have NOT been part of the CIMP development, despite the Tribes' repeated inquiries.	The bulleted items on the bottom of page 2-12 and on page 2-13 refer to mitigation measures discussed in the certified EIR. PG&E notes that mitigation measures were proposed in the Draft EIR, which was circulated for public review. The Tribe submitted substantial and lengthy comments on the Draft EIR, and it is PG&E's understanding that the Tribe also met with DTSC to discuss mitigation measures. The mitigation measures in the Final EIR were revised in response to the submitted comments from the Tribe and others. The mitigation measures will be implemented at various stages of the final remedy, and not all are required to be complete at the 30% design stage. PG&E acknowledges that the Tribe has been and will be involved in the implementation of specified measures. To date, as chronicled in Table 7-2, PG&E has engaged in numerous outreach efforts and has had many communications with the Tribes. The communications included transmitting documents such as draft disturbed area maps and the proposed methodologies for the Mature Plants and Floristic surveys. As of February 2012, the CIMP outline has been provided to and discussed with the Tribes and the Tribes will have additional future opportunities for input on its contents.	The proposed mitigation measures were provided in the Draft EIR for tribal comments. As a result of those comments, DTSC had several meetings with the Fort Mojave Indian Tribe and revised the mitigation measures for the Final EIR. Although the Fort Mojave Indian Tribe believes that DTSC did not offer sufficient discussions with the tribes on mitigation measures during its development, this is a topic of pending litigation. Please note that DTSC did require PG&E to work with interested tribes on the implementation of specific measures.	Defer response.		
73	Hualapai-35 and TRC-17			While Hualapai and other Tribes believe that the Colorado River is sacred and should be kept clean, Hualapai also believes that there should be an emphasis on protection of spiritual and cultural resources near the Topock Compressor Station. In the 30% Design report, the protection and recognition of spiritual resources was not addressed. Drillers, employees, scientists, and construction workers all must be educated regarding the spiritual importance of the area to the Tribes. If any employee exhibits outward disrespect for the spiritual importance of the area, then those employees should be removed from the project as soon as possible. The Tribes need verification that such an employee program is going to be implemented as part of the project. *[Next sentence appears only in the comment matrix]* In addition, during implementation of the project (construction/operation/maintenance), PG&E should implement and enforce a management plan that addresses human and solid waste in order to more fully protect the site. **TRC Recommendation:** This should be included within in the 60% design report discussions and plans.	Consistent with its obligations under the Programmatic Agreement's Monitoring Protocol, existing PG&E standard practice, and the EIR MMRP requirements, cultural sensitivity training is required of all staff, workers, and contractors engaged in activities within the APE to familiarize them with the sacred nature of the area so that they will perform their jobs in a respectful manner. Consistent with these obligations, PG&E will not tolerate any disrespectful behavior in the field and will remove any staff, workers, or contractors who do not comply with this section. Text will be added in the 60% design report indicating that environmental and cultural/historical resources and other tribal concerns are being considered and protected by PA, CHPMP, CIMP and EIR MMRPs.	Comment and response noted.	Comment and Response noted pending review of the 60% design submittal.		See Section 2.4.7 of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
Section 3 Comments—Design Basis and Assumptions									
74	DOI-23	Section 3		DOI acknowledges that the O&M Plan will include details of the proposed monitoring network, sampling frequency, and analytical parameters; however, please include discussion of how chromate and byproduct concentrations will be monitored down gradient of the IRZ and how monitoring data will be used to evaluate system performance and affect changes to system operations (e.g. substrate dosing).	These details will be part of the draft O&M plan. Preparation of that detailed plan is underway and includes these considerations. Partial discussions will likely not provide enough detail to be satisfactory. PG&E suggests a TWG meeting prior to submittal of the plan in the 60% design that includes an agenda item focused on the monitoring plan. Preliminary details at this time would be pre-mature.	Okay pending review of the groundwater monitoring and the O&M Plan	Okay pending review of 60% design submittal, the groundwater monitoring plan and the O&M plan.	Comment resolved.	See draft O&M Manual, Volume 2 – Sampling and Monitoring Plan.
75	HA-13	p. 3-1, Section 3.1 (Summary of Modeling)		Refer to comments on Appendix B.	Comment noted.		Comments noted and addressed separately.		See Appendix B of this BOD Report.
76	DOI-24	Section 3.1/3-2/ Last Paragraph		It is unclear in the depiction on Table 3-1 whether the wells are screened in Layers 2 or 4. It is presumed that they are but the table does not clearly depict this in the column entitled “Preliminary Well Count”.	Tables 3-1 through 3-4 will be clarified to better indicate screen zones in each well. Preliminary screen lengths for each model layer are provided in the column “Preliminary Screen Length”. If a model layer row does not have a screen length provided in this column, the preliminary design consists of a single screen across two or more of the model layers. Note that the estimated vertical depth of each model layer is provided in the column “Model Layer Thickness”. Well design, including placement of screens, screen length, etc., will be updated and detailed during the 60% and 90% designs. It should be noted, that final location and lengths of screens may be modified in the field during installation activities. Additional information regarding the design basis for individual well and aggregate flow rates will be provided the 60% design submittal, including Section 3, Appendix B, and the table footnotes. The discrepancies in the sums of flow rates result from the rounding of per-well or per-screen interval flow rates to appropriate significant digits. These discrepancies will be resolved in the 60% design submittal. Per comment #10 (DOI-9) and #232 (DOI-65), potential inclusion of the Area H well and other changes within the East Ravine will be evaluated based on the latest remedial investigation data available and included in the 60% design submittal. Information will be reflected appropriately in these tables.	Okay	Revised Tables 3-1 through 3-4 are acceptable pending review of 60% design submittal	Comment resolved.	See Tables 3.2-1 through 3.2-3, Table 3.3-1, Section 3.2, and Appendix B.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
77	DTSC-17	Page 3-2, Section 3.1 Summary of Modeling		Request adding contoured chromium plume to cross-sections (especially for B-B'). Contoured chromium maps should also be added to remedy maps to assist in evaluating remedy design.	The vertical delineation of the current chromium plume distribution can be added to the cross-section figures.	Okay		Comment resolved.	See Figures 3.1-2, 3.1-3, 3.1-4, and 3.1-6.
78	DTSC-18	Page 3-2, Section 3.2, In-situ Remediation	Second bullet	The purpose of the Inner Recirculation Loop is stated to be facilitation of groundwater flow through the IRZ. However, it is also noted in Appendix B, section 4.4.2, Riverbank Extraction that the design goal of the extraction wells were to both accelerate groundwater through the IRZ and to capture Cr(VI) located down gradient of the IRZ. DTSC also envisions that the extraction wells should be designed to capture any by-product formation that may be formed as a result of Cr(VI) reduction that would flow past the extraction wells. These goals should be consistent throughout the design document.	Text in section 3.2 will be updated to reflect that the Riverbank Extraction wells will both facilitate the groundwater flow through the IRZ and capture Cr(VI) located downgradient of the NTH IRZ. The Riverbank Extraction wells are also designed to control NTH IRZ generated byproducts in the deeper portion of the aquifer. The Riverbank wells are designed to be screened beneath the naturally occurring reducing rind to minimize negative hydraulic impacts on the reducing rind; and reduce the potential for well fouling in the Riverbank extraction wells caused by the presence of dissolved minerals in the naturally reduced groundwater in the rind. As discussed in response to comment #266 DOI-86, the riverbank extraction wells can be constructed in a manner that would allow them to be modified if observed conditions suggest it is necessary to control Cr6 migration. One approach would be to build the well so that the casing in the shallow unit could be perforated if water needed to be pumped from the shallow zone. Alternative designs will be considered and one selected and presented in the 60% design.	Okay pending review of the 60% design submittal. Please note it was DTSC's understanding prior to the 30% design that the Riverbank Extraction wells were stop gaps to capture not just Cr(VI), but also any byproduct formation from remedy that may expand toward and under the Colorado River. Currently as described, the Riverbank Extraction Wells will not have capture of the resulting by-products, This is an area of interest to stakeholders and agencies since the RAO is to ensure that the "geographic location of the target remediation area does not permanently expand following completion of the remedial action."		Comment resolved.	See Section 3.2.
79	DTSC-19	Page 3-3, Section 3.3, In-situ Remediation	First bullet of page. The stated purpose of the TCS recirculation loop is "to provide hydraulic capture of contaminated groundwater at these locations and to directly treat Cr(VI) under the TCS."	At present, the extent of contamination or the hydraulics of the TCS and East Ravine area is still under investigation. DTSC agrees that the purpose as stated is appropriate for the remedy, but the implementation of the conceptual extraction system may not be sufficient for that purpose. In addition, the measurement of that success will be unlikely for decades.	Comment noted. PG&E recognizes that the TCS and East Ravine areas are still being investigated and that as new information is gathered prior to and after remediation begins, adjustments to the system may be necessary.	Okay pending review of 60% design submittal		Comment resolved.	

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
80	DTSC-20	Page 3-3, Section 3.2.1	Up to 24 injection wells (i.e., NTH IRZ injection wells) situated within 16 locations or clusters also located within the NTH IRZ, that will be used to re-inject carbon-amended water into the aquifer	It is unclear if Appendix B model runs (B-27 to B-30) are results of 75 ft spacing or revised 150 ft spacing. Also, are they running all optional wells or just the proposed 16 locations? If the model is showing Cr(VI) transport running all wells, what will be the fate of the Cr(VI) as proposed in Fig 3-1? Also, what triggers the proposed future provisional wells shown in Fig 3-1? This section should explain or at least mention upfront the provisional NTH IRZ wells that are pictured along the NTH IRZ.	Text will be clarified in the 60% design to differentiate between the 75 ft and 150 ft NTH IRZ well spacing layouts and analysis. The Appendix B model runs (B-27 to B-30) are indicative of the revised 150 ft well spacing – primarily 150 spacing with several 75-foot spaced wells near the center of the line. The flows are reflected in B-26. The provisional wells in Fig 3-1 will be clearly labeled. The need to install and activate the proposed provisional NTH IRZ wells will be based on the monitored performance of the NTH IRZ and the generated reducing zone over time. Further discussion will be included in the 60% design.	Okay, pending review of 60% design submittal		Comment resolved.	See Section 3.2.1, Figures 3.0-1 and 3.1-1, and Appendix L (O&M Manual).
81	DTSC-21	Page 3-3, Section 3.2.1	3rd bullet	The numbers of wells in most figures do not correspond to 24 wells and 16 locations. PG&E should label all figures for clarity. Note: Fig 3-1 provided well IDs, but there are only 16 injection wells. The legend for the figure suggests that those are individual wells and not wells locations. It isn't clear until Table 3-1 which provided well counts at each IRZ. This needs to be more consistent and easier to track.	The presentation and labeling of the NTH IRZ wells will be clarified in the 60% design.	Okay, pending review of 60% design submittal		Comment resolved.	See Figures 3.0-1 and 3.1-1.
82	HA-14	p. 3-3, Section 3.2.1 (National Trails Highway ...)		The locations of the NTH IRZ Extraction Wells are not specified. It is understood that these wells are components of "clusters," but the configuration of a cluster should be depicted schematically somewhere to aid in understanding of how the system operates. What information will determine whether the NTH IRZ well spacing will be at 75 or 150 feet? Will this be determined during drilling or later during start-up operations? How long will it take to make such a determination? How will the monitoring data be used to facilitate such a determination?	Additional details regarding well clusters will be provided in the 60% design documents. Initially the model will be used to select spacing; drilling will not likely lead to spacing changes unless water quality data indicates an absence of a plume, Operational data collected from MW's will be used in conjunction with operational data to determine if more wells are needed. The need for more wells will take anywhere from a few months to several years to determine and will be dependent on the natural system's response and the success of less intrusive system adjustments. A more detailed discussion of monitoring data and its application will be included in the 60% design. These details are not fully developed at this time.	Comment and response noted.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		See Section 3.2.1.1, Table 3.2-1, and Appendix L (O&M Manual).

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
83	DTSC-22	Page 3-3, Paragraph 1, Section 3.2.1.1 Description – NTH IRZ		The paragraph starts out by stating, "The NTH IRZ Extraction Wells will be located far enough away from NTH IRZ Injection Wells to minimize the extraction of reduced water containing organic carbon or dissolved metals. " However, proposed extraction well IRZ-23 is located adjacent to injections wells on the north and south and with a similar well spacing as the rest of the IRZ line. The rationale for placing well IRZ-23 in its location should be specified in this section as should the potential for this well to capture reduced water/organic carbon/ byproducts. The basis for the range of extraction and injection well flow rates mentioned in the section should be cited. Was consideration given to having the IRZ extractors located to the south rather than north to assist with East Ravine/TCS extraction systems to the south?	The language for the NTH IRZ extraction well layout will be corrected. The three northern NTH IRZ extraction wells were positioned to minimize the number of NTH IRZ wells and offer hydraulic control of the northern low concentration end of the chromium plume. Approximately 15 different NTH IRZ well layouts and extraction/injection patterns were considered during the remedial design phase. The original design consisted of 40 wells with approximately 75 ft spacing consistent from North to South along the NTH. The well spacing and injection/extraction pattern then went through several iteration processes until the optimized NTH IRZ well layout was achieved. The NTH IRZ extraction well located in the center of the NTH IRZ line (IRZ-23) was located in this position to maintain/accentuate the eastern flow component of the groundwater. The two closest NTH IRZ injection wells (IRZ-21 and IRZ-25) are 150 ft away from IRZ-23. There is potential for fouling at this location so the monitoring program will take this into consideration. Adjustments can be made to well rates and carbon dosing in this vicinity to alleviate well fouling. Numerous well layouts and rates were considered with the groundwater flow and transport models to develop this optimized well layout. Not all scenarios were included in the design report. Consideration was given to locating the IRZ extractors to the south, however given the limited alluvial thickness in this area and the necessary injection volumes to maintain an effective NTH IRZ. Locating the NTH IRZ extractors to the north proved to be more advantageous in model simulations. Additional information will be added to the 60% design submittal.	In the response, PG&E states: "*Adjustments can be made to well rates and carbon dosing in this vicinity to alleviate well fouling.*" However, DTSC is still unclear how each of those adjustments interplays with the others. DTSC anticipates that information will be provided in the 60% design submittal.		Comment resolved.	See Section 3.2.1.1, Appendix B, and Appendix L (O&M Manual).

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
84	DTSC-23	Page 3-3, Paragraph 2, 3.2.1.1 Description – NTH IRZ		The paragraph starts out by stating, "The NTH IRZ extractions wells will be constructed using up to 12-inch nominal diameter well casing with one or two screened intervals to target specific intervals of the geologic formation." Which horizons/intervals are being targeted and why?	As described in Section 3.2.5.1, the screen intervals will be chosen based on the portions of the aquifer containing contaminants requiring remediation. Preliminary screen lengths for each model layer are provided in the column "Preliminary Screen Length" in Table 3-1. The preliminary design may consist of a single screen across two or more of the model layers. Well design, including placement of screens, screen lengths, etc., will be updated and detailed during the 60% and 90% designs. It should be noted that the final placements and lengths of screens may be modified in the field during installation activities.	Okay pending review of future design submittals.		Comment resolved.	See Attachment D of Appendix C Design Bulletin (Remediation Well Design and Field Construction Approach).
85	DTSC-24	Page 3-4, Organic Carbon Substrate Amendment System (MW-20 Bench)		The section should reference figures of the proposed system.	Comment is noted. The section will reference the appropriate design drawings and may be supplemented with report figures in the 60% design submittal.	Okay		Comment resolved.	See Section 3.2 (including Section 3.2.1.1 under the heading Organic Carbon Substrate Amendment System).
86	DTSC-25	Page 3-4, Carbon substrate storage		Why did PG&E not discuss the carbon substrate storage tank(s) sizing? This should be included in the design and on P&ID. Also, PG&E highlighted the ethanol system design to minimize fire/explosion during a Hinkley site visit. As PG&E is proposing ethanol as a carbon substrate at Topock, fire/explosion design should also be discussed in the design.	Preliminary carbon substrate storage tank sizes are provided in the Appendix D Equipment List. The carbon substrate tanks located at the MW-20 Bench and Transwestern Metering Station Bench are currently planned to be approximately 20,000 gallons and 3,000 gallons, respectively. Further detail regarding the carbon substrate storage design, including sizing, will be provided in the 60% design submittal. A discussion of fire/explosion protection design requirements, especially those related to the electrical installation, is provided in Section C.4.6 of Appendix C. Additional details will be included in the 60% design submittal.	Okay, pending review of 60% design submittal		Comment resolved.	See Section 3.2.1.1 under the heading Organic Carbon Substrate Amendment System and Appendix C (Section C.5).

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
87	DTSC-26	Page 3-5, Tanker Truck Unloading Pad and Portable Tanks		Tanker truck section discussed the construction of a pad to accommodate 110% of one tanker truck volume. Its design will need to be included. If this is included in a drawing, PG&E should reference its location. Similarly, the portable tanks are stated to be from 5 to 1000 gallon capacity, this is a large range. Drawings and diagrams in the final design will need to be more specific.	Comment is noted. The preliminary tanker truck unloading pad location is shown on Drawing C-9 of Appendix D. Additional pad design details will be included in the 60% design submittal. The use and design of portable tanks is provided to allow flexibility in system operation. Portable tanks for reagent delivery will be the exception not the rule. Thus, a range of 5 to 1,000 gallons is provided in the 30% design to accommodate the potential range of carbon dosages to the injection wells and uncertainties at the preliminary design phase. Additional design details regarding the portable tanks will be included in the 60% design submittal.	Okay pending review of the 60% design.		Comment resolved.	See Section 3.2.1.1 (under heading Portable Tanks) and Drawing S-06-03.
88	DTSC-27	Page 3-5, Portable Tanks		The text should elaborate on when portable tanks would be used for specific, targeted injections (How often would it occur? How many times? Where would it occur?). What is the decision point(s) for using a tank rather than installing a pipeline?	Portable tanks may be used in conjunction with substrates that are perishable (e.g., whey) and/or exhibit a long biodegradation half-life to facilitate a low volumetric dose. Portable tanks may also be preferred over pipelines at locations where the carbon injection volume is low enough, injections occur with long rest periods, or long pipelines are expected to pose health and safety, engineering design, and/or long term operation and maintenance challenges. Operational details, including the use of portable tanks for the direct injection of dilute carbon substrate solution at the wellheads, will be included in the O&M Plan. Additional design details regarding how the carbon substrate amendment system will accommodate portable tanks will also be included in the 60% design submittal.	Okay pending review of the 60% design.		Comment resolved.	See Section 3.2.1.1 (under heading Portable Tanks) and Appendix L (O&M Manual, Volumes 1 and 3).

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
89	DOI-25	Section 3.2.1.1/3-5/Organic Carbon Dosing and Delivery Strategy		It is stated that substrate use will be 700 gpd based on ethanol. How different would the flow be based on lactate as the substrate? When will the substrate to be initially used be selected? Please provide an example of how monitoring data will be used to adjust carbon substrate flow rates and frequency of injections. For the example, indicate which monitoring wells would be used, what data will be reviewed, and what would be the rationale to make the adjustments.	Based on the differences in density and organic carbon content between 95% ethanol and 60% sodium lactate, 700 gpd of ethanol is equivalent to approximately 1,100 gpd of lactate. It should be noted that the 700 gpd usage rate for ethanol is a maximum rate; the nominal target rate is 100 gpd. Based on the experience and successful treatment to date, the current plan is to start-up the system with ethanol. The 60% design will discuss the performance monitoring plan, including proposed monitoring well locations, sampling frequency, and target ranges of concentrations. Typically, MWs located within the In-situ Reactive Zone (IRZ) will be used to monitor organic carbon substrate distribution downgradient of the IRZ recirculation wells. Total Organic Carbon (TOC) samples will be collected from these wells and compared to target concentration ranges. If concentrations are too high or too low, adjustments of injection concentration, duration, or frequency, injection flowrates or other operational parameters may be made.		Okay pending review of the 60% design submittal.	Comment resolved.	See Section 3.2.1.1 and Appendix L (O&M Manual, Volumes 2 and 3).
90	DTSC-28	Page 3-5, Organic Carbon Dosing and Delivery Strategy		The basis for carbon substrate flow rates as well as TOC doses should be included in this section. Pilot Test data for the site should be utilized. This comment regarding stating the basis for the design also applies to other components of the remedy (e.g., inner recirculation loop, TCS recirculation loop) Clarify if carbon is planned to be recirculated between IRZ wells as originally proposed in the CMS/FS as it now appears to be a TOC injection only scenario. Distributing carbon across the IRZ transect is of concern if recirculation is not utilized as the floodplain pilot test demonstrated minimal lateral dispersion of a reducing zone. Will IRZ wells be designed with dual screens to assist in drawing carbon outwards from IRZ wells as done in the Upland Pilot Test? Why or why not?	**Organic Carbon Dosing and Flowrate Design** A section will be added to Appendix B in the 60 percent design discussing the results of in situ pilot tests and how these results were used in deriving a target TOC concentration for the remedy and will include a discussion the design principles that were presented at the January 19, 2012 TWG meeting. Organic carbon dosing is designed to achieve sufficient lateral distribution across the spaces between injection locations. As injected water travels away from a given injection well, the organic carbon substrate is consumed. An adequate concentration in the injection solution is required to ensure that there will be sufficient organic carbon substrate to cover the spaces between in the injection points. Modeling was utilized to develop a basis for rate, concentration, and frequency of carbon substrate injection to achieve sufficient organic carbon distribution and chromium treatment. By varying these factors within the solute transport model, a balance was achieved to minimize the potential of the Cr plume migrating past the NTH IRZ. If the TOC carbon substrate	Okay pending review of the 60% design submittal.		Comment resolved.	See Section 3.2 and Appendix B.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
					concentration or the injection rate were too low, the solute transport model indicated bleed through of the Cr plume between the NTH IRZ injection wells. Similarly, if the off cycle of the remedial system was too long, the potential of the chromium plume migrating past the residual reducing zone increased. **Recirculation System Design** Several recirculation designs were discussed in the CMS/FS and considered for the NTH IRZ, including the use of dual screen wells (with injection and extraction intervals within a single location), alternating injection and extraction wells along the IRZ, and the 30% BoD proposed configuration with injection wells along the line and minimal extraction wells along the line. As the commenter indicates, one advantage of alternating injection and extraction wells or using dual screen wells is to induce cross-gradients to facilitate lateral organic carbon distribution. However, in practice it is difficult to operate such configurations without extracting organic carbon substrate or treated water; thus complicating system maintenance. For example, organic carbon distribution proved somewhat difficult with the use of dual recirculation wells in the uplands pilot test. A portion of the organic carbon substrate injected into one of the dual screened wells, PTR-1, short-circuited vertically and was extracted by the extraction interval in the same location where the substrate was injected, limiting the horizontal distribution laterally across the deep zone (i.e. to PT-8D). Similarly, difficulties were encountered when using the alternating injection and extraction well design at Hinkley. In that system, it was very difficult to distribute sufficient carbon to treat the space between injection and extraction wells without extracting organic carbon or dissolved metals in treated groundwater and the result was a discontinuous IRZ that produced fingers of treated water downgradient of the IRZ interspersed with gaps where Cr(VI) was not treated. As a result that system was reconfigured to place injection wells along the line and extraction wells on the ends and in minimal places along the line, similar to the design proposed for Topock in the 30 percent design.				

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
					The currently proposed design includes continuous operation of injection wells along the IRZ, which will allow for a much greater volume injected and greater radius of influence to be achieved than with the point injections that were applied in the Floodplain pilot test. For comparison, an injection well in the proposed design that receives 20 gpm for a 6 month operational period will receive 5.2 million gallons of water, whereas PTI-1D received 60 thousand gallons in the Floodplain pilot test. A discussion of these considerations will be added to Section 3.2.1.1 on NTH Highway Extraction and Injection Wells in the 60 percent design.				
91	DTSC-29	Page 3-5, Remediation Well Maintenance System		The section indicates that well maintenance reagents could be dosed into the carbon amended groundwater conveyance piping network via the well maintenance reagent delivery systems at the MW-20 Bench. This would seem to invoke special hazardous waste piping criteria (e.g., double- lined) for certain reagents (e.g., acid washes).	As discussed in Section 3.2.5.2, piping materials will be compatible with the characteristics of the conveyed fluids, including any well maintenance reagents and double-walled piping will be used to for any fluids that are California hazardous waste.	See response to item 128.		Comment resolved.	
92	DTSC-30	Page 3-5, Remediation Well Maintenance System/Well Maintenance and Rehabilitation Reagents		The sections should indicate where remediation well maintenance procedures and details will ultimately be located.	Comment noted. Remediation well maintenance procedures and details will be included in the O&M plan to be submitted with the 60% design submittal.	Okay pending review of O&M Plan		Comment resolved.	See draft O&M Manual, Volume 1 – Operations and Maintenance Plan.
93	DOI-26	Section 3.2.1.1/3-5 and 3-6/ Remediation Well Maintenance System and Well Maintenance and Rehabilitation Reagents		The text states that chemical rehabilitation reagents may be injected at the well head and/or dosed into the carbon amended groundwater conveyance piping network. Additional discussion is required on how this will be accomplished in practice since the system is serving two different purposes. Also, please provide additional discussion regarding the affects of the proposed reagents on groundwater chemistry and the reducing environment of the IRZ.	A more detailed discussion of the chemical rehabilitation process will be included in the 60% design. Detailed protocols and safety requirements will be part of the final O&M plan. Acids and biological dispersants are the likely chemicals that will be used to rehabilitate IRZ injection wells. Acids will lower the pH of groundwater, potentially temporarily dissolving Cr(III) minerals that have formed within the screen, filter pack or aquifer within the immediate vicinity of the injection well. Cr(III) dissolved will either be removed from the well during rehabilitation or will re-precipitate as pH is buffered following rehabilitation. The biological dispersant is not expected to impact the groundwater chemistry or reducing environment of the IRZ during rehabilitation.	Okay pending review of 60% design submittal.	Okay pending review of 60% design submittal.	Comment resolved.	See draft O&M Manual, Volume 1 – Operations and Maintenance Plan.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
94	DTSC-31	Section 3.2.1.2, Design Basis – NTH IRZ, Page 3-6		Define which organic substrate will be used. PG&E state that the selection of the substrate will depend on the balance between the mode of delivery, the substrate properties and the rate of carbon utilization. When can you make assumptions to make this determination? PG&E should have enough experience and information on this critical substrate. Will the design be based on ethanol or lactate and why? Once a substrate is determined to be used, can it be substituted readily to another substrate? What would be the rationale for changing the substrate if geophysical conditions or contaminant reduction is not as successful as anticipated? In the Floodplain ISPT, the purpose was to review the efficacy of reduction without continuous injection of lactate (6 injection events) over a year in a well cluster, and in the Upland, you used a different substrate to demonstrate the efficacy of recirculation over 6 months (using 38K gallons of reagent) in two wells 140 ft apart. The two pilot tests have different parameters and goals, with different substrates. How are the results being used and related back to the remedy? PG&E should provide a discussion to tie in the pilot tests and remedy.	**Organic Carbon Substrate Selection and Implementation** As the commenter notes, the pilot tests evaluated lactate and ethanol organic carbon substrates. Both substrates have similar properties, such as degradation rates. The pilot test results demonstrated that both reagents are effective for chromium treatment. Based on the past success, level of experience, and cost effectiveness of each reagent considered, ethanol was chosen for use in the final remedy, as will be stated in the 60% design. Substrate selection may change over the lifetime of the project as substrate costing varies. In addition, other substrates, such as longer lasting substrates, could be useful for certain situations that arise over the life of the project, and as such documents written to date have preserved the option of using additional substrates. The 60% design will present the performance monitoring plan for evaluating substrate distribution and when different substrate may be needed to achieve sufficient distribution over the course of the project. To the extent possible, flexibility is being incorporated into the design to allow for changes in substrates. Modifications to system equipment, including pumps and flow meters, may be needed to change substrates from ethanol to other potential substrates such as lactate or emulsified vegetable oil. Whey would require more extensive modifications to the substrate storage and dosing infrastructure, given its perishable nature. Changing substrates would also require some system preparation activities, for example, cleaning of the storage tanks and reagent lines. **Organic Carbon Substrate Delivery Design** As the commenter notes, the pilot tests were also used to evaluate reagent delivery and to gather data necessary for full-scale reagent delivery design. With the variable volume point injections conducted in the Floodplain pilot test, the radius to volume relationship and mobile porosity were determined. These basic distribution properties were used in the transport modeling, allowing for analysis of a variety of recirculation system layouts. One of the main objectives of the Uplands pilot test was to test the ability to distribute	Okay		Comment resolved.	See Section 3.2.1.2, Appendix L (O&M Manual, Volume 3), and Appendix B.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

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<tr><th>Item</th><th>Comment Number*</th><th>Section/Page</th><th>Reference Text</th><th>30% Design Comment</th><th>PG&E Response to 30% Design Comment</th><th>DTSC Response to 30% Design Comment</th><th>DOI Response to 30% Design Comment</th><th>Final Comment Resolution</th><th>Where Responses are Reflected in the 60% Design Documents**</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>organic carbon by recirculation with recirculation wells with two screens, one used for injection and one used as extraction at each location. As discussed in the final report, the findings of the study indicated potential issues with distribution of organic carbon substrate in this recirculation design, due to vertical short circuiting between injection and extraction intervals that limited lateral distribution at the middle and deep intervals. Based on this information, the recirculation system for the final remedy does not include recirculation wells with injection and extraction intervals at the same location.
The 60% design will contain a discussion of the pilot test results and how they were used in the full-scale design.</td><td></td><td></td><td></td><td></td></tr>
<tr><td>95</td><td>Hualapai-17</td><td></td><td></td><td><u>Evaluation of First-order Rate Constants to Estimate Remedial Timeline</u>
First-order rate constants have been calculated for Cr(VI) reduction using data from the Upland ISPT. The rate constants can be used for estimating how quickly remediation goals will be met at a site. The rate constant is dependent on TOC concentration, and the Cr(VI) reduction rate constant (k) is determined graphically (Appendix A). From ISPT data, the Cr(VI) reduction rate constant ranges from k = 0.0021 d-1 for TOC =146 mg/L to k = 0.80 d-1 for TOC = 8,050 mg/L (Table 1, Figure 1). The rate Cr(VI) constant varies by two orders of magnitude. This means that the time required to remediate the plume while injecting TOC = 150 mg/L will take 381 times longer than it would take to remediate the plume using 8,050 mg/L.
Table 1. Summary of rate calculations for Cr(VI) reduction
<table>
<tr><th>ISPT Well</th><th>TOC, mg/L</th><th>First-order Rate constant k, d^{-1}</th></tr>
<tr><td>PT-9S</td><td>146</td><td>0.0021</td></tr>
<tr><td>PT-7S</td><td>896</td><td>0.0119</td></tr>
<tr><td>PT-8S</td><td>1740</td><td>0.0753</td></tr>
<tr><td>PT-7D</td><td>5430</td><td>0.3263</td></tr>
<tr><td>PT-7M</td><td>8050</td><td>0.8003</td></tr>
</table>
Data from the Upland ISPT indicates that some of the ISPT monitor wells show Cr(VI) reduction and some wells do not show Cr(VI) reduction in response to ethanol injections. Total organic carbon (TOC) injected into the groundwater system was successful in removing Cr(VI) from the aquifer in the immediate vicinity of certain wells. The wells with successful Cr(VI) removal were mostly located within 20 feet of the TOC</td><td>Kinetics and competition for organic carbon substrate
With regards to the comments on kinetics and competition, a complete response to this comment will be provided in the 60% design. Several key points that will be discussed to address the concerns raised in this comment will include:
• The various factors that contribute to the rate of decrease in Cr(VI) concentrations at each location, including the size of the active microbial population and the hydraulics of mixing at locations downgradient or cross-gradient of injection points. These factors confound the first order rate coefficient analysis and can explain the variation in rates observed.
• The amount of organic carbon distributed in the Uplands pilot test was greater than necessary due to the nature of the recirculation system tested, making it difficult to draw any conclusions about the relationship between the maximum concentrations observed (as noted in the comment table) and the rate of decreasing Cr(VI) concentrations. Rapid Cr(VI) reduction at locations like PT-7M, PT-7D, and MW-24A was achieved when TOC concentrations were lower than the maximum in the comment table.
• As discussed at the TWG meeting, the consumption for organic carbon substrate by various electron acceptors was accounted for in the design through a kinetic model, although the model does not differentiate between</td><td>Comment and response noted.</td><td>Comment and response noted. Further evaluation will occur during the review of 60% design submittal.</td><td></td><td>See Appendix B.</td></tr>
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APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
				injection. Wells further away from injection showed less success in Cr(VI) reduction. Chromium reduction was not successful in ISPT monitor wells where high nitrate and sulfate concentrations were present (Figure A1). In other wells where Cr(VI) removal was successful (wells showing high TOC concentrations), sulfate reduction occurred concurrent with Cr(VI) reduction (Figures A2 and A3), indicating that sulfate reduction is required to completely remove Cr(VI). Injection of TOC creates conditions suitable for sulfate reduction and formation of sulfide minerals (such as pyrite). As sulfate is being reduced, pyrite is being precipitated (probably as colloidal pyrite), and dissolved iron is not present in water samples. When the sulfate is completely consumed, dissolved iron begins to show up (Figures A2 and A3), and manganese concentrations increase dramatically due to the reductive dissolution of naturally present manganese oxides. The data indicate that sulfate and nitrate compete with Cr(VI) for reduction; therefore, it is likely that the proposed injections of low TOC concentrations (100 to 150 mg/L) will not be sufficient to fully remediate Cr(VI) in the Topock plume. The 30% Design report states that the IRZ line along the NTH IRZ will inject a nominal TOC concentration of 100 mg/L (maximum of 500 mg/L). As shown by the rate constants, these low TOC concentrations will take a longer time to remediate the plume than would higher TOC concentrations. In order to remediate the plume more quickly, an alternative may be considered where early in the remediation, high TOC concentrations are injected into the heart of the plume where the highest concentrations are located beneath and northeast of the Compressor Station. Byproducts will be generated by the injection of high TOC concentrations. During the same early periods, low TOC concentrations are injected into the NTH IRZ line in order to remediate the floodplain portion of the plume, and lower byproduct concentrations are generated using low TOC concentrations. Then as the byproducts from the heart of the plume migrate towards the Colorado River, the IRZ line can be turned into an oxidative line to prevent the byproducts from entering the river.	electron acceptors. As presented at the January 19, 2012 TWG meeting, the ISPT data demonstrates in many cases that Cr(VI) reduction occurs concurrently with other reductive processes such as nitrate, iron, and sulfate reduction and is more thermodynamically favorable than sulfate reduction. Some of these topics were discussed at the TWG meeting on January 19, 2012. A complete discussion of the data and concepts presented at the TWG meeting will be included in the detailed response to comments as part of the 60% design. In addition, there will be a discussion of the data from each monitoring location discussed in this comment, so that it is clear how all of the data was evaluated and interpreted and used to inform the current design. The possibility of using higher TOC concentrations in the higher Cr(VI) concentration areas at the Compressor Station could be considered as the system is started up and monitoring data are evaluated; but such changes will be balanced with the relative benefit in IRZ maintenance and the relative cost of by-product generation. The change of the NTH IRZ from a reductive barrier that is used to treat the Cr(VI) that is flushed through the barrier throughout the remedy to an oxidative barrier would be of limited value since the manganese generated in the heart of the plume has a very limited footprint.				

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
96	Hualapai-34			Additional Technical Considerations Have horizontal wells been evaluated as a way to potentially increase the area over which carbon can be introduced into the Cr(VI) plume, without having to increase the number of wells or infrastructure?	Horizontal wells were screened out for use in this application. There would be a number of significant technical challenges with using horizontal wells for this purpose and it is unlikely that horizontal wells would outperform the series of vertical wells currently proposed. It is also unlikely that horizontal wells could be used to replace the deeper wells or the deeper screens in the dual screen injection wells due to significant challenges with constructing a deep horizontal well. An assessment of the applicability of using horizontal wells in lieu of the shallow (vertical) injection wells indicated that difficulties in construction, inherently less efficient screen designs, difficulty in well development, less efficient well performance, difficult well maintenance, and the difficulty of well replacement all make horizontal wells a poor choice for this site.	Comment and response noted.	Comment and response noted.		
97	DOI-27	Section 3.2.1.2/3-6 and 3-7/ Appendix C		The text states that multiple carbon sources may be used during remedy implementation. Please explain how operational data will be used to evaluate substrate performance and what “triggers” will be used to prompt the use of an alternative substrate during remedy implementation.	Operational data collection and how the data will be used to adjust system operations will be discussed in detail as part of the O&M plan in the 60% design. The use of alternative substrates will be included in the O&M plan.		Okay pending review of 60% design submittal.	Comment resolved.	See draft O&M Manual, Volume 1 – Operations and Maintenance Plan.
98	DTSC-32	Section 3.2.1.3, Uncertainties and Assumptions, Page 3-7		Since PG&E proposes the use of adaptive operational approach, provide a general discussion of your adaptive protocol and criteria for adapting/adjusting the system; what is your anticipated adaptive review process that was used in the in situ pilot tests and what differences and how difficult will it be to make changes in the full scale design? What are your initial design criteria, estimated flow rates, carbon concentrations, specifications for each well? Will they vary based on geochemical or other differences?	Preliminary design criteria, including carbon concentrations, estimated flow rates, and well specifications, are discussed in Section 3.2.1.1. Preliminary design flow rates are also provided in Table 3-1. Operational modifications may include adjustments to injection rates, extraction rates, and/or organic carbon loading as discussed in Section 3.2.1.3. The 60% design submittal and O&M Plan will discuss the performance criteria that will trigger modifications to the operational approach, and will present the protocol for implementing such changes.	Okay pending review of 60% design.		Comment resolved.	See Appendix L (Draft O&M Manual, Volumes 2 and 3).

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
99	Hualapai-6			Evaluation and Application of In-Situ Pilot Scale Test Results Section 3.2.1.2 of the report does not appear to adequately address all the results from the pilot studies, and may suggest an incorrect conclusion from these studies. A summary description of both the upland and flood plain pilot studies should discuss not only the positive aspects of the pilot results, but highlight the uncertainties which were also revealed. For example, both ISPT studies show that 1) total organic carbon (TOC) concentrations are unevenly distributed within the IRZs, 2) there is a low overall correlation between ORP and TOC concentrations, and 3) even in the presence of high TOC and low ORP, some monitoring wells still show persistently high concentrations of Cr(VI).	In light of this comment, a discussion of the pilot test data will be included in a detailed response to comments in the 60% design document. In brief, with regard to the three comments: 1) In the Floodplain pilot test, the organic carbon substrate distribution followed a radius of influence/ injection volume relationship typical of injection into a single injection point. Locations that did not receive organic carbon were outside of the radius of influence or upgradient of the injection point. One of the main objectives of the Uplands pilot test was to test the ability to distribute organic carbon by recirculation with recirculation wells with two screens, one used for injection and one used as extraction at each location. As discussed in the final report, the findings of the study indicated potential issues with distribution of organic carbon substrate in this recirculation design, due to vertical short circuiting between injection and extraction intervals that limited lateral distribution at the middle and deep intervals. Based on this information, the recirculation system for the final remedy does not include recirculation wells with injection and extraction intervals at the same location. 2 and 3) Several factors may confound the relationship between TOC distribution, changes in ORP, and Cr(VI), such as hydrogeologic flow conditions, particularly for wells downgradient or cross-gradient of a small pilot test within a larger contaminated area, and lag time for establishment of the microbial population. In addition, as the reviewer commented in a separate comment, the measurement of ORP can be subject to interference and uncertainty which is why it is not used as a primary metric.	Comment and response noted.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		See Appendix B.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
100	Hualapai-7 and TRC-20			Evaluation and Application of In-Situ Pilot Scale Test Results The statement that *"reduction of Cr(VI) from mg/L concentrations (e.g., 3.35 mg/L in April 2006) to concentrations of less than a fraction of a µg/L (e.g., 0.2 µg/L)"* while true for a subset of the ISPT wells is not true for all of the wells. Floodplain ISPT wells PT3D, PT 4D, PT5D, PT6D, PE-1, TW-2D and TW3D all maintained Cr(VI) concentrations an order of magnitude above baseline even in the presence of elevated TOC levels (up to 326 mg/L). **TRC Recommendation:** It is reasonable to expect that local-scale variations may cause requirements (such as TOC concentration) to differ along the actual IRZ line. It is anticipated that a discussion of how system monitoring and designed-in flexibility will be used to 1) identify these areas, and 2) allow for more intense treatment to produce effective chromium reduction along every segment of the IRZ.	It is agreed that there will be local variations in TOC distribution along the IRZs planned for the final remedy. The 60% design will present the performance monitoring plan for evaluating substrate distribution and modifying operations to address areas that are not receiving sufficient organic carbon substrate. With regards to the pilot test data, the distribution of TOC was governed by the radius of influence (ROI) of the injection point (i.e. higher concentrations of TOC and tracer were distributed to monitoring well locations closer to the injection point) and the hydraulic gradient (i.e. outside of the ROI, TOC was distributed to downgradient locations and not to upgradient locations). A more detailed discussion of these monitoring well trends and the reasons carbon distribution as not expected or observed at extraction wells (TW-2D, TW-3D, and PE-1) will be included in the detailed response to comments in the 60% design.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		See Appendix B and Appendix L (Draft O&M Manual, Volumes 2 and 3).
101	Hualapai-8 and TRC-19			Evaluation and Application of In-Situ Pilot Scale Test Results Chromium reduction is dependent on TOC concentration, and the oxidation- reduction potential (ORP) can be used as a surrogate to measure the effectiveness of the carbon-induced reduction. Data from well MW-24A from the Upland ISPT show that TOC concentrations of 100 to 500 mg/L were effective in achieving ORP of -200 to -250 mV necessary for Cr(VI) reduction (Figure 1). However, data from well PTR-1 show that similar TOC concentrations were not effective in that area in achieving the range of ORP needed to cause Cr(VI) reduction. (see also data plots in Appendix A). **TRC Recommendation:** This suggests aquifer heterogeneity exists which may not have been factored into the current model and suggests that local-scale heterogeneity may dominate. It is anticipated that a discussion of how the impacts of heterogeneity will be monitored for during initial startup, and how contingencies to enhance and/or modify the system may be implemented to deal with such situations.	Heterogeneity is addressed in the groundwater flow model by a variable hydraulic conductivity distribution established during the groundwater flow model calibration process. This distribution was based on observed field data and further refined through parameter estimation (PEST). Documentation with respect to the groundwater flow model is presented in CH2M HILL 2005 and 2009. Heterogeneity is also addressed in the solute transport model by simulating the system as a dual domain model. This allows for interaction between the mobile and immobile porosities. The 60 percent design will include a performance monitoring program that will address these concerns and contingency plans. In addition, the detailed response to comments will be included in the 60 percent design and will include an analysis of the relationship between TOC distribution, redox conditions and hexavalent chromium reduction, including the information presented at the January 19, 2012 TWG meeting. With regards to the pilot test data, the data referenced in this comment was collected from a recirculation well, PTR-1, which represents mixing within the well and recirculation pipeline rather than distribution and treatment in the aquifer. As such, this data should not be used to assess in situ	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		See Appendix B and Appendix L (O&M Manual, Volume 2 and Volume 3, Section 2.1).

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
					treatment or make predictions for the full-scale system.				
102	TRC-5			Chromium data from the in-situ pilot studies (ISPT) show differing results in response to carbon injections. Some wells showed Cr(VI) reduction, and some wells did not show Cr(VI) reduction. Upland ISPT wells showed different Cr(VI) reduction rates for different TOC concentrations (Figure 1). Data from the Upland ISPT shows that nitrate (NO3) and sulfate (SO4) concentrations may be competing with Cr(VI) for reduction (Figures A1-A3). **TRC Recommendation:** This suggests aquifer heterogeneity exists which may not have been factored into the current model and suggests that local-scale heterogeneity may dominate. It is anticipated that discussions will take place regarding model updates, system monitoring, and designed-in flexibility in order to 1) identify recalcitrant areas, 2) refine the remedy time frames, and 3) allow for more intense treatment to produce effective chromium reduction along every segment of the IRZ.	Local scale aquifer heterogeneities are present in most systems. The groundwater flow model accounted for this heterogeneity by defining a hydraulic conductivity distribution based on available field data and through parameter estimation (PEST) during the groundwater flow model. Aquifer heterogeneities were accounted for in the solute transport model by simulating the model as a dual domain system with mobile and immobile porosities. The combination of a variable hydraulic conductivity distribution with dual domain aids in accounting for the heterogeneities present in the aquifer. It is agreed that there will be local variations in TOC distribution along the IRZ planned for the final remedy. The 60% design will present the performance monitoring plan for evaluating substrate distribution and modifying operations to address areas that are not receiving sufficient organic carbon substrate. With regards to the competition for electrons from ethanol by nitrate and sulfate, this has already been accounted for in the degradation rate for organic carbon used in the model. In reality, the organic carbon substrate will support reduction of a variety of electron acceptors, including nitrate and sulfate; in addition, sufficient organic carbon must be injected to achieve distribution throughout the target area. A summary of the concepts and data presented at the January 19, 2012 TWG meeting on this topic will be included in the detailed response to comments as part of the 60% design.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		See Appendix B and Appendix L (O&M Manual, Volumes 2 and 3).

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
103	DTSC-33	Section 3.2, Uncertainties and Assumptions for most remedial components	An adaptive operational approach is described by PG&E for almost all components of the remedy to be implemented.	Although an adaptive operational approach can be employed during the remedy, PG&E must describe to readers how changes in the specifications will effect and/or impact each component of the remedy. Evaluation metrics (short term measurable performance goals) will have to be developed, which will ultimately affect the redundancy and flexibility, and/or contingency part of the design. Because of the current PG&E approach, it is difficult to make any specific comments on the design including sizing, controls, spare piping, and the P&ID, etc.)	Preliminary design criteria, including carbon concentrations, estimated flow rates, and well specifications, are discussed in Section 3.2.2.1. Preliminary design flow rates are also provided in Table 3-2. These have included both nominal values and operational ranges (i.e., maximum and minimum) for consideration in the design at this stage, which will be further developed as the design progresses. These also consider modifications that may be made during the system operation. The 60% design submittal and O&M Plan will discuss the performance criteria that will trigger modifications to the operational approach, the protocol for implementing such changes, and how elements of the system are designed to accommodate the necessary adaptability.	Okay pending review of 60% design		Comment resolved.	Appendix L (O&M Manual, Volumes 2 and 3).
104	HA-15	p. 3-7, Section 3.2.1.3 (Uncertainties and Assumptions)		This paragraph highlights the relationship between the ability to circulate organic compounds at the NTH IRZ into the floodplain area and the impact of geologic and hydrogeologic heterogeneities within the aquifer. This is an important consideration, the effect of which will remain uncertain until the start-up and operation of the remedy. In order to ascertain the impact of such an uncertainty, it will be necessary to perform monitoring at strategic locations down gradient from the NTH IRZ and to have a contingency plan for addressing the potential for contaminant breakthrough. Such information should be provided in the 60%. Has PG&E performed any simulations based on scenarios assuming hypothetical pathways with higher hydraulic conductivities and then the type of contingency that would be necessary to control such breakthroughs? The Tribe notes that at the Hinkley Site, such a breakthrough occurred along the Central Area IRZ (as discussed in the December 13, 2011, meeting at Hinkley) after 44 months of operation.[4] Has anything been learned as a result of that occurrence that might be applicable to the Topock Site? [4] PG&E, 2012. "In-Situ Reactive Zone Treatment System Overview, Hinkley Gas Compressor Station, Groundwater Remediation Project." See Slide No. 14 "Central Area Treatment System Effectiveness – 44 Months" (8/11)	Heterogeneity is addressed in the groundwater flow model by a variable hydraulic conductivity distribution established during the groundwater flow model calibration process. This distribution was based on observed field data and further refined through parameter estimation (PEST). Documentation with respect to the groundwater flow model is presented in Hill 2005 and 2009. Heterogeneity is also addressed in the solute transport model by simulating the system as a dual domain model. This allows for interaction between the mobile and immobile porosities. The monitoring program will be described in detail in the 60% design. Contingency actions will also be described in the 60% design. The gap that exists in the Hinkley Central Area IRZ barrier is not due to a breakthrough but rather the lack of adequate injection well infrastructure in a portion of the IRZ line. After attempts to fill the gap using higher flowrates and increased TOC loadings failed, a new well was installed. The latest data indicates that the gap is being filled.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		See Appendix B and Appendix L (O&M Manual, Volume 2 and Volume 3, Section 2.1).
105	DOI-28	Section 3.2.2/3-7/ 1st Paragraph		The CMI/RD Work Plan also indicates that the inner recirculation loop provides secondary protection for the Colorado River by controlling the migration of byproducts generated by the IRZ. Please add this discussion.	This discussion will be added as a section in the 60% design submittal.	Okay pending review of 60% design submittal	Okay pending review of 60% design submittal.	Comment resolved.	See Section 3.2.2 and Appendix B.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
106	DTSC-34	Page 3-7, Section 3.2.2 Inner Recirculation Loop		The Inner Recirculation Loop (IRL) is stated to include four carbon-amended injection wells installed near the western margin of the groundwater plume north of I-40, yet some of these wells are not planned as carbon-amended wells and Table 3-4 suggests that all may be freshwater injection wells at some point in time. This section should clarify this issue.	Text will be updated to clarify the operation of the Inner Recirculation Loop wells. The current proposed layout has the northern 2 IRL injection wells receiving water from the Riverbank Extraction wells. The system is modeled without carbon amendment based on the projected chromium concentration from the Riverbank extraction wells; but the system is capable of delivering reagent to the Riverbank flow stream if Cr6 exceeds the target cleanup goal. The 2 southern IRL injection wells are simulated as freshwater injection wells. It is proposed that the IRL layout be flexible to potentially oscillate between freshwater and riverbank extraction water sources to alleviate potential byproduct impacts. Please also see RTC#262 (DOI-84). Additional details will be provided in the 60% design.	Okay pending review of 60% design submittal		Comment resolved.	See Section 3.2.2.
107	DTSC-35	Page 3-7, Section 3.2.2.1 Description – Inner Recirculation Loop		The rationale for having three to five of the River Bank Extraction Wells operated at any given time should be included in this section as should the criteria that would guide one to increase or decrease extraction rates.	This rationale will be included in the 60% design. It will include consideration of the need to: capture potential Cr(VI) concentrations located downgradient of the NTH IRZ, control IRZ by-product migration, accelerate the remediation timeframe through enhanced gradients, and minimize the effects of riverbank extraction on development and maintenance of the NTH IRZ . Monitoring wells will be used to help monitor the effectiveness of the NTH IRZ, and help determine the ideal Riverbank Extraction well pattern to maintain an appropriate balance of these operational goals.	Okay pending review of the 60% design submittal		Comment resolved.	See Section 3.2.2.1 and Appendix L (O&M Manual, Volume 2).

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
108	HA-16	p. 3-7, Section 3.2.2.1 (Description – Inner Recirculation Loop)		"River Bank Extraction Wells" This section generally describes the design of the River Bank Extraction Wells, indicating that these 12-inch wells may have two discrete screened intervals. Where will these be screened relative to the natural reductive zone in the rind of the fluvial sediments? What will determine whether one or two intervals are screened? While Table 3-2 indicates a maximum extraction rate of 500 gpm, it appears that the maximum capacity could be 850 gpm total. Is this rate of extraction consistent with the design? Are there any scenarios whereby contaminated groundwater upgradient from the River Bank Extraction Wells could either breakthrough, migrate around, or otherwise escape capture by the River Bank Wells? "Carbon-Amended Injection Wells" – Will injected freshwater also be amended with carbon prior to injection to facilitate chromium reduction?	The river bank extraction wells will be screened in Model Layers 3 and 4. Care will be taken to ensure that the extraction well screens do not intersect the natural reducing zone. No more than two screened intervals are included in any one well. The need for more than one screen is based on a maximum screen length of 40 feet. Refer to Table 3-1. Section 3.2.2.1 indicates that the expected total average river bank extraction flow rate is 150 gpm (based on the individual nominal extraction rates), and that there will be flexibility to increase this flow rate to 500 gpm. Although the sum of individual design capacities is 850 gpm, it must be noted that all the extraction wells will not be operating at full capacity at any given time. This data is consistent with the design of the extraction wells. Based on the projected operation of the system and the model results, breakthrough is not anticipated. The fresh water injection is planned for areas outside the plume and therefore the system does not include a carbon amendment.	Comment and response noted.	Comment and response noted.		
109	DOI-29	Section 3.2.2./3-8/ 21st Paragraph/last line		Add that amendment with carbon will occur if extracted flood plain groundwater chromate concentrations increase above the cleanup level.	This detail will be added to this section in the 60% design submittal.	Okay pending review of 60% design submittal.	Okay pending review of 60% design submittal.	Comment resolved.	See Section 3.2.2.1.
110	DTSC-36	Page 3-8, Carbon-Amended Injection Wells		The section indicates that the target dosage concentration for flow from the River Bank Extraction Wells is between zero and 50 mg/L of TOC and that TOC may be added to facilitate treatment of Cr(VI). The basis for the target dose and criteria for adding more (or less) TOC should be clearly explained in this section.	The rationale for this concentration range will be added to this section in the 60 % design. Low concentrations of organic carbon were planned for the carbon amended injection wells in the event that Cr(VI) is extracted at concentrations that require treatment. The low end of the range, 0 mg/L, was included in case Cr(VI) is not present in extracted water and in-situ treatment is not required. The maximum concentration of Cr(VI) anticipated based on modeling results is 13 ppb, below the background concentration of 32 ppb, indicating that treatment of this water is not likely required. Should Cr(VI) treatment be required, low concentrations of organic carbon will be added. Once the reducing zone is established, a low concentration of organic carbon would be required to consume the dissolved oxygen, nitrate, and chromium and to promote iron reduction for potential abiotic reduction of Cr(VI). For reference, approximately 3.4 mg/L of TOC from ethanol would be required to reduce 8 mg/L of oxygen, 2 mg/L nitrate as N, 13 ppb Cr(VI). The upper end of the range was	Okay pending review of 60% design		Comment resolved.	See Section 3.2.2.1.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
					established above this concentration to allow for additional consumption of TOC for cell growth, promotion of reducing conditions in the subsurface, and to accommodate for uncertainties in field implementation.				
111	DTSC-37	Page 3-8, Remediation Well Maintenance System		The rationale for operating the backwash pumps at two times the injection flow rates should be stated in this section. Would another rate be better? May different rates be employed based on responses at specific wells?	The proposed backwashing rate is based on experience gained from the operation of Aquifer Storage and Recovery systems. Backwashing is currently being evaluated on an IRZ well at the Hinkley Compressor Station. Preliminary operating data from Hinkley indicates that backwashing effectively prolongs the injection capacity of the IRZ well. Flexibility in the system operation is planned to allow for variable flows and frequency of backwashing based on system performance. Additional details regarding the backwashing rate and performance criteria for potential in-field adjustments will be addressed in the 60% design submittal and/or the O&M Plan.	Okay pending review of 60% design and O&M Plan		Comment resolved.	See Section 3.2.2.1 and Appendix L (O&M Manual, Volumes 1 and 2).
112	DTSC-38	Section 3.2.2.1, Carbon Amended Injection Wells, Page 3-8		What is the basis for the 50 mg/L? Would it be the same quantity regardless of substrate used? Will the injection rates vary by area or well? What are the rationale for this design?	See the response to comment 110 (DTSC-36) on the basis for the 50 mg/L upper bound on TOC concentrations. The stoichiometry discussed in that response was based on ethanol and would vary slightly if based on lactate (for the example given 5.1 mg/L of TOC from lactate would be required, compared to 3.4 mg/L of TOC from ethanol). This variation is small in comparison with the variability of field conditions. Injection rates and/or TOC concentration may be varied based on area or individual wells. Performance monitoring data will be used to inform the need for changes in the field.	DTSC assumes this to be part of the O&M plan. Okay pending review of future plan.		Comment resolved.	See Section 3.2.2.1 and Appendix L (O&M Manual).

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
113	DTSC-39	Section 3.2.2.1, Remediation Well Maintenance System, Page 3-8		What is the fouling rate anticipated based on historical knowledge?	As discussed in Section 3.2.4.3, to date, no significant fouling has been observed in the pilot IRZ system injection wells at Topock. This may be related to the batch injection configuration used in the Floodplain pilot (limited flow of nutrients through the screen), and the high-concentration ethanol solution used in the Uplands pilot (doubles as a biocide inside the well and related piping). It is also likely that the limited duration of the pilot studies may not have allowed adequate time for fouling to occur to a degree that it impacted operations; however, a longer duration full-scale system will likely have to deal with well fouling. The proposed frequency of well maintenance (e.g. backwashing on a weekly basis) was based on fouling rates observed during the Hinkley pilot test and other full scale experience. More detail regarding the well maintenance program will be included in the 60% design submittal and the O&M Plan.	Okay, pending review of 60% design and O&M Plan		Comment resolved.	See Appendix L (O&M Manual, Volume 1).
114	HA-17	p. 3-8, Section 3.2.2.2 (Design Basis – Inner Recirculation Loop)		On January 9, 2012, PG&E conducted a site walk for tribal participants to examine proposed sites for the inner recirculation loop and other proposed facilities. The Tribe's conclusions with regard to the proposed sites are presented as Attachment B to this comment letter. Of further concern is the siting of monitor well(s) associated with the inner recirculation loop as referred to in Section 3.2.2.3. Once the monitoring network is proposed as part of the 60% BOD, the Tribe requests a site walk to evaluate the acceptability of proposed monitoring sites and will provide comments on the acceptability of the locations proposed.	The Tribe's request for a site walk of proposed monitoring well locations, is noted. PG&E will contact the FMIT and other interested Tribes once the logistics for the site walk are determined.	Comment and response noted.	Comment and response noted.		At the Tribe's request, PG&E held a site walk of the proposed monitoring well locations on July 19, 2012. On July 27, 2012, PG&E received a letter from Dr. Leo Leonhart, on behalf of the FMIT, expressing appreciation for the site walk and documenting various discussions exchanged in the field. The monitoring well network is discussed throughout this BOD report and in draft O&M Manual, Volume 2 (Sampling and Monitoring Plan).
115	DTSC-40	Page 3-9, Section 3.2.3, TCS Recirculation Loop		The TCS recirculation loop will use both the RAV-EXT 1-4 wells and the MID-EX 1-4 wells. It is unclear how balance can be achieved from the COMP-INJ wells.	Text will be clarified and updated in the 60% design report. The nominal extraction rate for the East Ravine wells is 2 gpm, and the nominal extraction rate of the Northeast of TCS Extraction wells is 19 gpm. Therefore by combining the aforementioned extraction rates the nominal TCS injection rate is 21 gpm. The COMP-INJ wells are expected to be more than adequate for this injection rate.	Okay pending review of the 60% design submittal		Comment resolved.	See Section 3.2.3.1 and Table 3.2-3.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
116	DTSC-41	Page 3-9, Section 3.2.3.1 Description–TCS Recirculation Loop Extraction Wells Northeast of the Compressor Station		The section indicates that four extraction wells are anticipated. The section should indicate what would cause the number of extraction wells to increase or decrease. Also see similar comments regarding the basis for flow rates.	The well quantity, spacing, and flow rates were based on the simulated aquifer thickness and associated hydrogeologic characteristics. This system layout and operation was optimized using the groundwater flow and solute transport model. Based on the groundwater flow and solute transport model, the 4 extraction wells in the embayment area operating at a total of 19 gpm were sufficient to hydraulically contain this vicinity. Characterization of this area is primarily defined by MW-59, and there are limited other wells in this vicinity. Installation of the 4 proposed extraction wells will assist in refining the understanding of the hydrogeology of this area. If the aquifer conditions are different than anticipated, the number of extraction wells may need to be adjusted to achieve the desired hydraulic control in this area.	DTSC anticipates additional information (e.g., goal of the recirculation loop, hydraulic and water quality monitoring) to be provided in the 60% design and the draft O&M Manual.		Comment resolved.	See Section 3.2.3.1 and Appendix L (O&M Manual).
117	DTSC-42	Page 3-9, East Ravine Extraction Wells		This section should discuss how the East Ravine remedial approach has changed overtime. The basis for the following statement from the 2009 CMS/FS should be stated in this section, “Initial estimates are that approximately 15 wells, pumping a combined total of up to 10 gallons per minute, would be required to provide hydraulic capture of the area of Cr(VI) in East Ravine bedrock.” The East Ravine extraction system is now proposed to contain four wells pumping two gpm total.	A short discussion of the evolution of the East Ravine design will be added to this section of the 60% design. Data from the ongoing East Ravine groundwater investigation will also be discussed.	Okay pending review of the 60% design and draft O&M Manual		Comment resolved.	See Sections 3.2.3.1 and 2.1.2 and Appendix L (O&M Manual).
118	DTSC-43	Page 3-10, TCS Injection Wells		Based on TCS Injection well locations, DTSC is concerned that westward flow from these wells could push highly contaminated groundwater to the west in an uncontrolled manner. Note that freshwater injection wells to the north are located a significant distance away and that FW-INJ-4, located to the south, is pumping the smallest volume of freshwater. The section should indicate how this issue is being dealt with and, more importantly, how it will be addressed through groundwater monitoring and specific contingency protocols.	This was a critical consideration in the 30% design evaluation. Based on the modeling completed, the potential for westward flow is mitigated by injecting into FW-INJ-4. Although there are not any freshwater injection wells located directly to the west of the TCS injection wells, FW-INJ-4 (50 gpm) injects at more than double the rate than the combined TCS injection rate (21 gpm). This excess injection outside the footprint of the plume combined with the natural eastward flow gradient results in minimal westward flow near the TCS Injection wells. The groundwater flow and solute transport models indicate this eastward flow is maintained. The monitoring and contingency planning will be provided in the draft O&M Manual.	Okay pending review of 60% design and draft O&M Manual		Comment resolved.	See Section 3.2.3.1 and Appendix L (O&M Manual, Volume 2 and Volume 3, Section 2.1).

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
119	HA-18	p. 3-11, Section 3.2.2.3 (Uncertainties and Assumptions – TCS Recirculation Loop)		This section indicates that "Construction and cultural resources constraints may affect the design and operation ...." The Tribe would like to discuss specifics as to what parts of the design and operation are thought by PG&E or the Agencies to have been, or will foreseeably be, constrained by cultural resource considerations and the anticipated cost/schedule/performance impact of any such constraints.	The intention of this sentence was to explain that during the design, various constraints will be considered to avoid impacts. There are many elements of the system design – location of facilities, infrastructure, system profiles, etc, that were – and may be further - adjusted to accommodate the site constraints.	Comment and response noted.	Comment and response noted.		
120	DOI-30	Sections 3.2.3.1 and 3.2.3.2		The discussion contained within these two sections regarding the East Ravine Extraction Wells and Design Basis must be revised to reflect uncertainties in bedrock flow conditions resulting from the recent discovery of higher fracture flow conditions at Site H. (See General Comment 9) Given this, the discussion regarding the extraction wells in Section 3.2.3.1 must note that new information from the second phase of the investigation was not fully considered in the 30% design and it therefore can only be assumed that the groundwater production and radius of influence of the East Ravine Extraction Wells will be small. Consideration should be given to further evaluation and possible modification of the East Ravine bedrock remedy in the intermediate (60%) design. It is also recommended that the text in Section 3.2.3.2 be revised as follows: "Investigation of the East Ravine area has been conducted in two phases. The sustainable purge rates of wells drilled during the first phase were low, resulting in a preliminary conceptual model of a fracture flow system with limited interconnectivity and flow volume that was used as the basis for the 30% design. More recently during the second phase, one well location (Site H/ MW-70) exhibited relatively high extraction rates. At the time of the 30% design, it is unknown whether the conditions observed at Site H are isolated or represent potentially higher flow conditions than previously conceptualized for the East Ravine bedrock. ..."	The recently collected data was not considered in the 30% design, but will be included in the assessment and revisions to the system design as reported in the 60% design document. Any new information collected subsequent to the 60% design will be incorporated into the 90% design.	Okay pending review of 60% design submittal.	Okay pending review of 60% design submittal.	Comment resolved.	See Section 3.2.3.2.
121	DTSC-44	Page 3-11, Section 3.2.3.2 Design Basis– TCS Recirculation Loop		Maps with the extent of contamination should be included in the document to ensure the extent of the East Ravine plume is defined and to aid in evaluating that the remedy will clean up that portion of the plume.	Comment noted. Figures 2-3a through c depict the approximate extent of the CrVI plume.	Okay pending review of revised figures.		Comment resolved.	See Figure 2.2-1 of this BOD Report.
122	DTSC-45	Page 3-11, Paragraph 2, Section 3.2.3.2 Design Basis– TCS Recirculation Loop		The section indicates that sustainable purge rates of wells drilled during the first phase were too low for injection to be a viable remedial alternative. The basis for this statement should be included in the section as should the second phase data which did identify a higher permeability zone in bedrock.	Comment noted. This section o the 60% design document will include a discussion of the basis of this statement as well as a consideration of recent data collected in the ER/TCS investigation. Also please see response to RTC#10 (DOI-9).	Okay pending review of 60% design submittal.		Comment resolved.	See Section 3.2.3.2.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
123	DOI-31	Section 3.2.4.1/3-11/ 1st Paragraph		The operation of the CIP system requires more discussion. How often will the CIP system be used as this will require shutdown of substrate amended water injection? How much wastewater will it generate? The wastewater flow is not identified in Exhibits 3-5 or 3-7. How does it use the pumps, tanks, and metering equipment of the substrate amendment system?	Current experience with CIP systems for groundwater conveyance piping indicates that circulating a reagent amended water in a recirculation loop is an effective preventive maintenance solution to address problematic scale deposits. The reagents used are those categories of water treatment chemicals approved for use in drinking water systems. Ultimate selection of an effective reagent(s) will require bench-scale testing of actual scale deposits. Operation of the CIP system is expected to occur on an annual basis, but possible as little as once every five years. Operation of the CIP will take place over a limited period of time and be scheduled to take advantage of system shutdown periods. The volume of spent solution is expected to be roughly 10,000 to 40,000 gallons per event. The carbon amended water injection will be temporarily shut off during the CIP event (groundwater extraction will cease and clean water will be used to flush the lines). Each conveyance forcemain will be valved to isolate the wells and create a loop with its associated spare conveyance header which will originate and terminate with the CIP Tank (frac tank). Fresh water will be added to the CIP tank and amendments will be added (per the recommended recipe based on the testing program from the scale deposit samples). The CIP system will operate by recirculating the amended water in a loop. Upon completion, freshwater will be added to flush the lines. The conveyance lines will be valved to facilitate normal operation upon completion of the CIP program.	Okay pending review of 60% design submittal.	Okay pending review of the 60% design submittal.	Comment resolved.	See Section 3.2.4.1 and Appendix L (O&M Manual, Volume 1, Section 5.1).

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
124	DOI-32	Section 3.2.5.2/3-13/ 2nd Paragraph/2nd to last sentence		In all likelihood, first flush well rehabilitation water and possible CIP wastewater will have a pH less than 2, rendering it a characteristically corrosive hazardous waste. This would require double walled piping in wastewater transfer lines potentially everywhere. This requires more discussion.	The spent CIP solution will be considered a corrosive material (EPA hazardous waste number D002 [per 40 CFR 261.22]) at a pH less than or equal to 2 or greater than or equal to 12. Bench-test conducted on scale deposits would be conducted to determine suitable amendments and determine the pH of spent solution. An operational constraint that the neat (as-applied) amendment solution exhibit a pH greater than 2 or less than 12 will be considered. Acids have been used for decades in well rehabilitation. Acids are used to dissolve mineral precipitates on the well screen and in the nearby formation like calcium carbonate and sulfate, magnesium hydroxide, iron and manganese oxide, phosphates, silicates, and, of course, mixtures of all of these during well rehabilitation. Of those listed, the carbonates are the most easily dissolved with the resulting release of carbon dioxide. A simple example would be the action of hydrochloric acid on calcite (calcium carbonate). In this reaction, the acid HCl breaks apart the calcite, ($CaCO_3$) into the salt ($CaCl_2$) and carbonic acid (H_2CO_3) which further breaks down into water (HOH) and carbon dioxide (CO_2), which bubbles off. This reaction is carried out by most mineral acids against carbonate deposits and accounts for the rapid evolution of gas during cleaning of wells with this type of deposit. The well water pH is measured as an indication that the acid has reacted with the encrustation to the degree that the acidity of the solution had been lost and all possible reaction has been completed. At the PGE Hinkley Compressor Station, well rehabilitation amendments are added to the well and allowed to loosen scale and deposits for a period of 12 to 72 hours. The pH is measured and verified to be above 2, before the first well volumes are pumped from the well (e.g., first flush). This operational approach will be an option. A second option is as follows, first flush rehabilitation water will be pumped out of the well with a temporary rehabilitation pump through temporary piping, pH neutralized using a permitted mobile treatment unit (if needed), and contained in temporary tanks located near the wellhead. All temporary tanks and piping, as well as the area surrounding the wellhead, will have adequate spill containment.		Okay pending review of 60% design submittal.	Comment resolved.	See Sections 3.2.4 and 3.2.5.2.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
125	HA-19	p. 3-12, Section 3.2.5 (General Design Elements – In Situ Remediation)		General design considerations for the in-situ components as well as all other components of the remedy that involve well construction should consider the eventual need to decommission these intrusive facilities. As mentioned earlier, the Tribe has entered into discussions with PG&E, DTSC, and DOI and other stakeholders in regard to considerations for well decommissioning that would be preferred in deference to the sacred landscape within which these facilities have been or will be constructed. Comments with regard to infrastructure siting alternatives in Attachment B provide further rationale supporting preferences of the FMIT Tribal Community.	The design will take into consideration the component life-cycles and eventual decommissioning process for each element of the remedial system. The design will adhere to any agreements made regarding well and system decommissioning. PG&E will draft a Decommissioning Plan for Remedy Facilities and Restoration, and the Tribes will be consulted prior to the decommissioning of any remediation facility.	Comment and response noted.	Comment and response noted.		
126	DTSC-46	Page 3-12, 3.2.5.1 IRZ Well Design, Number of Wells per Location	In areas with greater saturated thickness within the NTH IRZ, a two well cluster will be employed to facilitate recirculation of groundwater and carbon through the target zone.	Clarity is needed for design of injection wells. Is this saying there will be recirculation between wells or simply recirculation within the inner loop? PG&E has conducted a pilot test using dual screen recirculation wells to increase the reach of carbon dosing. However, the drawings and descriptions are not clear how PG&E intends to run these systems.	A dual screen well will be employed if the saturated thickness exceeds 40 to 100 feet and two screens are necessary to ensure targeted distribution of substrate in each zone. A well cluster will be employed if more than two well screens are required to provide full coverage of the target contaminated zone at locations where the vertical aquifer thickness is more than 110 feet thick. The purpose of the multiple wells per location is to ensure adequate discrete control of the injection fluid into the formation not to promote recirculation within the well cluster.	Okay		Comment resolved.	See Section 3.2.5.1.
127	DTSC-47	Page 3-12, Casing and screen material and type		The section should comment on long term corrosion issues (especially in high TDS waters) as well as fouling issues that may be dependent on the type of casing/screen material selected (also see page 3-13, paragraph 2 of Section 3.2.5.2). Will cathodic protection be utilized?	Comment noted. The 60% design will include a more detailed discussion of materials of construction for the extraction and injection wells.	Okay pending review of 60% design		Comment resolved.	See Sections 3.2.1.1 (under heading Well Maintenance and Rehabilitation Reagents) and Section 3.2.5.1, and Appendix L (O&M Manual, Volume 1).

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
128	DTSC-48	Page 3-13, Section 3.2.5.2, IRZ Pipeline Design and Operation	Piping will be single-walled unless it is used to convey: (1) groundwater or remedy - produced water that is California hazardous waste; or (2) concentrated carbon substrate. In these cases, double-walled piping will be used.	Where are the areas that PG&E anticipates to encounter California Hazardous Waste and concentrated carbon substrates? In reviewing the design document, it would appear that PG&E does not believe there will be any California Hazardous Waste and little, if any, of concentrated carbon substrate transference. DTSC believes PG&E should, in addition to the current proposal, use double walled piping for management of any untreated extracted water to protect against leaks due to the cultural sensitivity of the area as well as the possibility of contamination that could be leached from the soils, which have not been completely investigated, to the groundwater.	Based on modeling, groundwater with Cr>5 ppm could be extracted from the IRZ extraction well, IRZ-23. Additional information about the subsurface conditions will be obtained as we start to install remediation wells. With regards to the suggested use of double walled piping for management of extracted water (that are below hazardous waste characteristic level) to protect against leaks due to concerns over the possibility of contamination leaching from the soils (which have not been investigated) to the groundwater, it should be noted that soil data do exist for the AOCs that overlap with the remedy infrastructure as shown in Figure 2-15. Supplemental soil sampling is being planned to complete the soil investigation and current schedule shows completion of the investigation prior to the start of groundwater remedy construction. Further, baseline soil samples will be collected to document baseline site conditions at the time of remedy construction. In addition, the overlapped AOCs are located within the plume footprint for which an active remediation will be implemented for decades. Additional evaluation of the potential for leaks and methods of leak detection and control will be performed and included in the 60% design.	Okay pending review of the evaluation in the 60% design		Comment resolved.	See Appendix C (Design Criteria).
129	DTSC-49	Page 3-13, Section 3.2.5.3, Flexibility and Redundancy		PG&E has proposed in Figure 3-1 many “provisional wells” along the IRZ, however, there are no rationale for these wells, nor are they mentioned in this section or part of the design discussion in 3.2.5. If these wells are proposed as provisional wells, they should be discussed.	Additional details regarding the purpose and locations of provisional wells will be clarified in the 60% design submittal.	Okay pending review of 60% design		Comment resolved.	See Sections 3.2.2, 3.2.3.1, and 3.2.5.3, and Appendix L (O&M Manual, Volumes 2 and 3).
130	DOI-33	Section 3.3/entire section		There is limited discussion of monitoring the fresh water supply for water quality indicators during remedy implementation. Please provide additional discussion of how the fresh water supply will be monitored (i.e. frequency, water quality parameters) to ensure that the water quality remains suitable for use.	The forthcoming O&M plan will include a monitoring plan for the final remedy, which will include discussion of monitoring for the fresh water source.		Okay pending review of O&M plan as part of the 60% design submittal.	Comment resolved.	See draft O&M Manual, Volume 2 – Sampling and Monitoring Plan (Section 5.2, Monitoring of Freshwater Supply Source).

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
131	HA-20	p. 3-14, Section 3.3 (Freshwater Supply)		The discussion in this section and on Exhibit 3-3 indicates that in consideration of alternative locations for a freshwater extraction well, a location in the Park Moabi area was ruled out largely on the basis that its hydraulic influence would adversely affect the remedy. This begs a question as to the impact of a potential future private well offsite. What type of assessment was done to consider such a scenario? Additionally, please refer to comments of the TRC regarding the need to consider an alternative freshwater supply for the upgradient injection.	As described in Section 5 (Institutional Controls), model simulations were conducted to determine how close a private well would have to be in order to adversely affect the hydraulic performance of the remedy. Institutional controls are proposed for the area shown on Figure 5-1, to prevent private wells from being built within the area where pumping might adversely influence the remedy. In response to this comment, a technical memorandum will be prepared to present the evaluation of the three potential freshwater sources and PG&E's conclusion.	Noted pending review of tech memo.	Noted pending review of tech memo.		See Appendix J of this BOD Report.
132	DTSC-50	General Comment on Section 3.3, Freshwater Supply		It is important that PG&E provides a rational and logical decision matrix for the freshwater supply. The decision should be based on objective data and reasoning which would layout and balance the pros and cons associated with each of the three potential freshwater sources prior to selection of the preferred source. The comments below highlight DTSC's issues associated with PG&E's conclusion and should be carefully evaluated and modified for the 60% design.	In response to this comment, a technical memorandum will be prepared to present the evaluation of the three potential freshwater sources and PG&E's conclusion.	Okay pending review of TM		Comment resolved.	See Appendix J of this BOD Report.
133	DTSC-51	Page 3-14, 1st bullet	(e.g., a spare header for the conveyance of carbon amended groundwater).	A spare header is mentioned, but they are not reflected in the P&ID. Similar issue for the Clean In Place system.	Comment is noted. Spare headers will be called out in the P&IDs in the 60% and 90% submittals.	Okay pending review of future P&IDs		Comment resolved.	See Appendix D.
134	DTSC-52	Page 3-14, Section 3.3.1, Freshwater Supply Sources		The section introduces potential sources of freshwater supply for the remedial project and favors the HNWR-1 Arizona well and disfavors a California well or river source. Limitations of the California well or river source are summarized, however, limitations associated with the Arizona well are absent. Limitations/drawbacks of the Arizona well must also be mentioned in this section (e.g., excessive pipeline infrastructure, adverse water quality [arsenic, chromium], additional hydraulic effect that could send byproducts or chromium further into Arizona). As indicated previously, PG&E needs to prepare a comprehensive list of all water wells in the Topock area. The water quality of the wells should be tabulated and summarized. Exhibit 3-1 should be updated with this information. The exhibit should also include river water data for comparative purposes. Discussion with community members has indicated that water supply wells exist at the Topock Marina area adjacent to the I-40. If community member information is correct, these wells have not been identified in previous PG&E reports provided to DTSC. Although DTSC agrees with PG&E's criteria for evaluating freshwater supply options, PG&E has not provided sufficient data to suggest that the	In response to this comment, a technical memorandum will be prepared to present the evaluation of the three potential freshwater sources and PG&E's conclusion.	Okay pending review of TM		Comment resolved.	See Appendix J of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
				HNWR-1 well to be the overall superior option. While PG&E argues that using an existing well would avoid disturbance, it fails to account for the extra miles of additional piping which must be trenched and installed outside of an area that is considered the project area. Equally important is that PG&E's current knowledge of the HNWR-1 well is that there are elevated levels of arsenic beyond the MCL, and hexavalent chromium concentrations above the localized concentrations which will be injected into California. Exhibit 3-3 states that "River water is low in dissolved solids, but contains suspended solids, microbes, and trace contaminants, such as perchlorate, pesticides, herbicides, and pharmaceutical compounds. River water could not be injected without conditioning." DTSC currently does not have data suggesting that there are elevated concentrations of the suggested contaminants found within the river water within the project area. The basis for such a statement has not been established. Furthermore, the design document should indicate if disinfection would truly be needed. Will conventional well water require filtration or disinfection? What specific analyses and criteria will be conducted to determine if disinfection and filtration are necessary? DTSC understands that PG&E currently has in-line filters for the water imported from wells Topock 2 and 3. Is the necessary conditioning system similar? The document should respond to these issues. Exhibit 3-3 continues with "Construction of a river intake structure or subsurface infiltration gallery would be likely result in more disturbance than drilling of a well. Depending on where the intake was located, the length of buried pipeline could [be] less than for either of the other two options. Additional disturbance associate with potential conditioning plant construction." DTSC agrees that the needed pipeline WILL be less than for either options. PG&E also states that "much of the river intake construction disturbance could be mitigated if permission could be obtained to mount the river intake from the I-40 or the railroad bridge." Given that statement, PG&E has not demonstrated to DTSC that this design is infeasible, especially for similar design at pipeline bridges. This section also mentions that groundwater in the shallow zone from a "river well" beneath the river would contain water that is geochemically reduced with elevated concentrations of iron and manganese, which could foul the injection wells. First, isn't this issue already a concern for amended injection wells. Won't river bank extraction wells also eventually exhibit reducing					

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
				conditions and potentially foul or foul injectors and therefore require a conditioning system? Could the "river well" be designed to preferentially filter oxic water from the river and minimize concerns with reduced water? The document should conduct an in-depth evaluation of the different systems that could be utilized for designing a direct river intake that would minimize or eliminate filtration concerns (e.g., Can a manufactured filter pack be placed over the inlet screen to the intake). What range of filtration systems could be designed to accommodate the remedy? Does infrastructure currently exist for importing water to the station or near the station from a water supplier or alternative source? Can blending water sources be considered to address limitations and utilize strengths of the different options? PG&E must provide a balanced evaluation considering the adverse impacts of the groundwater based on current understanding of the water quality from HNWR-1.					
135	DTSC-53	Page 3-14, section 3.3.1 Freshwater Supply Sources	In addition, pumping freshwater from this area [at Park Moabi] would have an adverse effect on the performance of the remedy.	The section indicates that pumping 600 gpm from a well near Moabi Regional Park would decrease the flux across the IRZ line by about 7%. The report should quantify the significance of this flux decrease. Furthermore, this amount has not been substantiated with the model. Would river leakage mute adverse hydraulic effects if a Park Moabi well was put near the river or on the Park Moabi peninsula? Is this properly accounted for in the model? Furthermore, this amount of change should be easily alleviated by proper engineering of hydraulic movement which PG&E did not discuss. The section concludes by stating, "Because pumping freshwater from a hypothetical well near Moabi Regional Park well PM-03 or an area closer to the Compressor Station would have an adverse effect on remedy performance, the preferred option with respect to this criterion is to pump freshwater from a well in Arizona or from the river." The section should state how far north or west (or east) of Park Moabi a well would need to be located to have minimal adverse effect on remedy performance.	In response to this comment, a technical memorandum will be prepared to present the evaluation of the three potential freshwater sources and PG&E's conclusion.	Okay pending review of TM		Comment resolved.	See Appendix J of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
136	Hualapai-24			Water Rights for Fresh Water Wells The source of fresh water for the Topock project is planned to be supplied from one or more wells located in Arizona. The water rights and legal points of diversion for these wells must be presented to the Tribes to prove that PG&E can lawfully divert water from the Mojave Basin aquifer. The riverbank extraction wells, if operated, will undoubtedly draw Colorado River water through the organic layer into the extraction wells. The water rights and legal points of diversions for these extraction wells must be presented to the Tribes to prove that PG&E can lawfully pull water from the sacred Colorado River.	The scope of PG&E's existing water entitlements were described and assessed in Chapter 4.12 of the EIR that was certified by DTSC (and in the Draft EIR that was circulated for review and comment). This analysis included both the amount of water needed for the project and the points of diversion. The EIR concluded, "Any of these points of diversion are permitted" under PG&E's existing Lower Colorado Water Supply Project entitlements. The EIR evaluated water use during construction, during operation, and during decommissioning of the remedy, and in each instance, the EIR concluded that the existing entitlement was more than sufficient to serve the project needs. Given that this issue was fully disclosed and assessed in the EIR, the commenter is referred to that document.	Comment and response noted	Comment and response noted.		
137	Hualapai-25 and TRC-16			Water Rights for Fresh Water Wells Also, the current fresh water supply for the remedy is the single well, HNWR-1. There presently appears to be no alternative for water supply to the site. Are the existing TCS supply wells Topock-2 and Topock-3 intended to provide a contingency source for injection water to maintain a positive groundwater flow? **TRC Recommendation:** Discussion of fresh water supply alternative/contingency should be included in the 60% design report.	Currently, HNWR-1 is proposed as the primary well to supply the freshwater injection system for the groundwater remedy and the compressor station. To date, pumping conducted by the Refuge indicate that HNWR-1 is likely able to supply sufficient water for both purposes (planning is underway for additional pump test at this well). The current supply wells for the compressor station (Topock 2 and 3 wells) would remain connected as a back-up supply, although at present it is not certain that these wells would have sufficient capacity to supply the compressor station, the groundwater remedy, and the other customers of Southwest Water company. Additional discussion about freshwater contingency plans and the results of aquifer testing at both Topock 2 and 3 and HNWR-1 will be provided in the 60% design submittal.	Comment and response noted.	Comment and response noted. Further evaluation will occur during the review of supplemental fresh water supply information and the 60% design submittal.		See draft O&M Manual, Volume 3 – Contingency Plan for freshwater contingency plans. The Topock-2/3 pump test results are summarized in a tech memo that is included as an attachment to the RTC table in Appendix J The pump tests are also discussed in Section 3.3 of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
138	Hualapai-32			Further Considerations for 60% Design Evaluation Fresh-water from other sources and injected into the Site ideally would have water-quality characteristics similar to the aquifer geochemistry corresponding to different levels of the aquifer (shallow, middle, and deep). This means that for injections in the shallow part of the upland aquifer, TDS concentrations of injected water should to be on the order of 2,000 to 4,000 mg/L, for the middle level 4,000 to 6,000, and the for the deep aquifer TDS concentrations need to be 6,000 to 12,000 mg/L, depending on the location. The concern is that disparities in introduced water would result in density-driven fingering of injected waters that would be compounded with the geologic heterogeneities and result in a prolonged remediation time frame.	See response to comment HA-8a. The variation in density over the majority of the site is not considered significant enough to cause density-driven fingering. However, fingering due to aquifer heterogeneity is fairly common, and the monitoring program will be used to detect concentrations that deviate from model predictions due to fingering and other processes. Aquifer heterogeneities were modeled in the floodplain (where data are plentiful) during calibration with PEST. Additional heterogeneities that give rise to unexpected groundwater levels and/or concentrations will be identified by monitoring and incorporated into the model as necessary. The revisions to the model will assist in adjusting pumping or injection rates if necessary to minimize cleanup time.	Comment and response noted.	Comment and response noted.		
139	DOI-35	Section 3.3.1.1/ 3-15/ Last Paragraph		It is stated that the current design flow rate for freshwater injection is 600 gpm. This value does not align with the fresh water extraction flow rates (minimum, nominal, maximum) in Exhibit 3-4. Please explain.	The text will be revised to clarify that the current design and modeled flow rate for freshwater injection is 550 gpm. The freshwater supply extraction flow rates in Exhibit 3-4 included the freshwater usage of 110 gpm by TCS (see footnote a).		Okay	Comment resolved.	See Section 3.3 of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
140	DTSC-54	Page 3-15, Quantity of Water Available	"During remedy implementation, several of the Freshwater Injection Wells will be installed in areas where no previous wells have been drilled and hydrogeologic conditions are unknown. If the aquifer is more transmissive than anticipated in these areas, additional freshwater would be needed to create the gradient necessary for remedy operation. On the other hand, if the aquifer is less than transmissive than anticipated, less water would be needed."	DTSC is concerned by the statement that drilling is occurring in areas where no wells have been drilled and hydrogeologic conditions are unknown. All the proposed "FW" wells are located at or in close vicinity to existing wells. Furthermore, groundwater modeling based on site (as well as regional) hydrogeology is controlling remedy design and selection. The cited text must be revised. DTSC does request that PG&E locate the old "resort" well on figures (this well had been noted in older PG&E documents) and indicate what information is available from this well as it is located in the same area as FW-INJ-1.	In the alluvial fan depositional environment of the Topock site, hydraulic properties can vary dramatically over a distance of several feet. The groundwater model grid cells are intentionally made large enough to be able to average this small scale variability, however at the scale of a well, (a foot or so in diameter), there is potential that hydraulic conditions considerably different from average may be encountered. Only one of the proposed FW wells (FW-INJ-2) is nearby a location where aquifer testing has been conducted to estimate hydraulic properties of the aquifer. PG&E is unaware of any aquifer test data or well logs for the former well at the former Rancho Colorado near FW-INJ-1, but will locate and provide all available information for that former well in the 60% design. It is unlikely that any information regarding the former Rancho Colorado well will significantly decrease the uncertainty regarding performance of proposed well FW-INJ-1. Near Well FW-INJ-4 the aquifer pinches out. Well XM-9, drilled in bat cave wash just south of this location, was dry. No aquifer tests have been conducted in this area. The nearest test was a step-drawdown test at TW-1, but this location is outside the influence of that test. There is no way to be certain that the FW wells will be able to achieve the design flows until those wells are installed and tested. PG&E believes the original text accurately captures the uncertainty inherent in predicting the performance of new wells in an alluvial fan environment.	Okay		Comment resolved.	
141	DOI-34	Section 3.3.1.1/ 3-16/4th Paragraph		The 900 gpm flow rate for HNWR-1 is less than the 1,310 gpm maximum flow requirement identified in Exhibit 3-4 for the freshwater supply line. Calculations should be provided to substantiate that there will be adequate yield from this well for the Topock remediation project during peak water demand. Also, flow demand for HNWR's continued use of this well for irrigation needs to be accounted for, and if there is no demand, then it should be documented.	According to information received from US Army Corp of Engineers, well HNWR-1 produced 900 gpm with a pumping water level at 80 feet below land surface during the initial testing. During the subsequent revegetation project, the HNWR-1 well was pumped at rates exceeding 1,000 gpm for periods of 12 hours or more. The well screen extends from a depth of about 92 to 157 feet. PG&E will coordinate with the Refuge on the HNWR's demand for this well and to evaluate the well capacity to meet this and other needs.	Okay.	Okay.	Comment resolved.	See Section 3.3 and Appendix J of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
142	DTSC-55	Page 3-16, Quantity of Water Available	"PM-01 was used for several years, but reportedly produced relatively poor quality water with a TDS concentration of 3,000 mg/L. Well PM-02 was tested at 430 gpm but there was no record of the drawdown so no estimate of specific capacity could be made. Both of these two wells had mineralized water. The water from PM-02 was so saline that it was considered unusable and the well was apparently never put into production (LeRoy Crandall & Associates, 1986)."	Park Moabi area: The document should determine where the best location for a well in California might be located. This may be based on geology as well as historical pumping. Pumping data from PG&E test wells (TW wells) as well as IM3 extractors, injectors, etc. should also be cited as they are representative of California conditions. Data from "PMM Supply" from the Background Study must be cited and evaluated. It is suggested that hydraulic data be collected from PM-01 and PM-02 due to higher yields. The section comments (see column to left) on the poor water quality of wells PM-1 and PM-2 even though it is not the appropriate section to be commenting on water quality. More importantly, poor water quality is not defined. The "poor" TDS quality of 3,000 mg/L (note that the 3,000 mg/L value cited appears to be an error as PG&E data indicates TDS ranged from 800 to 1,000 mg/L circa 2005 to 2006 in PM-1) cited may be quite satisfactory for injection during the remedy since the injection area TDS ranges from approximately 1,000 mg/L to 6,000 mg/L depending on depth. The document must discuss desired injection water quality in detail and indicate that IM-3 injection wells have always been injecting treated water with TDS around 4,000 m/L into the FW-INJ-2 locale. The discussion on "poor water quality" should be rewritten for the 60% design. PM-01 analytical data must be summarized and tabulated. See comments above and below regarding PM-01 as the data from this well is not being properly accounted for and summarized. Arizona Wells: All data from Topock 1 must be included in the report including the reason why it was abandoned and replaced with Topock 2 and 3. Other wells in Arizona should be evaluated (see comments above). The results of upcoming hydraulic testing on HNWR-1, Topock 2 and Topock 3 should be provided to DTSC asap and incorporated into this document. The quality of hydraulic testing on Topock 2 and 3 should be stated as it is noted that old pump data are cited to characterize well hydraulics. From the quantity perspective, this section must conclude that the river is obviously the most proven source of water supply in the area and scores above California and Arizona wells.	The PMM Supply well referred to in the Background Study Report is well PM-03. It was considered in the evaluation. This point will be clarified in the text. In response to this comment, a technical memorandum will be prepared to present the evaluation of the three potential freshwater sources and PG&E's conclusion.	Okay pending review of TM		Comment resolved.	See Section 3.3 and Appendix J of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
143	DTSC-56	Page 3-18, Paragraph 2, Water Quality and Potential Need for Pre-Conditionin g Prior to Injection	'As noted in Exhibit 3-1, one of the wells drilled at Moabi Regional Park (well PM-02) produced highly mineralized water and was never put into service. The other high-capacity well (PM-01) produced water with a TDS concentration around 3,000 mg/L. Based on the relatively high mineral content of the water, there is some doubt whether a well at Moabi Regional Park would produce water that is geochemically compatible with the injection wells and the aquifer at the Topock site."	The second paragraph discusses "the relatively high mineral content of the water" without discussing quantitative water quality needs for injection. The discussion is poor and misleading as IM-3 injection water of 4,000 mg/L is not discussed and has been operating successfully for over 5 years. The text should be stricken and a balanced evaluation conducted. See comments on "poor water quality" above. Exhibit 3-1 does not cite appropriate information for well PM-01. PG&E sampled this well as part of the background study (November 2009) six times from 2005 and 2006 for a large suite of analytes and identified it as well "PMM-Supply". How PG&E came to overlook this data is concerning as it has direct bearing on Park Moabi supply well evaluation. Exhibit one should be modified to indicate that the casing depth of PM-01/PMM-Supply is 180 feet and not 190 as reported as based on Table 2-1 of the 2009 background study report. The perforated interval should be revised to indicate a dual screen from 28-42' and from 65-180'. Unlike that stated in Exhibit 3-1, PM-01 data for chromium and arsenic are available. Cr(VI) measures about 9ug/L while arsenic is around 2 ug/L. All data should be accurately tabulated in Exhibit 3-1 or an equivalent table. Provide a detailed discussion regarding geochemical compatibility of imported water in the section. Discuss IM-3 injection water quality data in the section as well. Data from the 2009 background study report must be utilized. Figure 2-4 of that report displays a Piper diagram that indicates that the PMM-Supply is geochemically similar to the site as it plots near site wells P-2, MW-10, MW-11, MW-17, and MW-18. This is contrary to what is stated in this section. Piper diagrams must be utilized in the geochemical discussion in this and other appropriate sections. Data tables should be prepared listing all Park Moabi analytical data for water wells. Additional Park Moabi analytical data should be collected as the document indicates that the data base is not extensive (However, note comments referring to existing data from PMM-Supply). The trace metal data discussion in this paragraph must be rewritten as the PMM-Supply data (most extensive and comprehensive dataset for any well evaluated in the freshwater supply section) that was overlooked by PG&E indicates that the water is of high quality. Manganese, iron, and total suspended solids are very low or below low detection limits suggesting that pre-conditioning prior to injection would not be needed. Trace metals are also low including the constituents arsenic and Cr(VI) - see Exhibit 3-1 discussion above. Based on this information, the section	The PMM Supply well referred to in the Background Study Report is well PM-03. It was considered in the evaluation. This point will be clarified in the text. In response to this comment, a technical memorandum will be prepared to present the evaluation of the three potential freshwater sources and PG&E's conclusion.	Okay pending review of TM		Comment resolved.	See Section 3.3 and Appendix J of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
				must conclude that the water quality of PPM-Supply well is superior (low minerals, low plugging/fouling potential, low trace metals, and geochemically compatible) to all other water wells.					
144	DTSC-57	Page 3-18, Paragraph 3, Water Quality and Potential Need for Pre-Conditioning Prior to Injection		As previously discussed with PG&E, additional HNWR-1 analytical data should be collected since, as stated in the document, that the well has only been sampled once. Any conclusions regarding the water quality of this well are therefore provisional. Sound decisions cannot be made without adequate data and data evaluation. Data tables should be prepared listing all HNWR-1, Topock 1, 2, & 3 analytical data. Analytical data for other Arizona water wells should also be tabulated.	In coordination with the Refuge, the HNWR-1 well was sampled on February 23 and March 14, 2012, and will be sampled again in April. Data will be incorporated into the forthcoming technical memorandum on freshwater sources evaluation.	Okay pending review of TM		Comment resolved.	See Section 3.3 and Appendix J of this BOD Report.
145	DTSC-58	Page 3-18, Paragraph 4, Water Quality and Potential Need for Pre-Conditioning Prior to Injection		The section should discuss the following issues about hexavalent chromium. First, data regarding chromium should be appropriately summarized (e.g., well data should not be omitted - see PMM-Supply discussions above). The document should note that the HNWR-1 well exhibits a hexavalent chromium concentration about double PMM-Supply. DTSC desires that as low a hexavalent chromium concentration as possible be used for freshwater supply due to its toxic nature and since the uncontaminated aquifer area planned for freshwater injection exhibits very low to nondetect chromium concentrations at depth that increase upward in the aquifer profile (see Figures 2-3 a, b, and c of the document). Chromium added to the deeper portion of the aquifer could result in a potential increased risk/threat as a result of implementing the remedy. The section should acknowledge this concern and include it as criterion used to evaluate freshwater supply sources. The issue is not to simply pick a value below the regional background value of 32 ug/L. The section should conclude that the river would be the superior source of water with respect to hexavalent chromium concentrations as proven by the massive river data base that are typically nondetect for chromium (even excluding non-PG&E data bases).	In response to this comment, a technical memorandum will be prepared to present the evaluation of the three potential freshwater sources and PG&E's conclusion.	Okay pending review of TM		Comment resolved.	See Section 3.3 and Appendix J of this BOD Report.
146	DTSC-59	Page 3-18, Paragraph 5, Water Quality and Potential Need for Pre-Conditioning Prior to Injection		The arsenic section must be rewritten. The section must acknowledge that the regional background arsenic UTL of 24.3 ug/L is inappropriate for the site as a screening criteria for freshwater injection (See DTSC comments on the Revised Groundwater Background Study dated February 29, 2008). The section should indicate that the average concentrations of arsenic in the vast majority of site monitoring wells are below the background UTL of 24.3 µ/L. The section should mention that Figure 2-7 of this document illustrates that arsenic concentrations are approximately 3 ug/L in all portions of the	In response to this comment, a technical memorandum will be prepared to present the evaluation of the three potential freshwater sources and PG&E's conclusion.	Okay pending review of TM		Comment resolved.	See Section 3.3 and Appendix J of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
				aquifer where freshwater injection is planned. The section should also cite the 2009 regional background report and include Figure 2-7 from that report which illustrates that the highest arsenic concentrations in the region, which are greater than MCLs, occur in the immediate vicinity of well HNWR-1. The section should further state that the background report suggests potential hydrothermal activity in Arizona is associated with the elevated arsenic. DTSC requests that areas outside the area of elevated arsenic and hydrothermal activity also be evaluated for freshwater supply. DTSC has concerns with importing and injecting water containing arsenic above the MCL and above site specific background concentrations on the California side of the river. In addition, DTSC is concerned with ARAR compliance such as meeting Basin Plan standards established by the Regional Water Quality Control Board. DTSC is reluctant and may not be allowed to authorize injection of imported water into the ground that exceeds MCLs and degrades the aquifer. DTSC desires that as low an arsenic concentration as possible be used for freshwater supply due to its toxic characteristic. Typical arsenic (and other analytes) concentrations of river water should be discussed and documented. The section should conclude that based on existing data, well HNWR-1 has the poorest water quality with respect to arsenic in the study area.					

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
147	DTSC-60	Page 3-18, Paragraph 5, Water Quality and Potential Need for Pre-Conditioning Prior to Injection		Arsenic modeling simulations are discussed in this section and suggest that elevated arsenic above MCLs from well HNWR-1 would naturally adsorb to iron oxides in the aquifer matrix when injected into California waters leaving a minimal arsenic footprint. The section must comment on potential well fouling associated with HNWR-1 arsenic (and any other constituents) precipitation into the pores throats of the formation during injection as the section postulates that arsenic is removed in such a manner. The section must clarify how Arizona water that is argued to be geochemically similar in the preceding paragraphs, would then become dissimilar with respect to arsenic when injected in California. The section must indicate why dissolved arsenic is stable in aerobic waters withdrawn from well HNWR-1, but would become unstable when injected into aerobic waters in California. The section should also cite that it was not anticipated in prior documents, that freshwater supply injection would entail injecting water with detrimental constituents at concentrations above an MCL into aquifers containing concentrations less than MCLs.	In response to this comment, a technical memorandum will be prepared to present the evaluation of the three potential freshwater sources and PG&E's conclusion.	Okay pending review of TM		Comment resolved.	See Section 3.3 and Appendix J of this BOD Report.
148	DTSC-61	Page 3-20, Paragraph 1		As stated earlier, there is speculative discussion regarding trace pollutants in the River. River data for the specific area must be cited to support assumptions and quantify any valid concerns. Have trace river pollutants been discovered at the Topock site area? Have these pollutants migrated into the aquifer due to IM-3 pumping or injection? The section must indicate what testing has already been conducted in the Topock area to ensure PG&E's concerns with trace river pollutants have not already adversely impacted the aquifer that we are trying to clean up? PG&E should evaluate its own data set as well as others for the Topock area (e.g., MWD). PG&E must also discuss and evaluate how pumping from freshwater supply wells could draw river water (polluted or not) across aquifers and towards pumping centers. This portion of the paragraph needs to be revised. The paragraph concludes that "water from the river or from a river infiltration gallery is not preferred based on the criteria of water quality." This statement cannot be made without river water data to support it. DTSC recalls that MWD's river data base for the area did not exhibit elevated trace metals and that testing did not detect perchlorate. It would therefore seem that the river would have superior water quality. See comments above on section 3.3.1 Freshwater Supply Sources (Page 3-14) related to freshwater filtration and conditioning. Based on existing information in the document, PG&E will need to	In response to this comment, a technical memorandum will be prepared to present the evaluation of the three potential freshwater sources and PG&E's conclusion.	Okay pending review of TM		Comment resolved.	See Section 3.3 and Appendix J of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
				make a good faith effort addressing design of a river water conveyance system and any needed conditioning. Conditioning systems already planned for the remedy should be discussed and summarized for comparative purposes. This will allow an educated assessment of the various freshwater sources.					
149	DTSC-62	Page 3-20, 1st paragraph	In addition, water pumped from an infiltration gallery would likely contain elevated concentrations of iron and manganese due to the geochemically reducing conditions present in the fluvial sediments surrounding and underlying the river.	PG&E has not provided fresh water selection criteria on what concentration would be acceptable for the remedy to discount the use of infiltration gallery. Furthermore, in reviewing the concentrations from the California slant wells, the manganese concentration ranged from 200 ppb to approximately 2.5 ppm where most of the higher concentrations are from MW53D. Iron data ranged from 100 ppb to 7 ppm where most of the ppm range data are from the shallow well 52S. Is it possible to design the infiltration gallery to target zones with lower concentrations of unwanted constituents?	In response to this comment, a technical memorandum will be prepared to present the evaluation of the three potential freshwater sources and PG&E's conclusion.	Okay pending review of TM		Comment resolved.	See Section 3.3 and Appendix J of this BOD Report.
150	DTSC-63	Page 3-20, Paragraph 2, Disturbance Associated with Construction	"The river intake structure would likely represent the greatest level of disturbance both during and after construction of any of the three options. Much of the river intake construction disturbance could be mitigated if permission could be obtained to mount the river intake from the I-40 or the railroad bridge."	The section will need to be revised to explain and support the contention that the river intake structure would likely represent the greatest level of disturbance. It is not clear what criteria are being used to make this assessment. Is it volume of soil disturbed? Is it aesthetics? Is it time taken to construct? It is also not clear what PG&E is envisioning for the structure and what range of intake designs exists that would address the needs of the remedy. PG&E should attempt to consider an intake design with as minimal a disturbance as possible. The document should clarify why the freeway or railroad bridge are cited for mitigating disturbance. The section should also comment on why the other bridges to the south are not being considered. Also see comments above on section 3.3.1 Freshwater Supply Sources (Page 3-14) related to freshwater filtration and conditioning.	In response to this comment, a technical memorandum will be prepared to present the evaluation of the three potential freshwater sources and PG&E's conclusion.	Okay pending review of TM		Comment resolved.	See Section 3.3 and Appendix J of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
151	DTSC-64	Page 3-20, Paragraph 3, Disturbance Associated with Construction	"Based on a preliminary evaluation of the type and amount of construction for the three identified options, using the existing HNWR-1 well in Arizona is the preferred option. By using an existing well, which has already been proven to provide an adequate quantity and quality of water, additional well drilling would be avoided." "If wells at Moabi Regional Park were selected as the water source, it is likely that several wells would need to be drilled in order to find a sufficient quantity and quality of water."	This section needs to be rewritten pending additional data to be collected for both the PMM-Supply well and HNWR-1 well. In addition, PG&E should also include a better analysis and evaluation of the river intake option. It is premature to select the HNWR-1 well based on the evaluation presented in this document as it lacks specifics with respect to evaluation criteria as well as data to support selection. The section should indicate that the water quality of HNWR-1 has not been proven and that the one sample collected from it so far yields elevated arsenic and hexavalent chromium. The disturbance associated with it also seems significant (significant length of buried pipe and a bridge span). Please clarify how the quantity of water from HNWR-1 has been proven (How many times has it been hydraulically tested? For how long and what rate and drawdown? What is its normal pumping rate? How many hours has it pumped water?) The same questions apply to any well being considered. The section should comment that the PMM-Supply water quality appears satisfactory, if not superior, when compared to other wells. Clarify why several wells would need to be drilled at Park Moabi (clarify the desired pumping rate and water quality for the remedy). PMM-Supply yields superior water quality at relatively high yields. If it still didn't provide sufficient quantity, wouldn't one just install one well in a neighboring area? What happens if HNWR-1 cannot provide a sufficient quantity of water either short term or long term?	As mentioned in response to comment #144 DTSC-57, the HNWR-1 well was sampled, in coordination with the Refuge, on February 23, 2012, and will be sampled again in March and April. Data collected will be summarized in the forthcoming tech memo. As mentioned in responses to comments #142 DTSC-55 and #143 DTSC-56, PMM-Supply well (in the Background Study report) is also called PM-03. Well PM-03 has been sampled on an annual basis and was recently sampled in the December 2011 annual event. Data will be summarized in the forthcoming tech memo. In response to this comment, a technical memorandum will be prepared to present the evaluation of the three potential freshwater sources and PG&E's conclusion.	Okay pending review of TM		Comment resolved.	See Section 3.3 and Appendix J of this BOD Report.
152	DTSC-65	Page 3-20, Paragraph 4, Disturbance Associated with Construction		This paragraph needs to be rewritten pending additional data and analysis. See previous comments on water quality, disturbance, conditioning, and water compatibility.	In response to this comment, a technical memorandum will be prepared to present the evaluation of the three potential freshwater sources and PG&E's conclusion.	Okay pending review of TM		Comment resolved.	See Section 3.3 and Appendix J of this BOD Report.
153	DTSC-66	Pages 3-20 and 3-21, Preferred Freshwater Supply Option to Carry into Design		This paragraph and Exhibit 3-3 need to be rewritten pending additional data and analysis. See previous comments on water quality, disturbance, conditioning, and water compatibility. Based on the limited evaluation presented in the document, DTSC favors the river intake structure with filtration.	In response to this comment, a technical memorandum will be prepared to present the evaluation of the three potential freshwater sources and PG&E's conclusion.	Okay pending review of TM		Comment resolved.	See Section 3.3 and Appendix J of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
154	DOI-36	Section 3.3.2/3-22/ Exhibit 3-4		The minimum, nominal, and maximum freshwater extraction and injection flows do not balance. Is this to be interpreted that the injection flow rates relate to well design only? The nominal and maximum design flows for UPGRAD-INF-4 are the same value. Is this a mistake? Per footnote d, the pipeline capacity of 1,310 gpm is based on maximum flow to freshwater (600 gpm) and carbon amended injection wells (600 gpm) (plus TCS usage). The 600 gpm values cannot be gleaned from any information in Exhibit 3-4.	Exhibit 3-4 will be revised to clarify the following points: 1. The minimal, nominal, and maximum flow rates for the wells represent the design flow rates established for each of the individual wells. The total minimal, nominal, and maximum flow rates have been established through groundwater modeling scenarios throughout the remedy duration, and therefore the aggregate flow rates for the minimum and maximum do not balance. The minimum flow rate indicates that one or more injection wells are not used (for example FW-INJ-2). The maximum flow rate scenario indicates that the provisional well (FW-INJ-3) would be in operation. 2. The nominal and max flows of 200 gpm for UPGRAD-INJ-4 as summarized in Table 3-2 are correct. This flow rate was employed in the nominal and maximum scenarios. Under all scenarios, freshwater will be injected into UPGRAD-INJ-4. 3. The current design and modeled flow rate (shown in Appendix B) for freshwater injection is 550 gpm (200 gpm for UPGRAD-INJ-4, 100 gpm each for FW-INJ-1, FW-INJ-2, and UPGRAD-INJ-3, and 50 gpm for FW-INJ-4). In addition, the compressor station has a demand of 110 gpm. The nominal flow rate in Exhibit 3-4 will be revised to 660 gpm. 4. The conveyance pipe for freshwater from AZ will be sized to accommodate the max aggregate flowrate for the entire Outer Loop injection well network (including FW-INJ-4) of 600 gpm (see footnote d of Table 3-2), the max aggregate freshwater flow rate for the Inner Loop injection well network (e.g., UPGRAD-INJ-2, UPGRAD-INJ-3, and UPGRAD-INJ-4 are receiving freshwater at the maximum flow rate) of 600 gpm, and TCS usage (110 gpm). The maximum flow rate in Exhibit 3-4 will be revised to 1,310 gpm.	Okay pending review of 60% design submittal.	Okay pending review of 60% design submittal.	Comment resolved.	See Exhibit 3.3-4 of this BOD Report.
155	DOI-37	Exhibit 3-4		The exhibit indicates that a fourth fresh water injection well may be installed, if necessary. Please indicate on a figure possible locations for installation of the fourth fresh water injection well.	If it is not possible to inject a sufficient quantity of water in one of the three primary locations, a fourth injection well may be needed. It would likely be located somewhere near the location where additional injection capacity was needed. Possible locations for this well will be provided in the 60% design.		Okay pending review of 60% design submittal.	Comment resolved.	See Figure 3.0-1 of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
156	DTSC-67	Page 3-23, Exhibit 3-4, and Page 3-24 1st Paragraph	Superscript of Pipeline capacity, 1310 gpm. "[d] This total includes the maximum flow to Carbon-amended Injection Wells (600 gpm) and Freshwater Injection Wells (600 gpm) plus the maximum for TCS usage (110 gpm)." Also, "to accommodate potential future operational changes associated with the remedy while maximizing the use of existing facilities, the design incorporates the current freshwater supply system for the Compressor Station."	According to PG&E during telephone discussion on February 8, 2012, PG&E is evaluating the fresh water supply infrastructure separately from current TCS usage except for common components such as water storage tank. PG&E stated that the water supply for TCS use will continue to be Topock 2 and 3 wells. However, the cited text suggests the contrary that the design parameters would include TCS operational usage of 110 pgm. See also Figure 3-10 flow diagram from Fresh Water Supply Well (HNWR-01). PG&E should clarify if operational uses at the TCS are accounted into the design. DTSC believes that tying Compressor Station needs into the remedy is outside the project scope and has not been accounted for in previous documents and potentially limits, unnecessarily, selection criteria that should be developed for selecting a freshwater source (e.g., total flow demand for the remedy is stated to be a nominal 250 gpm, but 360 gpm if Compressor Station needs are added to flow demands). There is no apparent need to potentially burden the groundwater remedy with the needs of an unrelated project. If there is desire by PG&E to share infrastructure (e.g., Compressor Station storage tanks), then the infrastructure should be operated or retrofitted to accommodate separate systems, if needed, or replaced by new infrastructure. Exhibit 3-4 should be revised to address these concerns.	The February 8, 2012 discussion was centered around the rationale for certain planned infrastructure (specifically the freshwater supply storage) associated with freshwater supply from Arizona. PG&E explained that for storage, the shared use of the existing TCS freshwater storage tanks (currently receives water from Topock 2/3 wells) minimizes the need for installation of a separate new tank and is consistent with the mitigation directives to use existing facilities where available. In addition, PG&E explained that since the existing tanks also receive Topock 2/3 water, this means that Topock 2/3 well water can serve as a backup to the HNWR well water, which could minimize the need for another well to be drilled in Arizona. This aspect will be verified in the 60% design submittal. Because of its relatively small volume, the Compressor Station water usage does not drive/impact the size/footprint of planned remedy infrastructure (e.g., the 12-inch freshwater pipeline from HNWR well to the existing TCS storage tanks). A new freshwater line is needed to convey water from AZ regardless, and the size of this line is not impacted by the 110 gpm TCS usage.	Okay.		Comment resolved.	

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
157	DTSC-68	Page 3-24, Section 3.3.2 Design Basis for Freshwater Supply System	"To accommodate potential future operational changes associated with the remedy while maximizing the use of existing facilities, the design incorporates the current freshwater supply system for the Compressor Station. The Compressor Station's current water need (approximately 110 gpm) is served by Topock-2 and -3 supply wells in Arizona; the freshwater is conveyed via a pipe crossing the Colorado River on the arch bridge. Coordinating with the Compressor Station's water supply allows for the potential increase in freshwater demand by the remedy to be met with minimal additional infrastructure (see Section 3.3.2.2 for details)."	The document must clarify what is being stated. Are separate pipelines from Topock 2/3 and another freshwater source being proposed? It appears that water from Topock 2/3 is proposed to be mixed with the remedy freshwater in the storage tanks. If this is indeed the case, then the section on freshwater quality must acknowledge this blending of waters and highlight Topock 2/3 water quality. A comprehensive listing of all data from Topock 2/3 is necessary. As DTSC has concerns with elevated hexavalent chromium and arsenic that are also present in Topock 2/3, the mixing of Topock 2/3 water with the freshwater source may also be of concern.	The existing pipeline from Topock 2/3 will remain as is. There is a new pipeline conveying freshwater from the HNWR well proposed in the 30% design. The Topock 2/3 water quality will be presented in the forthcoming Freshwater Water Supply Source Evaluation Tech Memo (see response to comments #142 DTSC-55 and #144 DTSC-57)	Okay		Comment resolved.	See Appendix J of this BOD Report.
158	DTSC-69	Pages 3-24 to 3-25, Section 3.3.2.1 Freshwater Supply Piping Network	With the current preliminary design, the primary benefit of a looped system is having the operational redundancy and flexibility to minimize unplanned downtime over the decades-long life of the remedy. The energy savings associated with a looped system are small given the current design since most of the freshwater injection flow will not require pumping. This could change if the final design is different. As currently designed, the looped segment is less than 2,200 feet long or just over 10% of the total freshwater pipe length (21,200 linear feet).	The desired operational redundancy should be weighed closely against Tribal concerns as the redundant Bat Cave Wash loop is located adjacent to the Maze. The section should also comment on the long term repairs to the Bat Cave Wash segment knowing that periodic storm events can destroy infrastructure located in this particular wash. The reason postulated for the loop is that it would minimize remedy downtime. It is uncertain how big a concern downtime is at this point. A discussion of downtime should be presented that lists disadvantages and assesses if they are critical over the short and long term.	The draft O&M Manual will include a section that discusses pipeline maintenance. The draft O&M Manual is part of the 60% design submittal. In the 30% design, PG&E proposed a looped configuration in the piping, power, and control systems to provide more system reliability. A looped system offers redundancy in critical utility connections which are often difficult to access and repair. With a looped system, most final remedy wells could be served from either direction in the loop, allowing many of the wells to remain in operation while repairs were made to underground utilities. Other benefits of a looped system commonly include reduced energy usage due to lower pressure losses. For this project, the energy savings are small since the primary pumping is for well backwashing; this occurs infrequently and the injection lines are gravity fed so no energy is required.	DTSC will review the design as it becomes available.		Comment resolved.	See Figure 3.0-1 of this BOD Report. The Bat Cave Wash piping corridor has been eliminated; piping is routed through the NTH piping corridor and crosses Bat Cave Wash on two aerial crossings.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
					It is important to note that, in contrast to IM-3 which is designed to reverse the natural gradient in the floodplain, the Final Remedy is designed to enhance the natural groundwater gradients at the site. If the Final Remedy is shut down, the natural gradient will continue to move the chromium plume across the IRZ barrier, but at a slower rate. The NTH IRZ is designed to operate passively for long periods with no carbon substrate injection. Consequently, short periods of downtime will not have a significant effect on the ability of the remedy to meet RAOs. In contrast, relatively short periods of IM-3 downtime during times of low river level can result in a failure to meet the IM-3 goal of gradient control. Therefore the design of the Final Remedy can be more tolerant of failures that would result in short periods of downtime than was possible with IM-3. The remedy design should therefore focus on prevention of failures that could result in long periods of downtime, lasting several weeks or months which, over the life of the remedy, could add significantly to the overall cleanup time. The effects of downtime depend in large part on the location and nature of the failure. PG&E anticipates most failures of mechanical or electrical components can be repaired within a few days to weeks. There will be an appropriate level of spare parts and service capabilities to respond to component failures quickly. Failures of underground piping, power, or control links could take longer to repair due to the difficulty of access. The loop system was one way to provide redundancy in the utility links. Providing redundant piping and conduits in a common trench is another option for including redundancy. In response to DOI's and DTSC's direction (see comment #182), the 60% design submittal will include a modified design to eliminate the Bat Cave Wash segment. It is feasible to loop the system by doubling back in the piping corridors on National Trails Highway and on old route 66 without going through Bat Cave Wash. The main drawbacks are the increased pipe lengths and increased trench widths (e.g., additional pipe lengths of 17,000+ feet for freshwater, 17,000+ feet of electrical conduits, etc.). The drawback will be magnified under an aboveground piping scenario.				
				Could the looped system in Bat Cave Wash be replaced with a longer loop that would simply double back in existing trenches?					

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

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159	HA-21	p. 3-24, Section 3.3.2.1 (Freshwater Supply Piping Network)		The first paragraph indicates that of the total 21,700 feet of freshwater piping, approximately 25 percent, will be aboveground and 75 percent underground. What will determine this placement and is a map showing the aboveground vs. underground runs available? Please refer to Attachment B with regard to the Tribe's position on the placement of piping above vs. underground.	Figure 3-1 of the 30% BOD Report shows the aboveground vs. underground piping runs. This figure will be revised in the 60% design to reflect DOI's and DTSC's direction to modify the piping network to eliminate the piping/conduit segment in Bat Cave Wash. PG&E will evaluate the feasibility of additional locations for aboveground piping (in addition to locations already proposed in the 30% design) during the development of the 60% design. In general, the rationale for placing **electrical conduits** underground (versus aboveground) is as follows: <u>High voltage supply lines (from supply source to transformers)</u> – the National Electrical Safety Code (NESC or ANSI/IEEE C2-2007) is the American National Standard to which public or private US electric utility companies adhere to for design, installation, and maintenance of electrical supply lines. The NESC includes safety requirements for three types of utility construction: 1. Rules for Electric Supply Stations and Equipment (Substations) 2. Rules for Overhead Electric Supply and Communication Lines 3. Rules for Underground Electric Supply and Communication Lines Any design that does not conform to the requirements set out by the NESC is considered non-Code compliant. An above-ground, non-overhead, high voltage supply line is an example of non-Code compliant. <u>Low voltage distribution lines (after transformers to wells)</u> – Besides the risk of electrical injuries from contact, long runs of exposed electrical conduit also present additional design and O&M challenges because: 1. When the conduit is above ground and/or exposed to the sun, the wiring in conduit will be subject to extreme changes in temperature. This will cause the wire plastic or rubber covering to become brittle over time, and failures will be much more likely to occur. Repairs will be complex when the runs are long. Failures, depending on where they are, can take hours to days to isolate and weeks to repair. 2. Over long runs, the design will need to accommodate expansion and contraction of the conduit. The wiring does not expand and contract at the same rate as the conduit. This movement, can also lead to	Comment and response noted. DTSC notes that the certified FEIR included impact analysis for underground piping where possible based on information provided by PG&E on the conceptual design. Although DTSC recognizes the Tribes recommendation for siting pipelines and electrical transformers above ground, as discussed with the Tribes during the 3/20 meeting, other factors such as safety and regulatory constraints must be balanced with cultural resource considerations. DTSC agrees that the necessity of the pipeline network within the Bat Cave Wash be reevaluated.	Comment and response noted. The federal agencies have consulted with the Tribes on the 30% design with particular focus on this and related comments. The Tribes comments and the discussions which occurred during consultation meetings were considered in our direction to PG&E regarding modifications to the design including the implementation of the double-back loop along NTH, eliminating the BCW trenching. The federal agencies believe these design modifications take into account the impacts to the site and to some extent reduce the overall affects of the remedy on the cultural, religious, and spiritual values held by the Tribes for the TCP within the APE while recognizing our responsibility for protecting public safety, reducing ecological and visual impacts in the area. DOI, BLM, FWS and BOR are evaluating other options for above ground pipe runs, including in the areas adjacent to Old Route 66 and the Topock Compressor Station.		See Figure 3.0-1 of this BOD Report for piping alignment. PG&E further evaluated placement of piping in the utility corridor (underground or aboveground) during the 60% design development. Results of the evaluation are shown on Figure 3.0-1 of this BOD Report and the rationale is provided in Section C.2.2 of Appendix C (Design Criteria).

APPENDIX I
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Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

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					failure. 3. The wire and conduit will need to be larger if aboveground than underground, due to the temperature derating that will be required per code. In some cases, this will require two conduits where the underground design would require only one conduit. Basically, this will increase the infrastructure and footprint required for this installation. For **freshwater and remedy produced water piping**, the rationale for placing them underground (versus aboveground) is to not only avoid increased visual impacts, but also to protect the health, safety, and free movement of humans and animals. It will also protect the integrity of the remedy infrastructure, and minimize remedy footprint and future O&M challenges. There are a number of roadways with a heavy volume of vehicular traffic in the project area, including National Trails Highway in CA, Mohave County Road 10 in AZ, and the Compressor Station access road. Pipelines within the ROW of these roads was all placed underground in the 30% design. If motor vehicle accidents were to occur on these roads, they could cause serious injuries and significant damage to properties and remedy infrastructure (e.g., a car hits a pipe rack or a utility pole). More specifically, aboveground utilities do not have a breakaway component to dissipate the energy exerted from a vehicle crashing into them such as a light pole or a traffic cabinet with a breakaway base. The pipes will remain stationary and cause greater bodily harm to the occupants of a vehicle as well as create a service disruption. Exposed utilities would require a protective barrier of some sort, such as a concrete barrier or enhanced guard rail, which would further increase the footprint. In addition, elevated pipe racks (where vehicular traffic or health and safety preclude a near-ground level installation) would require a structural footing advanced below surface, possibly to a significant depth. Depending on the geotechnical characteristics of the soils, driven pile foundations may be necessary. Further, given the inherent vulnerability of aboveground piping (members of the public have been known to shoot pipes and large rocks or other debris may strike the pipe during a storm event, in addition, pipe will need periodically re-coated) there would be more maintenance of the piping required				

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

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					(compared to underground piping) and therefore more disturbance to nearby habitats as a result of maintenance activities, should piping be installed aboveground. An additional advantage to belowground pipe for the water system is the increased selection of piping materials available. Aboveground piping is limited to metallic materials (ferrous or non-ferrous) due to sunlight and piping durability. Metallic piping is susceptible to corrosion and requires lining and coating maintenance during the lifetime of the project. Belowground piping material, including fiberglass and HDPE, are far less susceptible to corrosion and are in many cases smoother, requiring smaller pipe sizes to transmit water. In the 30% design, the exceptions to underground piping are as follows: • For protection of the old Route 66 roadbed, a short section of pipe and conduits was designed aboveground in the upland area. This is consistent with the existing water injection line from IM3 to the East Mesa. However, it is PG&E's preference to install final remedy facilities in this location belowground, if it can be accomplished consistent with applicable cultural resources protection standards. PG&E is evaluating this and will propose underground facilities along this corridor, if appropriate. • The **freshwater pipe** crossing the Colorado River is placed aboveground on the Arched Bridge because placing this pipe under the Colorado River is more intrusive, complex, and is not necessary. • The **new freshwater pipe** from the Arched Bridge to the existing storage tanks will follow the alignment of the existing freshwater pipe. The reason that both water pipelines will be aboveground is because of their close proximity to PG&E's large, high-pressure gas pipeline.				
160	DOI-38	Section 3.3.2.2/ 3-25/2nd Paragraph		What is the TCS fire flow storage requirement and how is it factored into the design basis for the freshwater storage tank capacity?	The fire flow storage requirement is defined by the California Fire Code and administered by the San Bernardino County. The Code looks at the size and type of buildings and the building materials. More information, including storage requirements will be provided in the 60% design.		Okay pending review of 60% design submittal.	Comment resolved.	See Section 3.3.3.2 and Attachment E (Firewater System Hydraulic Analysis) of Appendix C (Design Criteria) of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

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161	DTSC-70	Page 3-25, Section 3.3.2.2 Freshwater Supply Storage		See comments above for section 3.3.2 Design Basis for Freshwater Supply System, Exhibit 3-4, Page 3-22, 23 and 24. Provide some clarification/details regarding the "fire flow storage requirement for the remedy."	See response to comment #160 DOI-38. It should be noted that the fire flow requirements apply to the Station as a whole including remedy buildings.	Okay pending review of 60% design submittal.		Comment resolved.	See Section 3.3.3.2 and Attachment E (Firewater System Hydraulic Analysis) of Appendix C (Design Criteria) of this BOD Report.
162	DTSC-71	Page 3-25, Section 3.3.2.3 Freshwater Injection Wells	"Injection wells will be constructed using up to 14-inch nominal diameter well casing with one or two discrete screened intervals."	The rationale for selecting one or two discrete screened intervals should be explained as should the anticipated location of the screen(s).	The depth and interval of the freshwater injection well screens will be determined in the field after the pilot borehole has been drilled at each respective location. The depth and length of the well screen(s) will be dependent upon the materials or lithology encountered during drilling to insure the well is built in the target aquifer. It is possible that a well may be built with two discrete screened intervals if a fine grained hydrogeologic unit separates two water bearing zones of significant thickness. Wells with two discrete screened intervals could provide flexibility during operation if it is determined injection into one unit versus another, is more effective at meeting the remedy goals. Also see response to comment #76 (DOI-24) (revise Table 3-1 through 3-4).	Okay pending review of 60% design submittal.		Comment resolved.	See Section 3.3.3.4 of this BOD Report.
163	DOI-39	Section 3.4/3-26/ Exhibit 3-5		There are 42 injection/IRZ wells if COMP-INJ-1 and 2 are included, and 40 if not. Exhibit 3-5 indicates 41. There are 13 non-IRZ extraction wells, not 14 as indicated in Exhibit 3-5. Footnote b – It is not clear how 6 months on and 18 months off equates to 30 backwashes per year. This is also not clear from Appendix F. Appendix F indicates that the IM-3 injection wells are backwashed 24 times per year, which is inferred to be a minimum number of backwashes required by the IRZ injection wells. Substrate is not injected into these wells so backwashing of the IRZ injection wells could be considerably more frequent. More discussion is required.	The well count of 41 injection/IRZ wells came from 32 IRZ wells + 4 upland injection wells + 2 TCS injection wells + 3 freshwater injection wells. The well count of 14 non-IRZ extraction wells came from 5 riverbank extraction wells + 8 Northeast of TCS/East Ravine extraction wells + 1 freshwater extraction well. The number of 30 backwashes per year came from the assumption that IRZ wells are backwashed weekly while they are in service, and are backwashed at a less frequent basis while they are not in service. The weekly backwash assumption was based on the Hinkley test at the IRZ well SA-RW-19, and not the IM3 injection wells.		Okay.	Comment resolved.	See Exhibit 3.4-1 of this BOD Report. As shown in the exhibit, there are 32 injection wells (24 IRZ + 4 IRL+ 2 TCS + 2 Freshwater), 4 IRZ extraction wells, 12 non-IRZ extraction wells (5 Riverbank, 5 East Ravine, 2 TW Bench), and 1 freshwater supply well.
164	DTSC-72	Section 3.4 Remedy-produced Water Management		Although this section described in some detail the remedy produced water management approach, the design of the system (e.g. the automatic backwashing system) does not seem to be reflected in the P&ID.	Comment noted. Additional information will be included in the 60% design submittal.	Okay, pending review of the 60% design submittal.		Comment resolved.	See Appendix D of this BOD Report (Engineering Drawings).

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
165	HA-22	p. 3-26, Section 3.4 (Remedy-Produced Water Management)		This section indicates that approximately 7.3 million gallons of remedy-produced water (RPW) will be generated annually and provides a preliminary management plan. On p. 3-29, it is suggested that there may be a need for future changes in this plan. Is it likely that one of the future options will include the need for on-site treatment and therefore the construction of a new water treatment plant?	It is possible that in the future, there may be a need for on-site treatment. If and when that need is first recognized, it is anticipated that agencies/stakeholders will be engaged and Tribes will be consulted in accordance with applicable established communications and consultation requirements.	Comment and response noted.	Comment and response noted.		
166	DOI-40	Section 3.4.1/3-27/ 3rd Paragraph		What criteria are used to determine transport of rehab wastewater by pipeline or truck? A pH greater than 2 (not a characteristically corrosive hazardous waste) would be a criterion if remedy-produced water lines are not double lined. (Also see comment pertaining to page 3-13.) It is stated that once rehab water is determined to be suitable to convey in the wastewater lines, it will be pumped using portable pumps tied into the pipeline via tee connections. This implies rehab wastewater will be collected in a tanker truck. This would require secondary containment for the tanker truck at each well. Also, if the wastewater is suitable for conveyance in the pipelines, would it not be directly pumped in to the pipeline using the backwash or groundwater extraction pump? Please clarify.	The regulatory criteria for allowable transport of produced water (from well rehabilitation) by single –walled pipeline is pH>2, dissolved Cr<5 ppm, and dissolved As<5 ppm. At this time, PG&E does not intend to convey water that exhibits hazardous waste characteristics in produced water conveyance pipelines. In practice, well rehabilitation involves removing the existing infrastructure such as the extraction or backwash pump and downhole piping to enable insertion of rehabilitation equipment such as jets and swabbing devices. Therefore, normally present backwash pump would not be available for conveying produced rehabilitation water. First flush rehab water would, instead, be pumped out of the well with a temporary rehab pump through temporary piping, pH neutralized, and contained in temporary tanks located near the wellhead. All temporary tanks and piping will have adequate spill containment, as well as the area surrounding the wellhead.		Okay pending review of 60% design submittal.	Comment resolved.	
167	DOI-41	Section 3.4.2, Paragraph 1, Last Sentence		This statement is very misleading. Although the treated water would be used for a purpose, it will not be returned to the aquifer and could constitute a consumptive use.	The statement is meant to convey the concept that use of remedy wastewater in the cooling towers would preclude the need to pump an equivalent amount of groundwater for cooling water. Thus, the use of remedy wastewater in the cooling towers would not increase the consumptive use of water at the compressor station. This statement will be clarified in the 60% design submittal.		Okay pending review of the 60% design.	Comment resolved.	See Section 3.4.2 of this BOD Report.
168	DOI-42	Section 3.4.2/3-27/1st Paragraph		Indicate that a dedicated infiltration gallery in Bat Cave Wash is not being considered at this time because it is pending the findings of the soil RFI/RI and CMS/FS.	For clarification, the following text will be added to the 60% design submittal: "(note that an infiltration gallery in Bat Cave Wash is not being considered at this time because it is pending completion of the Soil RFI/RI and CMS/FS)"		Okay pending review of the 60% design.	Comment resolved.	See Section 3.4.2 of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
169	DTSC-73	Page 3-28, Section 3.4.2 Reuse/Disposal Options and Conditioning, Exhibit 3-6		Exhibit 3-6, Item 2, "Other Constraints" which discusses using the evaporation ponds for discharge should mention that Regional Water Quality Control Board input is required as they regulate the ponds. It should also be noted that these evaporation ponds are outside of the EIR project boundary and additional environmental review may be necessary. The note at the bottom of the exhibit indicates that the Infiltration Gallery in Bat Cave Wash option is deferred until after completion of the Soil RFI/FS and CMS/FS. First, DTSC and a Tribe commented on the Gallery as it affected the soil work plan. PG&E indicated that the Gallery was no longer being considered, and therefore, soil comments related to the Gallery were dropped from further consideration. The note in this exhibit indicates that the soil comments should again be addressed. Notes on Figure 3-1 are different than the notes on Exhibit 3-6. These notes should be clarified and be made consistent throughout the document. PG&E needs to clearly indicate if it is permanently dropping its disposal option at the Bat Cave Wash gallery and Park Moabi sewage ponds from further consideration as part of the remedy design.	Comment noted. The following text will be added to Exhibit 3-6, Item 2, "Other Constraints" (similar to the text in Appendix F, Table F-5, page F-11): As mentioned in the response to DTSC comment #19 (Appendix F, page F-29), PG&E agrees that the TCS ponds are located outside of the EIR project area, but are still inside the Area of Potential Effects (APE). Sending water to the TCS ponds would be done by running a pipe to the existing cooling tower blowdown system. This new pipe would be located on the TCS property. So, no construction would occur outside of the approved project area. The footnote #5 in Figure 3-1 says "Potential infiltration gallery is pending completion of soil RFI/RI and CMS/FS. This footnote is not inconsistent with the footnote on Exhibit 3-6 which states that the infiltration gallery in Bat Cave Wash is not proposed in this submittal (i.e., included in the 30% design), pending completion of the Soil RFI/RI and CMS/FS. The infiltration gallery in Bat Cave Wash is being deferred/ retained and not dropped until after completion of the Soil RFI/RI and CMS/FS. Further evaluation of the Park Moabi sewage pond option will be performed at the 60% design stage, and the evaluation results will be included in the 60% design submittal. Also see response to comment #63 (DTSC-13)	Okay pending review of 60% design submittal.		Comment resolved.	See Section 3.4.2 of this BOD Report.
170	DOI-43	Section 3.4.2.1/3-29/ Exhibit 3-7		First note – please explain why chromium levels in backwash from freshwater injection wells would be high enough to warrant Option 1 or 4 management. Also, it appears you mean option 2 and not 4. With regard to first flush rehab water, the options for disposal are limited to TCS ponds or trucking offsite. This implies dissolved constituents are a major constraint for wastewater reuse (not simply low pH or high solids for which the treatment system has been designed to address). This requires further discussion.	The first note is an older note, a remnant of the drafting process and will be removed from the 60% design submittal. As discussed, the possibility of processing the first flush rehab water at the produced water conditioning plant will be evaluated in the 60% design.		Okay pending review of 60% design submittal.	Comment resolved.	See Section 3.4.2.1 of this BOD Report. Also see Appendix F of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
171	DOI-44	Section 3.4.2.2		Backwash water from the IRZ injection wells will contain substrate. There should be discussion of possible biofouling of the filters and control measures.	Ethanol is soluble and will not foul the filters. The most potentially fouling water would be produced water from IRZ wells or carbon amended injection wells. As discussed in Appendix F of the 30% BOD, a pilot test has been underway at Hinkley since June 2011 to evaluate backwash frequency and backwash water quality at the IRZ well SA-RW-19. Noted observations from the Hinkley pilot test included: 1) frequent backwashing appears to reduce the buildup of solids (resulting from biomass buildup) and organic carbon in the tested well and 2) the biomass settles quickly in the settling tanks. The Hinkley test is ongoing and the data will be incorporated into the 60% design. In addition, coagulants/flocculants will also be evaluated during the 60% design (see page 3-33 of the 30% BOD) for potential benefits in improving settling of suspended solids in produced water. If the use of these agents is determined to be beneficial, this would require the installation of chemical storage tanks, chemical feed or metering pumps, and controls.		Okay pending review of the 60% design.	Comment resolved.	See Section 3.4.2.2 of this BOD Report.
172	DOI-45	Section 3.4.2.2/3-30/ 1st Paragraph		It is stated that “in the event that the produced water is hazardous, permitted transportable treatment units could be used.” Is pH the only criterion for evaluating whether the rehab wastewater is hazardous? Would the permitted treatment units be owned by PG&E to facilitate immediate use, or would the service be subcontracted to a vendor?	The criteria for evaluating whether produced water from rehabilitation is hazardous are 1) pH for corrosivity and 2) dissolved chromium and arsenic for toxicity. There has not been a decision regarding ownership of permitted treatment units or outsourcing of treatment services for this site.		Okay.	Comment resolved.	
173	DOI-46	Section 3.4.2.2/3-30/ 1st bullet		It is stated that “remedy-produced water that has significantly higher concentrations than what exists in the aquifer…” Do you mean higher concentrations of dissolved solids? Please elaborate.	The statement refers to significantly higher concentrations of solids or dissolved constituents (e.g., byproducts) in remedy produced water than in what exists in the aquifer.		Okay.	Comment resolved.	
174	DOI-47	Section 3.4.2.2/3-30/ 1st and 2nd bullet		As indicated in the comment on Section 3.4.1, it is implied that first flush rehab wastewater will be collected in a tanker truck. There is also the possibility of using permitted transportable treatment units (see first comment on Section 3.4.2.2) or using the conditioning plant. Then there is the option to use the wastewater conveyance lines, or truck the wastewater to the conditioning plant, and finally the option to dispose of the wastewater off-site or at the TCS evaporation ponds with or without treatment. Although this will certainly need to be fleshed out in the O&M plan, there needs to be more discussion in 30% design on how this will work in practice with such a complex decision tree.	See response to comment #6 DOI-6.	Okay pending review of the 60% design.	Okay pending review of future documents.	Comment resolved.	See draft O&M Manual, Volume 1 – Operations and Maintenance Plan.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
175	DOI-48	Section 3.4.2.2/3-30/last paragraph on the page		How will temporary fluctuations in water quality result in achieving background water quality? This sentence should be reworded for clarification.	The subject sentence carried forward an important point made in the 2009 CMS/FS, Section 3 (Remedial Action Objectives), and that is in order to attain the RAOs for Cr(VI), substantial movement of groundwater in the target remediation area – either through natural or induced measures - will be necessary, and under active treatment for Cr(VI), it is expected that significant mixing of groundwater in the target remediation area would occur both vertically and horizontally, As a result, water quality and concentrations measured at individual monitoring wells are expected to change during the course of the remediation from concentrations present today. For clarification the second sentence of the paragraph will be revised to read: "Temporary fluctuations in water quality will occur during remedy implementation prior to achieving RAOs. Institutional controls will prevent…"	Okay pending review of 60% design submittal.	Okay pending review of 60% design submittal.	Comment resolved.	See Section 3.4.2.2 and Appendix F of this BOD Report.
176	DOI-49	Section 3.4.2.2/3-32/third bullet from the bottom		It should be made clear that the discussion refers to first flush rehab water only. It should also be indicated that this water will be conditioned as required. There should be mention of secondary containment. A truck loading station in the Maintenance Shop seems odd and should be discussed further.	This text will be clarified in the 60% designed to be unconditioned produced water. Having a truck loading station in Maintenance Shops Area of TCS will give flexibility to handle this water. Specifically, given the proximity of the COMP-INJ-1/-2 and FW-INJ-4 wells, it would not be difficult to pump to the Influent Tanks at the Remedy Produced Water Conditioning Plant. As mentioned in Section C.4.5 (Secondary Containment) of Appendix C (Design Criteria), secondary containment will be sized and designed in conformance with applicable codes and standards. This will be reflected in the 60% design.	Okay pending review of the 60% design.	Okay pending review of the 60% design.	Comment resolved.	See Section 3.4.2.2 of this BOD Report
177	DOI-50	Section 3.4.2.2/3-32/second bullet from the bottom		It is not indicated that produced water conveyance piping will be double walled. If they are not double walled, then the lines cannot be used to convey characteristically corrosive hazardous waste (pH<2). Please discuss.	As indicated in Section C.4.1 (Piping) of Appendix C (Design Criteria), piping materials will be compatible with the characteristic of the conveying fluids and will be single walled unless the pipe is used to convey: 1) groundwater or remedy-produced water that exhibits hazardous waste characteristics or 2) concentrated carbon substrate. In these cases, double-walled piping will be used. At this time, PG&E does not intend to convey water that exhibits hazardous waste characteristics in produced water conveyance pipelines.	Comment and response noted. However, DTSC, in general, prefers the use of double wall piping for untreated waste water. DTSC will consider PG&E's proposal after review of the leak detection system evaluation in the 60% design submittal.	Okay pending review of 60% design submittal.	Comment resolved.	See Appendices C (Design Criteria) and D (Engineering Drawings)

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
178	DTSC-74	3.4.2.2 Conditioning	"Under the management plan presented above, removal of dissolved constituents will not be required because the injected water quality will be similar to the aquifer water quality in/near the Carbon-amended Injection Wells, the IRZ wells, and the Freshwater Injection Wells. Temporary fluctuations in water quality that may occur within the remedy footprint during remedy implementation will ultimately result in achieving background water quality for hexavalent chromium when the remedy is complete, and institutional controls will prevent use of affected groundwater while the remedy is being implemented. Furthermore, contaminant migration to the river that could potentially affect water quality goals or beneficial uses does not occur during remedy implementation through groundwater extraction along the river bank. PG&E believes that this interpretation is consistent with the requirements of the anti-degradation provisions of 40 CFR 131.12 and State Water Resources Control Board Resolution No. 68-16."	Metrics to ensure that "injected water quality will be similar to the aquifer water quality" will need to be developed by PG&E and obtain agency approval. As noted by comments on hexavalent chromium and arsenic related to the freshwater source, DTSC desires that the waters outside the current contaminant plume boundary not be degraded beyond site specific background conditions.	Comment noted. Additional information will be included in the Freshwater Supply TM.	Okay pending review of the Freshwater Supply TM.		Comment resolved.	See Section 3.4.2.2 and Appendix J of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
179	DTSC-75	3.5 Other Utilities and Supporting Facilities		A soil management plan related to building and soil disturbance must be provided with the design. DTSC notes that PG&E is scheduled to submit the draft Operation and Maintenance plan with the 60% design. Therefore, the soil management plan and sampling and analysis plan should be included. Please note that PG&E should consider the following four objectives as part of those plans: 1) developing current conditions/background for comparison in the future during the eventual decommissioning of the unit –this cannot be deferred; 2) characterizing, for proper soil management, potentially contaminated soils in areas known or suspected to be contaminated (at AOCs or SMWUs); 3) assessing soils in areas without a known history of contaminant releases; and 4) geotechnical data to support the design.	A soil management plan will be prepared and submitted with the draft O&M Manual.	Okay pending review of the O&M plan and the sampling and analysis plan		Comment resolved.	See draft O&M Manual Volume 4 – Soil Management Plan.
180	HA-23	p. 3-34, Section 3.5.3 (Buildings and Structures for Major Equipment)		Please refer to earlier comments (See Comment No. 10) regarding cautions regarding the use and acceptability of previously disturbed areas.	See response to comment HA-9.	Comment and response noted	Comment and response noted.		See Section 3.5.3 of this BOD Report.
181	HA-24	p. 3-35, Section 3.5.4 (Access Roads and Pathways)		The discussion in this section pertaining to the use of on-site materials requires further discussion with the Tribe. In particular, it appears there may be relevance to the ongoing discussions regarding disturbed soils handling policy.	Comment noted. Ongoing discussions about displaced soils handling policy between PG&E, agencies, and Tribes will be reflected, as appropriate, in the 60% design submittal.	Comment noted.	Comment noted		See Section 3.55 of this BOD Report. Also see draft O&M Manual, Volume 4 – Soil Management Plan.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
Alternatives for Siting Infrastructure/Infrastructure Considerations									
182	HA-33			On January 9, 2012, members and representatives of the Fort Mojave Indian Tribe ("the Tribe" or "FMIT") and the Hualapai Tribe participated in a briefing and site walk of the project area led by representatives of PG&E. The purpose of the site walk was to examine the locations of various infrastructure components of the Topock Final Groundwater Remedy in the field. This included proposed pipeline routings, well locations, chemical storage tanks, electrical transformers, etc. In addition to the proposed facility locations presented in the 30% BOD, possible alternative locations were examined and the logistics of changing to these locations were discussed. This site walk was particularly useful and afforded the participants to carry information back to the Tribes for consideration. Subsequently, on January 20, 2012, a meeting and teleconference was held with members of the FMIT Tribal Community as well as representatives of the Hualapai Tribe, Colorado River Indian Tribes (CRIT), and Cocopah Tribe in addition to certain members of the TRC. The following is a summary of the FMIT's comments and conclusions with regard to the particular alternatives presented for infrastructure siting. <u>General Statement</u> The proposed pipeline corridors and groundwater wells are located in and adjacent to areas that are sacred to Native American Tribes. The mere entrance to these areas for purposes other than Tribal activities is itself a desecration of the site and the placement, use and maintenance of project structures (pipeline corridors and groundwater wells) is even a greater desecration. All of these desecrations are unacceptable to the Tribes. However, the following comments reflect our best attempt to address the adverse effects associated with the 30% BOD with the hope that the desecration that is ongoing will be minimized to some degree by our recommendations on how to treat the land. For several of the facilities, including transformers and pipeline routings, it was suggested by PG&E that construction could be either above or underground. In general, the consensus of the Tribal Community was that, whenever possible and despite the undesirable visual impact of such structures, an above-ground configuration would be preferable on the rationale that it would involve less intrusion into the sacred grounds both during construction and eventual decommissioning and dismantling. This is further discussed below. A figure is attached to depict the preferences of the	Comments are noted. As directed by DOI and DTSC, PG&E will modify the piping network to eliminate the piping/ conduit segment in Bat Cave Wash. PG&E will evaluate the feasibility of additional locations for aboveground piping (in addition to locations already proposed in the 30% design) during the development of the 60% design. It should be noted that (in addition to increased visual impacts) a more-extensive above ground pipeline configuration will pose many challenges including health and safety, engineering design, and long term operation and maintenance challenges. Thermal design considerations may require substantial additional footprint to allow for expansion/contraction loops as well as a potentially large support structures (e.g., pipe rack, conduits or cable tray, shade assembly). Further it is likely that significant lengths of pipe racks will need to be elevated to allow the passing of vehicular traffic, adding to visual impacts. Detailed rationale for aboveground vs. underground piping/electrical conduits are also provided in response to comment #159 HA-21. Also see response to comment #183 HA-34 on electrical transformers.	Comment and response noted. DTSC notes that the certified FEIR included impact analysis for underground piping where possible based on information provided by PG&E on the conceptual design. Although DTSC recognizes the Tribes recommendation for siting pipelines and electrical transformers above ground, as discussed with the Tribes during the 3/20/12 meeting, other factors such as safety and regulatory constraints must be balanced with cultural resource considerations. In response to comments received from the Fort Mojave Indian Tribe and Hualapai Indian Tribe DTSC has directed PG&E to modify the design to eliminate the piping/conduit segment in Bat Cave Wash and to replace this with the double-back loop along NTH.	The federal agencies have consulted with the Tribes on the 30% design with particular focus on this and related comments. The Tribes comments and the discussions which occurred during consultation meetings were considered in our direction to PG&E regarding modifications to the design including the implementation of the double-back loop along NTH, eliminating the BCW trenching, an area that is in close proximity to the Topock Maze. The federal agencies believe these design modifications take into account the impacts to the site and to some extent reduce the overall affects of the remedy on the cultural, religious, and spiritual values held by the Tribes for the TCP within the APE while recognizing our responsibility for protecting public safety and reducing ecological and visual impacts in the area.		See Figure 3.0-1 of this BOD Report for piping alignment. PG&E further evaluated placement of piping in the utility corridor (underground or aboveground) during the 60% design development. Results of the evaluation are shown on Figure 3.0-1 of this BOD Report and the rationale is provided in Section C.2.2 of Appendix C (Design Criteria).

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

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				Tribe as presented during the site walk.					
183	HA-34			<u>Electrical Transformers</u> The Tribe was told during the January 9, 2012, site walk that there are seven step-up transformers proposed in order to provide power along the pipeline route to sever the wells and other loads (p. 3-33, Section 3.5.1). PG&E stated it has the option of either installing these transformers in underground vaults or above ground. Since all the remedy's electrical components were not disclosed in the EIR, additional mitigation for impacts to cultural resources and aesthetics may be necessary with either option, The Tribe has considered these options and recommends the following: 1. The design of the electrical system may be overly conservative to require this number of transformers. PG&E should review the electrical component design to determine if the number of transformers can be reduced. 2. In consideration of the invasive activities that would be required to install transformers underground and then to dismantle them at the end of the project, the Tribe recommends that all transformers be constructed above ground even though there may be visual impacts. 3. The Tribe concurs with the siting of the transformer adjacent to the IM3 WTP to the alternative location next to Bat Cave Wash.	PG&E will continue to evaluate and optimize the design of the electrical system, including the precise locations of the transformers, and additional information will be presented in the 60% design. PG&E will consider these comments in formulating the 60% design. Also refer to response to comment #159 HA-21 for rationale for aboveground vs. belowground. In general, PG&E placed transformers belowground due to health and safety concerns similar to piping. However, wherever possible, transformers can be co-located (aboveground) with planned aboveground buildings, e.g., the MW-20 bench. The aboveground building acts as a barrier and provides protection from traffic. With respect to the design of the system, page 3-19 of the Final EIR states generally that the electrical connections will be placed in underground vaults wherever feasible. Counsel for the Tribe has confirmed in discussions with counsel for PG&E that the references to consideration of mitigation measures refers to measures from the EIR, and not additional measures.	Comment and response noted pending review of 60% design	Comment and response noted pending review of 60% design.		The number of transformers was reduced from 7 to 6 after further evaluation. A future provisional transformer was also identified in the event the future provisional well IRL-7 needs to be installed and operated. Their locations are shown in Figure 3.0-1 of this BOD Report.
184	HA-35			<u>Pipeline Routings</u> A number of pipelines are included in the design for the purposes of routing freshwater from the supply well in Arizona (HNWR-1) across the Colorado River to the upland freshwater injection wells and from the floodplain extraction wells adjacent to the western bank of the Colorado River to the upgradient injection wells as part of the inner recirculation loop. Consistent with the recommendation presented earlier with regard to running these pipelines above vs. underground, the Tribe recommends that, wherever possible, the routings should be above ground. In particular, 1. This includes pipelines associated with FW-INJ-4; MID-EX-1,-2,-3, and -4; UPGRADINJ-1,-2-3, and -4. 2. FW-INJ-4 piping would cross Bat Cave Wash, but the Tribe would still prefer that the piping be positioned above ground. 3. The proposed routing of the freshwater pipeline across the Colorado River to the Compressor Station should stay along former Route 66 rather than moving uphill to the El Paso gas pipeline right of way (ROW).	As directed by DOI and DTSC, PG&E will modify the piping network to eliminate the piping/conduit segment in Bat Cave Wash. The details of the pipeline configuration associated with UPGRAD-INJ wells, MID-EX wells and FW-INJ-4 will be dealt with in more detail during the 60% design phase. However, it must be noted that above ground piping will involve many potential challenges such as health and safety, long term operation and maintenance and engineering design issues. Detailed rationale for aboveground vs. belowground is presented in the response to comment #159 HA-21. The comment regarding routing freshwater pipeline crossing the Colorado River along the former Route 66 will be taken into consideration for evaluation during the 60% design.	Comment and response noted. DTSC notes that the certified FEIR included impact analysis for underground piping where possible based on information provided by PG&E on the conceptual design. Although DTSC recognizes the Tribes recommendation for siting pipelines and electrical transformers above ground, as discussed with the Tribes during the 3/20 meeting, other factors such as safety and regulatory constraints must be balanced with cultural resource considerations. In response to comments received from the Fort Mojave Indian Tribe and Hualapai Indian Tribe DTSC has directed PG&E to modify the design to eliminate the piping/conduit segment in Bat Cave Wash	The federal agencies have consulted with the Tribes on the 30% design with particular focus on this and related comments. The Tribes comments and the discussions which occurred during consultation meetings were considered in our direction to PG&E regarding modifications to the design including the implementation of the double-back loop along NTH, eliminating the BCW trenching. The federal agencies believe these design modifications take into account the impacts to the site and to some extent reduce the overall affects of the remedy on the cultural, religious, and spiritual values held by the Tribes for the TCP within the APE while recognizing our responsibility for protecting public safety, reducing ecological and visual impacts in the area.		PG&E further evaluated placement of piping in the utility corridor (underground or aboveground) during the 60% design development. Results of the evaluation are shown on Figure 3.0-1 of this BOD Report and the rationale is provided in Section C.2.2 of Appendix C (Design Criteria).BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
						and to replace this with the double-back loop along NTH.			
185	HA-36			<u>Alternate Injection Well Siting</u> The Tribe considered the alternative locations discussed for the various injection wells associated with the inner recirculation loop. The following are the consensus recommendations. 1. FW-INJ-2 should be placed within the former Route 66/National Trails Highway (NTH) ROW instead of the currently proposed location. It is understood that this placement would require vaulting and that the NTH is a historic landmark. However, a utility vault in a "public highway" is not inconsistent with typical highway purposes, whereas it would be a less impactful desecration than placing it on unpaved Tribal sacred grounds. 2. UPGRAD-INJ-2 and UPGRAD-INJ-3 also are not sited in acceptable locations. As with FW-INJ-2, both should be moved onto the former NTH ROW and installed in vaults. 3. UPGRAD-INJ-4 also is not sited in an acceptable location. The preferred location would be within the median of I-40. However, PG&E stated that siting in the median was denied by Caltrans on the grounds of future plans to widen the I-40 to six lanes. This point needs independent verification and a consultation between Caltrans and the Tribes may be in order for Caltrans to reconsider its options. Therefore, the Tribe requests that an effort to re-approach Caltrans be made by the Agencies in coordination with the Tribes, explaining the conflicts with alternate locations. In particular, the timing of the proposed widening should be considered and evaluated in terms of the temporary use of this area as an injection well site. Assuming that plans for highway widening are sufficiently distant in the future, perhaps the site could be used in the interim and the well abandoned in favor of an alternate location when the road widening project begins. 4. Assuming that Caltrans remains unwilling to grant access for siting UPGRAD-INJ-4 in the I-40 median, the Tribe would prefer its placement within the drainage bottom east of the presently proposed location, as indicated on the attached figure, as opposed to the presently proposed site. **Additional comments/notes from Attachment B Map:** • Do not use this access road for UPGRAD-INJ-2. • Keep FW-INJ-2 in this area, closer to access road. • Remove IM-3 improvement from this area	As discussed at the 3/20/12 meeting with agencies and Tribes, PG&E will modify well locations as follows (in the 60% design) : 1. Relocate FW-INJ-2 as suggested in the Attachment B map of the FMIT's comment letter. This well will placed in an underground vault. 2. Relocate UPGRAD-INJ-3 to a location closer to the old Route 66. To avoid the So Cal gas pipeline, PG&E propose this well be located on the north side of old Route 66. This well will placed in an underground vault. Relocate UPGRAD-INJ-2 as suggested in the Attachment B map of the FMIT's comment letter. This well will placed in an underground vault. A new access road connecting to the old Route 66 will be designed in the 60% design for accessing this well. 3. As previously stated, PG&E met with Caltrans early in the design process to discuss the siting of an injection well in the median of I-40. PG&E was informed that siting of a well in the median of I-40 is not acceptable because of a) the median could be used in the future plans for widening of I-40 and b) the health and safety hazard associated with installing and maintenance of a well in the median. 4. Relocate UPGRAD-INJ-4 to the wash located just west of the proposed well location in the 30% design. An access road off the old Route 66 will be designed in the 60% design for accessing this well. PG&E proposes that the pipelines and conduits connected to this well will be installed underground in the roadbed of the newly-constructed road. Since this well will be located in a wash, PG&E proposed to place the well inside a semi-underground vault for easy access and to avoid water from inundating the vault in case of a flow event.	Comment and response noted. DTSC concurs with the modified well locations as proposed.	The federal agencies have consulted with the Tribes on the 30% design with particular focus on this and related comments. The Tribes comments and the discussions which occurred during consultation meetings were considered with respect to the modifications to the design concerning well locations in the upland area as indicated in the response.		See Figure 3.5-9 of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
				and restore. • Is the location of UPGRAD-INJ-1 in future Tribal land? • Move UPGRADINJ- 3 to this location. • Move UPGRADINJ- 2 south and grade access road to Route 66. • Ridges in this area not acceptable for wells. • Move UPGRADINJ- 4 to this location.					
186	HA-37			<u>TOC Amendment Storage Tank</u> The Tribe reviewed alternative sites for construction of a 2,500 gallon storage tank for supplying the total organic carbon (TOC) amendment (ethanol) for *in situ* treatment at the "Transwestern Pipeline bench." The Tribe prefers the location along the Compressor Station entrance road, as opposed to the hillside, based on the expectation of less intrusion. **Additional comments/notes from Attachment B Map:** Recommended location for Alcohol tank.	Comment noted. These alternative locations will be reviewed in detail as part of the 60% design.	Comment and response noted.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		After further evaluation, PG&E located the 3000-gallon carbon storage tank against the hillside to maximize the amount of available space for shared use of the Transwestern Bench space by the Topock remediation project and Transwestern gas operations.
187	HA-38			<u>Impacts to Tribal Land</u> As a general principle, the Tribe's preference is for as little remediation infrastructure to be placed on its property as possible. The Tribe and PG&E should consider this in implementing necessary access to the area.	The Tribe's preference is recognized and will be further considered during the development of the 60% design, consistent with the 2006 Easement Agreement and the 2006 Settlement Agreement between the Fort Mojave Indian Tribe and PG&E. A statement to this effect will be included in the 60% design submittal.	Comment and response noted.	Comment and response noted.		After further evaluation and consideration of Tribe's preference, PG&E relocated freshwater injection well FW-1 to outside the FMIT property line. See Figure 2.4-1, FW-1 is the western most well that is located just south of the FMIT property.
188	Hualapai-26			<u>Selection of Remediation Well Locations</u> *UPGRAD-INJ-1*: The pipeline that connects the UPGRAD-INJ-1 well should be above ground as indicated above, as this is the less-intrusive option. The well structure should also be above ground. There are no recommendations for re-locating this well.	As directed by DOI, UPGRAD-INJ-1 will be placed in belowground vault. Please refer to comment #159 HA-21 and #182 HA-33 for considerations regarding above vs. underground piping. For protection of the old Route 66 roadbed, a short section of pipe and conduits was designated as aboveground in the upland area in the 30% design. This is consistent with the existing water injection line from IM3 to the East Mesa. However, it is PG&E's preference to install final remedy facilities in this location belowground, if it can be accomplished consistent with applicable cultural resources protection standards. PG&E is evaluating this and will propose underground facilities along this corridor, if appropriate.	Comment and response noted.	Comment and response noted pending review of 60% design. During consultation meetings with the federal agencies, the tribes expressed their interest to have upland well structures below ground. The design will reflect this preference.		After further evaluation, PG&E proposed underground pipe trench along this segment of Route 66. See rationale in Section C.2.2 of Appendix C (Design Criteria).

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
189	Hualapai-27			Selection of Remediation Well Locations *UPGRAD-INJ-2 and 3*: Well completions should be above ground as should connecting pipelines. Locations of these two wells however, are unacceptable. We concur with the Fort Mojave Indian Tribe to re-locate both UPGRAD-INJ 2 and 3 to the former Route66/National Trails Highway right-of-way as this is less intrusive and does not require the construction of a new road, creating further desecration to the area.	As directed by DOI, these wells will be relocated and placed in belowground vaults. Also see response to comment #159 HA-21 and #185 HA-36,	Comment and response noted.	Comment and response noted pending review of 60% design. During consultation meetings with the federal agencies, the tribes expressed their interest to have upland well structures below ground and move *UPGRAD-INJ-2 and 3*. The design will reflect the results of those discussions.		See Figure 3.0-1 of this BOD Report.
190	Hualapai-28			Selection of Remediation Well Locations *UPGRAD-INJ-4*: It is understood that the current locations proposed for remediation wells and infrastructure was initially placed with an attempt to consider both efficacy of the system, and minimizing surface disturbance. However, the current location of injection well UPGRAD-INJ-4 is troubling for two reasons. First, the physical location for this well is very near remnants of the Topock Maze which are still present in this generally disturbed area. Any additional traffic and disturbance in this area, especially over the decades-long time frame of the remediation would very likely result in further degradation of these remaining portions of the maze. In addition, the elevation of this well site is very close to that of the central portion of the maze located south, on the other side of I-40. Therefore, this well location is extremely visible and disruptive when viewed from the maze. We concur with the Fort Mojave Indian Tribe to re-locate UPGRAD-INJ-4 into the drainage east of the proposed location. This location is the preferred choice as it is at best, minimizing adverse effect to the ridge-line above and reduces visibility of well activities in an area that is sacred.	As directed by DOI and as discussed in the 3/20/12 meeting with agencies and Tribes, this well will be relocated to the wash located just west of the proposed well location in the 30% design. An access road off the old Route 66 will be designed in the 60% design for accessing this well. The pipelines and conduits connected to this well will be installed underground in the roadbed of the newly- constructed road. Also see response to comment #185 HA-36. Since this well will be located in a wash, PG&E proposes that it be placed inside a semi-underground vault for easy access and to avoid water from inundating the vault in case of a flow event.	Comment and response noted.	Comment and response noted pending review of 60% design. During consultation meetings with the federal agencies, the tribes expressed their interest to have upland well structures below ground and move UPGRAD-INJ-4. The design will reflect the results of those discussions.		See Figure 3.0-1 of this BOD Report.
191	Hualapai-29			Selection of Remediation Well Locations *FW-INJ-1*: It is understood that FW-INJ-1 is located to the north on the floodplain west of the access road (Route66/National Trails Highway). If this well fails, or is subject to salinity, where will an alternate injection well be placed?	Salinity would not preclude successful completion of an injection well, however, if low permeability aquifer materials were encountered in this area that limited the amount of water that could be injected, additional injection wells could potentially be drilled nearby in hopes of finding better aquifer materials, or an additional injection well could be installed at an acceptable location somewhere between FW-INJ-1 and FW-INJ-2.	Comment and response noted.	Comment and response noted.		Upon further evaluation, PG&E removed the FW-INJ-1 well previously located to the north on the floodplain west of the access road.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
192	Hualapai-30			Selection of Remediation Well Locations *FW-INJ-2*: Well completions should be above ground as should connecting pipelines. Location of this well however, is unacceptable. We concur with the Fort Mojave Indian Tribe to re-locate FW-INJ-2 further into the former Route66/ National Trails Highway right-of-way as this is less intrusive and does not require the construction of a new road, creating further desecration to the area.	As directed by DOI, these wells will be relocated and placed in belowground vaults. Also see response to comment #159 HA-21,	Comment and response noted.	Comment and response noted pending review of 60% design. During consultation meetings with the federal agencies, the tribes expressed their interest to have upland well structures below ground and move FW-INJ-2. The design will reflect the results of those discussions.		See Figure 3.0-1 of this BOD Report.
193	Hualapai-23 and TRC-14			Infrastructure Considerations **Pipelines**: The Hualapai, and others, completed a Topock site-walk on January 9, 2012 of the proposed 30% design pipeline infrastructure. After due deliberation, we concur with the Fort Mojave Indian Tribe to have all pipelines placed aboveground. By doing this, it is hoped that adverse effects associated with the remedy infrastructure will be minimized. Site location data for all pipelines will be maximized in this manner. Additionally, considerable remediation infrastructure, mainly a pipeline, is planned for Bat Cave Wash. Whether buried or at ground-level, this infrastructure will be subject to temporary inundation, scour, or burial as a result of future flood events in the wash. **TRC Recommendation:** It may be appropriate to complete a hydrologic and hydraulic evaluation of Bat Cave Wash to determine water surface elevations at key locations for design storm events of interest, e.g., the 100-yr storm / flood. In general - digital as-built/record drawings, based on accurate field surveys, should be prepared to document the placement of all project infrastructure, particularly subsurface elements. Further, all non-ferrous or non-conductive buried infrastructure (particularly pipelines) should be installed with detection tape or wire. These actions will serve to minimize ground and subsurface disturbance for modifications, repair or future removal. **Transformers:** It is understood that there are plans for 7 to 10 transformers necessary for electrical conversion. Hualapai concurs with the Fort Mojave Indian Tribe in that we prefer all transformers to be constructed aboveground. The design of the electrical system appears to conservative due to the length of each line. We asked that the electrical system be reviewed in regards to possibly reducing the number of required transformers.	As directed by DOI and DTSC, PG&E will modify the piping network to eliminate the piping/conduit segment in Bat Cave Wash. Also see response to comment #159, HA-21 for rationale on aboveground vs. belowground piping/electrical conduits; and response to comments #159 HA-21 and #183 HA-34 regarding transformers.	Comment and response noted. DTSC notes that the certified FEIR included impact analysis for underground piping where possible based on information provided by PG&E on the conceptual design. Although DTSC recognizes the Tribes recommendation for siting pipelines and electrical transformers above ground, as discussed with the Tribes during the 3/20 meeting, other factors such as safety and regulatory constraints must be balanced with cultural resource considerations. In response to comments received from the Fort Mojave Indian Tribe and Hualapai Indian Tribe DTSC has directed PG&E to modify the design to eliminate the piping/conduit segment in Bat Cave Wash and to replace this with the double-back loop along NTH.	The federal agencies have consulted with the Tribes on the 30% design with particular focus on this and related comments. The Tribes comments and the discussions which occurred during consultation meetings were considered in our direction to PG&E regarding modifications to the design including the implementation of the double-back loop along NTH, eliminating the BCW trenching. The federal agencies believe these design modifications take into account the impacts to the site and to some extent reduce the overall affects of the remedy on the cultural, religious, and spiritual values held by the Tribes for the TCP within the APE while recognizing our responsibility for protecting public safety and reducing ecological and visual impacts in the area.		See Figure 3.0-1 of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
194	TRC-15			It is understood that the current locations proposed for remediation wells and infrastructure were initially placed with an attempt to consider both efficacy of the system, and minimizing surface disturbance. However, some current proposed locations of wells and infrastructure are not desirable for the Tribes. Placement of these structures and wells should be done with consideration to the preservation of the physical archeological resources, as well as in a way to minimize subsurface disturbance. **TRC Recommendation:** We understand that discussions and evaluations are ongoing on this issue with the Tribes, and specific alternate routes and well locations will be included in the 60% design as these discussions reach a conclusion.	Comment noted. As directed by DOI and DTSC, PG&E will modify the piping network to eliminate the piping/conduit segment in Bat Cave Wash, relocate upland wells (except UPGRAD-INJ-1), and place the wells in belowground vaults. An exception is the vault for UPGRAD-INJ-4. Since this well will be located in a wash, PG&E proposes that it be placed inside a semi-underground vault for easy access and to avoid water from inundating the vault in case of a flow event.	Comment and response noted.	The federal agencies have consulted with the Tribes on the 30% design with particular focus on this and related comments. The Tribes comments and the discussions which occurred during consultation meetings were considered with respect to the modifications to the design concerning well locations in the upland area as indicated in the response.		See Figure 3.0-1 of this BOD Report.
Section 4 Comments — Operations and Maintenance Provisions									
195	DTSC-76	Section 4 Operations and Maintenance Provisions		DTSC defers review of this section until sufficient information is provided to allow for a meaningful review.	Comment noted.	Okay.			
196	HA-25	p. 4-2, last para.		This text refers to the preparation of a “sampling and monitoring plan” as part of the 60% design submittal. The Tribe is interested in particular in the monitoring network configuration, including proposed new monitor well locations.	Comment noted.	The sampling and monitoring plan will be provided to the tribes as part of the 60% design review.	Comment noted.		See draft O&M Manual – Volume 2, Sampling and Monitoring Plan

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
197	MWD-1	O&M Provisions		Metropolitan recommends that the following items be further developed in the forthcoming Draft Basis of Design Report/60% Design Submittal for the Final Groundwater Remedy because they are not addressed in the 30% Design Submittal. 1. Groundwater Monitoring Program (GMP), 2. Operation and Maintenance Plan (O&M), 3. Contingency Plan, and 4. Transition Plan from IM-3 to full Remedy Metropolitan believes these programs and plans are integral to successfully implementing and operating the remedy and to protecting the water quality of the Colorado River. Specifically, the GMP will need to identify and describe existing new wells that will become part of the program, the purpose of each well in the network, monitoring parameters, and monitoring frequency. Groundwater monitoring parameters should include both water quality and groundwater levels. Remedial Action Objectives (RAO) for water quality (surface and groundwater) and groundwater levels should be defined in the GMP for protection of the Colorado River and other sensitive habitats/sites and for process control measures to optimize elements of the remedy. The O&M Plan developed for the Groundwater Remedy System should be separate from the GMP and identify the means and measures for operating and maintaining the system. The Groundwater Remedy fail or compliance objectives are not met. Time frames should be included in the contingency plan for implementing corrective measures and they should be implemented in such a way that they are protective of Colorado River water quality and other sensitive habitats/sites.	PG&E appreciates MWD's recommendation and is committed to submit an O&M Manual that meets the substantive regulatory requirements. The O&M Manual will include the following: 1. O&M Plan – including routine O&M procedures, maintenance and site management practices. 2. Groundwater/Water Sampling and Monitoring Plan – including monitoring goals, compliance and performance monitoring, sampling methods, and data management practices. 3. Contingency Plan – including the in situ remediation system, compliance monitoring, remedy produced water management system, freshwater supply, power supply, and SCADA. 4. Soil Management Plan 5. O&M Health and Safety Plan Details of the transition from the IM3 system to the final remedy will be provided in the 60% design report.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal and O&M plan review.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal and O&M plan review.		See draft O&M Manual

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
198	MWD-2	O&M Provisions		A plan needs to be fully developed and described in the 60% Design Report on the transition from the currently operating IM-3 Treatment Plan to full operation of the Groundwater Remedy. It is imperative that during the transition the hexavalent chromium plume in the floodplain is not allowed to migrate closer to or beneath the river, particularly if there is a possibility that portions of the plume would move beyond what could be captured by the Groundwater Remedy's Riverbank Extraction Wells. It is important to maintain the hydraulic gradient protecting the river during this transition period. In order to better understand changes in the plume as well as its movement during the transition period, the 60% Design Report should include a chemical reaction and solute transport simulation of the Transition Plan using the project's numerical model. The simulation time steps should be sufficiently small to take into account the hydraulic and chemical changes that are occurring as the elements of the remedy are brought online. The simulation should include the timing of the National Trails Highway In-situ Reductive Zone, extraction of fresh water at the Havasu National Refuge Well, injection of fresh water, activation of the Inner Recirculation Loop and activation of the Topock Compressor Station Recirculation loop. Modifications of the base Transition Plan should also be considered and simulated to better understand and optimize the transition to meet implementation objectives, including protection of the Colorado River's water quality.	The details of the transition from the IM3 system to the final remedy will be provided in the 60% design. During remedy transition and operation, some hexavalent chromium currently in the floodplain will move toward the river bank extraction wells where it will be captured. To the extent possible, the model will be used to evaluate the changes in the plume during the transition period. The shortest time step that is meaningful to model is one month so modeling will be supplemented with monitoring and adjustment during the transition period. As suggested, consideration of alternative sequencing of start-up of the system components will be evaluated to assess whether additional assurance of plume control can be obtained by modifying the sequence of start-up.	Comment and response noted.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		See Section 7.3 of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
199	Hualapai-10 and TRC-6	O&M Provisions		Evaluation and Application of In-Situ Pilot Scale Test Results There is concern that the values of oxidation-reduction potential (ORP) reported in the Topock reports are obtained from platinum-electrode measurements. These platinum-electrode values do not accurately represent the oxidation-reduction potential (Eh) of the subsurface geochemical conditions. Redox couples need to be analyzed (for example, Fe(III)/Fe(II) or Se(VI)/Se(IV) or As(V)/As(III)) in order to track the progress of remediation. The tracking of Eh conditions during remediation will give a more accurate representation of the subsurface redox conditions, and accurate Eh values can be used to describe geochemical speciation through theoretical Eh-pH diagrams. **TRC Recommendation:** It may be appropriate to discuss this during a TWG meeting, and incorporate in monitoring plans within the 60% design report.	The ORP measurements are made with a silver-silver chloride electrode, which is approximately 200 mV less than the standard hydrogen electrode used in reporting Eh values. We agree that this measurement alone provides only an approximate measure of the groundwater redox conditions. Laboratory measurement of redox indicators that will be part of the monitoring program include dissolved oxygen, nitrate, dissolved manganese, dissolved iron, and sulfate. Although more detailed speciation of oxidation state of iron, arsenic and selenium is possible, it is usually not necessary. For example, at the pH range of the site, iron measured in a dissolved iron analysis will likely be comprised of ferrous iron. For arsenic, the driving force for dissolution is the establishment of reducing conditions under which arsenic associated with iron minerals will be released during iron reduction, regardless of arsenic oxidation state. The measurement of dissolved iron and dissolved arsenic concentrations are typically sufficient to understand the establishment of metal reducing conditions and resulting changes in solubility of arsenic.	Comment and response noted.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		
200	Hualapai-18 and TRC-11			Addressing Potential Byproducts, Arsenic, Other Metals The generation of byproducts, including arsenic, barium and manganese, in areas downgradient of the IRZ may be higher than that anticipated by the 30% design report. During the Upland ISPT, arsenic concentrations were reported as high as 97 µg/L in well PT-7D. Arsenic production in well PT-8S appears to be related to the reductive dissolution of manganese rather than sulfate reduction (Figure A2). Increased concentrations of barium in excess of the 1,000 µg/L MCL were observed during the Upland ISPT. **TRC Recommendation:** The monitoring program for the IRZ system should include background and then periodic analysis of Title 22 Metals, possibly annually for a selection of wells, to ensure excessive generation of unwanted byproducts is not occurring. It is anticipated to see this addressed in the monitoring program included in the 60% design report.	PG&E agrees that monitoring of arsenic, barium and manganese are integral components of the performance monitoring program, and these constituents will be included in the plan presented in the 60% design. The monitoring plan will be submitted with the 60% design for review and comment. With regards to the Uplands pilot test data referenced, the elevated concentrations of arsenic and barium measured in the Uplands pilot test were related to the distribution of higher than necessary amounts of organic carbon substrate during that pilot test. Lower concentrations are planned for the final remedy. The commenter is correct that arsenic dissolution is related to metals reduction, rather than sulfate reduction, although iron reduction and the release of arsenic associated with iron minerals may have played a more significant role than manganese reduction. The increase in barium concentrations is likely associated with sulfate reduction and the dissolution of barium sulfate.	Comment noted. Further evaluation will occur during review of 60% design.	Response noted. Further evaluation will occur during review of 60% design.		See Section 2.3 of this BOD Report and the draft O&M Manual – Volume 2, Sampling and Monitoring Plan.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
201	Hualapai-19			Addressing Potential Byproducts, Arsenic, Other Metals In addition, we support further analysis of the potential for increased arsenic concentrations resulting from injection of freshwater containing arsenic such as well HNWR1 which has arsenic concentrations in excess of 10 µg/L.	Additional analysis will be provided in the 60% design submittal.	Comment and response noted.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		See draft O&M Manual Volume 2, Section 5.2.
202	Hualapai-20 and TRC-12			Addressing Potential Byproducts, Arsenic, Other Metals Cr(VI) is unstable in the presence of TOC. Many samples which would be collected to monitor the NTH IRZ will also contain TOC as it is the amendment being introduced. Comparison of data from the Upland ISPT suggests field-analyzed Cr(VI) concentrations were greater than laboratory-analyzed Cr(VI) concentrations. This appears to be linked to high TOC concentrations in the water samples (Figure 2). Therefore, there needs to be a discussion regarding the differences between immediate field analyses versus standard laboratory-certified analyses and the possible impact of longer holding times on water samples analyzed for Cr(VI) where TOC is also present. **TRC Recommendation:** This may be appropriate for a TWG discussion. In addition, results of field and standard laboratory analysis should be compared to evaluate if field measurements of Cr(VI) are systematically different from companion laboratory samples. Other potentially unstable constituents should also be addressed, such as Fe(II) and S(II-). This will be important as the monitoring program for the remediation system is being designed.	US EPA methods will be used for all laboratory analyses of Cr(VI). These methods were carefully developed in US EPA laboratories and include detailed protocols for sample preservation to ensure that the target analyte concentrations are not altered during sample transport or storage prior to analysis. In response to this comment, a discussion of the laboratory and field methods for measurement of Cr(VI) will be included in the sampling and analysis section of the O&M plan that will be submitted in the 60 percent design. The impacts of the various reductants mentioned here, TOC, Fe(II) and S(II-) and holding time will be included.	Comment and response noted.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		See draft O&M Manual Volume 2 (Sampling and Monitoring Plan), Section 7.1.
203	Hualapai-21			Addressing Potential Byproducts, Arsenic, Other Metals Manganese concentrations might be the most persistent by-product of the remediation. Will manganese travel through the reducing layer beneath the Colorado River, then discharging into the river? What will be the manganese concentrations and loads in the Colorado River? Risk assessment models are needed to describe the effects of manganese concentrations on downstream wildlife and Tribal water users.	The solute modeling indicates that manganese concentrations generated as byproducts will be less than the current manganese concentrations already present in the reducing rind along the river. As noted in the response to comment #258, a more in-depth analysis of the spatial distribution of the reducing rind (Mn concentrations and geochemical redox indicators) will be considered for the 60% design. The net effect on the manganese concentrations in the river will also be evaluated. Additionally, a one-dimensional hyporheic zone model for Mn is also being developed for the 60% design, which will be used to evaluate geochemical/hydrological processes governing manganese behavior near the groundwater-river water interface as groundwater flows toward the river. Risk assessment models are not considered necessary.	Comment noted, please also see response to comment #258.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		See Appendix B.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
204	Hualapai-22 and TRC-13			The Importance of Detailed and Focused Monitoring Plan With the issues of potential byproducts, uncertainties with respect to heterogeneities in the local geology, and the uncertainties that come with any remediation system, it will be important that the monitoring program for the Topock IRZ be designed to monitor those parameters which modeling and experience indicate may be an issue. More intensive monitoring in the early years of operation would hopefully minimize any negative developments, as well as be able to allow the system to be modified quickly to response to developing conditions. **TRC Recommendation:** It is anticipated that a reasonably detailed monitoring program will be included within the 60% design report.	A detailed O&M plan will be included as part of the 60% design and include information related to organic carbon substrate distribution, chromium removal effectiveness, and by-product monitoring.	Comment and response noted.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		Also see draft O&M Manual, Volume 1 – Operations and Maintenance Plan and Volume 2 – Sampling and Monitoring Plan.
Section 5 Comments – Institutional Controls									
205	HA-26	p. 5-1, General		Can ICs be developed to further facilitate the intent of FEIR Mitigating Measure CUL-1a-2, which is intended to ensure unrestricted Tribal access to sacred areas? Could an IC address the restriction of access by non-Tribal members to such areas at certain times?	Consistent with the requirements of the Programmatic Agreement, there are access plans in place and/or underway to ensure Tribal access to, and use of, the project area for religious, spiritual, or other cultural purposes. For example, on November 26, 2011, BLM issued a Tribal Access Plan for Federal Properties, the purpose of which is to "assure the rights of Tribes to access their places of spiritual and cultural importance located on federal lands within the boundary of the APE." Access plans must be consistent with existing laws, regulations, and agreements governing property in the project area, including ICs. ICs function to ensure the health of humans and the environment, and to prevent interference with the final remedy by limiting access on specific property until access can be safely provided.	An IC can restrict specific use of the land, but DTSC cannot exclude non-Tribal members to certain areas based on tribal affiliations. ICs are for the protection of human health and the environment and to facilitate operation and maintenance of the remedial system. DTSC will be working with the federal agencies on the enforcement mechanisms of any necessary Institutional Controls at federally owned properties. .	The federal agencies are evaluating potential options for use restrictions for property under our jurisdiction.		

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
206	DOI-51	Section 5		Please modify the first paragraph as follows: "Institutional controls (ICs) are a component of the selected final groundwater remedy. These are legal and administrative mechanisms adopted to limit or prohibit activities on specified property that could interfere with the integrity of the remedy or compromise the continued protection of human health and the environment. The target timeframe for having the ICs in place is prior to remedy construction. It is anticipated that most of these controls would remain in place for the duration of the remedy; that is, until the RAOs are achieved. The ROD states that the ICs adopted by the selected groundwater remedy for the Topock site are specified in the *BLM Lake Havasu Field Office Resource Management Plan* issued in May 2007 (BLM 2007) and in the *1994 Lower Colorado River National Wildlife Refuges Comprehensive Management Plan* (USFWS and BOR 1994). These plans restrict surface uses and use of the groundwater on federal lands." In the last paragraph, please remove the sentence, "The land use considerations included in the management plans identified above will be incorporated into restrictions on federal lands." As the first paragraph in this Section already states, the CERCLA ROD for the Topock groundwater remedy specifically states that ICs are imposed on the project area through the applicable federal management plans. Adding this sentence at the end of the Section is not necessary.	The paragraph will be modified as suggested.		Okay pending review of 60% design submittal.	Comment resolved.	See Section 5.0 of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
207	DTSC-77	Page 5-2, Section 5.1, Define Areas for Future Restrictions, and Figure 5-1	The pumping scenarios include high-volume groundwater pumping (e.g., irrigation well) to the northwest at either Moabi Regional Park or along the eastern edge of San Bernardino County leased land, and a domestic water supply well (assuming one household with no lawn or swimming pool) within the BOR property area to the west of the plume and north of BNSF Railroad (APN 50-151-03 on Figure 5-1). Results from these initial simulations suggest an area for Category 1 restrictions as depicted in Figure 5-1.	What are the pumping parameters used? Also, what is the rationale for inclusion of one household with no lawn or swimming pool? Please provide the model simulation runs for evaluation. Finally, in Figure 5-1, DTSC notes that PG&E has identified an area roughly surrounding the remedy infrastructure for Category 1 ICs, but with little rationale. Furthermore, PG&E did not identify or outline the parcels requiring Category 2 ICs, which may limit potential future development of private parcels including those of the Topock Marina (see table 5-	The pumping scenario included a hypothetical extraction well at Park Moabi pumping at 400 gpm, a typical average rate for golf courses in this region (Source: Green, R.L. 2005. Trends in Golf Course Water Use and Regulation in California. UC Riverside Turfgrass Research Facility. Web publication: http://ucrturf.ucr.edu/). The pumping center was placed at different locations on Park Moabi with pumping rates assigned to model layers 2-4, and plume flow lines were examined. A hypothetical domestic well was also included outside of the plume footprint and placed at different locations to examine the potential for injected recirculation water flow lines to be drawn towards the well. Together, the simulation from pumping of these two hypothetical wells was used to define the area for Category 1 ICs. An additional simulation of the hypothetical domestic well was conducted, with additional features including a pool and lawn. The assumed average pumping rate of 1,440 gallons per day, based on water consumption of a quarter-acre lawn and maximum evaporative losses for pools in the Lake Havasu area The addition of these features makes virtually no difference in the simulation The closest potential domestic well location would eventually intercept freshwater injection flowlines, regardless of the domestic well pumping rate, but the recirculation water flowlines will not pass through the area outside of the IC boundary as shown on Figure 5-1, based on the current remedy configuration. PG&E is contacting the Topock Marina Resort to inquire about potential water use and source. Information obtained will be used to inform the evaluation of ICs in the 60% design. The level of details presented in Table 5-1B is typical at the 30% design stage when infrastructure and pipeline locations on most parcels are still changing. After the locations have been settled on specific parcels, land issues such as legal description, easements and encroachments will be determined and processed. Additional details will be presented in the 60% design submittal. Section 5.1 defines the area for Category 2 ICs. The level of details presented in Figure 5-1 and the section is typical at the 30% design stage when infrastructure and pipeline locations on most parcels are still	Okay pending review of 60% design submittal.		Comment resolved.	See Section 5.1 of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
				1B). PG&E must adequately identify such impacts on the figure for transparency and evaluation. As stated, Figure 5-1 and the section do not appear to address institutional controls beyond Category 1. For Arizona, modeling in Appendix B indicates the remedy causes flow to Arizona and therefore potential for chromium or byproducts to escape capture during the remedy. Additionally, enhanced pumping in Arizona could exacerbate conditions (e.g., from the planned Topock 66 Resort and Spa). At a minimum, simulation of pumping wells in Arizona must be undertaken (low and higher flow scenarios). Depending on results, additional ICs may be needed in Arizona. Furthermore, PG&E argues that pumping at Park Moabi has detrimental effects on the remedy. If this is true, one would expect a larger area delineated for institutional controls. SoCal Gas had requested pumping rights in the area. If that is true, it should be discussed in this section as well as other applicable sections. Note: Parcel APN 650-151-03 referenced in the text could not be located on Figure 5-1. Please revise the figure or text.	changing. After the locations have been settled on specific parcels, land issues such as legal description, easements and encroachments will be determined and processed. Additional details will be presented in the 60% design submittal. Additional modeling is being done to simulate various pumping scenarios to evaluate freshwater supply sources. That information will be included in the forthcoming freshwater source evaluation tech memo, and will be used to inform the evaluation of ICs (in the 60% design). According to information from BLM (early 2011), SoCal Gas had planned for a well near the water tanks between I-40 and Moabi Regional Park. The well could be up to 500 feet deep and was intended for cathodic protection, and not for pumping of groundwater. The text will be revised to reference APN 650-151-05.				
Section 6 Comments – Preliminary Evaluation of Approvals, Permits, and Easement/Access Requirements									
208	DOI-52	Section 6.1		The Consent Decree should be referenced in this paragraph as well.	Comment noted. The final Consent Decree will be referenced when it is available.		Noted.	Comment resolved.	See Section 5.3.1 of this BOD Report.
209	DTSC-78	Page 6-1, Section 6.2, Anticipated Approvals/ Permits/ Agreements for Access to Non-Federal Lands		PG&E should also consider permits necessary for river intake from pipeline bridge, I-40 bridge, or railroad bridge. Based on location and ease of connection to existing infrastructure, DTSC would prefer to evaluate a river intake from or near the pipeline bridge.	DTSC's preference for evaluation of a river intake from or near the pipeline bridge is duly noted. As mentioned in previous responses, a technical memorandum will be prepared to present the evaluation of the three potential freshwater supply sources (wells in Arizona, River, wells in California) and to present PG&E's conclusion. Should a river intake is needed, PG&E will, in compliance with EIR Mitigation Measure BIO-3b, coordinate and cooperate with USFWS and other fisheries biologists to determine suitable and acceptable location(s) for the intake structure(s) to avoid spawning habitat of special status fish species.	Okay pending review of the Freshwater Supply TM.		Comment resolved.	See Appendix J of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
210	HA-27	p. 6-1, Section 6.2 (Anticipated Approvals/Permits/Agreements for Access to Non-Federal Lands)		While PG&E has easements for access to the parcel now owned by the FMIT, whether these activities will involve any different or additional presence on this parcel should be clarified and the general statement about the Tribe's preference to limit such activity to the extent practicable should be referenced.	The 2006 Easement Agreement between the Tribe and PG&E covers access as well as activities such as operation and maintenance of facilities. The Tribe's preference is recognized and will be further considered during the development of the 60% design, consistent with the provisions of the Easement Agreement and the 2006 Settlement Agreement entered into between the Fort Mojave Indian Tribe and PG&E. A statement to this effect will be included in the 60% design submittal.	Comment and response noted.	Comment and response noted.		See Section 5.3.2 of this BOD Report.
Section 7 Comments – Compliance with ARARs and EIR Mitigation Measure Monitoring Program									
211	DOI-53	Section 7.0		In July 2011, the Office of Environmental Health Hazard Assessment (OEHHA) of California Environmental Protection Agency published a Public Health Goal (PHG) for hexavalent chromium of 0.02 parts per billion (ppb) or micrograms per liter (µg/L) in drinking water. Although this was not identified as an ARAR or TBC in the DOI ROD, given the high public interest regarding this goal, it may be appropriate to provide a short discussion in this section.	As DOI noted in the comment, although the PHG for hexavalent chromium is not an ARAR or TBC in the DOI ROD, given the high public interest regarding this goal, the following text could be added to Section 7.0 of the forthcoming 60% design submittal: On July 27, 2011, the Office of Environmental Health Hazard Assessment (OEHHA) established a public health goal (PHG) of 0.02 micrograms per liter (µg/L) for hexavalent chromium. The California Department of Public Health and OEHHA describe the PHG as follows: "A PHG is not a regulatory standard. It is only one step in the process of developing an enforceable standard that is set by the California Department of Public Health (CDPH) for drinking water that public water systems must meet. The PHG will contribute to California Department of Public Health's development of a primary drinking water standard (maximum contaminant level, MCL) that is specific for hexavalent chromium. Hexavalent chromium is currently regulated under the 50-micrograms per liter (µg/L) MCL for total chromium in California."	Okay.	Okay	Comment resolved.	See Section 6.2 of this BOD Report.
212	HA-28	Section 7.0		Specific laws relating to cultural concerns should be added to this section as well as applicable State laws. Additionally, State of California Governor Brown has issued directives regarding consultation with Native American Tribal Governments.	PG&E defers to DTSC/DOI Additionally, this section includes a reference to Table 7-3, which sets forth ARARs, including cultural resource laws that are ARARs.	Comment noted. DTSC will comply with all policies established as a result of the Governor's directives.	Comment noted. Within the CHPMP on pages 7 through 10; under Section 1.4 Regulatory Context there is an adequate discussion of Federal Law, ARARs and state law for both Arizona and California.		

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
Section 8 Comments – Project Delivery Strategy/Updated Schedule									
213	HA-29	p. 8-2 et seq., Section 8.3 (Phasing Alternatives/Transition from Interim Measure to Final Remedy)		This section is of particular interest to the Tribe. As discussed in the general comments, the existence of the IM3 WTP on Tribal sacred grounds is causing significant spiritual distress and impact to the well-being of the Tribal Community. The criteria proposed to evaluate transition alternatives (Section 8.3.1) do not rigorously consider alternatives that could lead to a more rapid decommissioning of the IM3 WTP, which is of prime interest to the Tribe. PG&E should state whether there are any scenarios under which it is foreseeable that the IM3 WTP might be restarted after remedy startup and, should there be such reasonably a foreseeable scenario(s), develop a rationale that would support a more rapid determination to decommission the IM3 WTP based on plume control. It is not apparent within this section that such considerations were applied in the transition plan. Also, quarterly submittals of relevant data should be required following the completion of start-up of the National Trails Highway (NTH) In Situ Reductive Zone (IRZ) wells in order to determine progressively the trend towards achieving plume control and when plume control can reasonably be assured. With regard to the expectations of the Tribe, this section misdirects the key consideration of the removal of the IM3 facilities, instead emphasizing the termination of IM3 operations and dismantling of its associated infrastructure. (see p. 8-4, 1st full paragraph) In regard to the IM3 decommissioning decision, it is significant to note that in this same section it is stated that, during the transition from IM3 to the final remedy, the loss of hydraulic control exerted by the IM pumping would not pose a significant concern due to the slow migration rate of the contaminants as well as the capacity of the "reducing rind" to attenuate contaminants before reaching the Colorado River.	PG&E acknowledges the Tribe's statement of its position regarding the decommissioning of IM-3. These topics are currently being addressed in confidential settlement discussions between the Tribe, DTSC and PG&E, and PG&E defers any response on these issues to those settlement discussions.	Comment noted. Decommissioning of IM-3 is the subject of litigation by the Fort Mojave Tribe.	Defer response.		In response this comment a discussion of criteria for approval for IM3 decommissioning plant has been added to Section 7.4 of this BOD Report.
214	HA-30	p. 8-3, 1st para. Section 8.3.2 (Evaluation of Proposed Transition Plan)		The first line should read "led" instead of "lead."	The change will be made as requested.	Noted.	Noted.		See Section 7.3.2 of this BOD Report.
215	DOI-54	Section 8.3.3, Last Paragraph		The shutdown of IM-3 and the potential impacts to groundwater, perceived impacts to the Colorado River and, conversely, the potential impacts to the remedy from continued operation is of significant interest to the Tribes and stakeholders. It is recommended that this discussion be significantly expanded.	The details of the transition from the IM3 system to the final remedy will be further discussed in the 60% design as requested.	Okay pending review of 60% design submittal.	Okay pending further evaluation during the review of 60% design submittal.	Comment resolved.	See Section 7.3 of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
216	DOI-55	Section 8.3/8-3 and 8-4/3rd and 4th bullets		The bullets indicate the operations will take 3-6 months. What are the criteria for successful start up necessitating a 3-6 month duration?	An allowance of 3 to 6 months for start up of the freshwater wells is provided in the preliminary design to allow for incremental start up of the extraction well and the injection wells in the uplands. Balancing and measurement of water levels near the injection wells will be required as well as adjustments if necessary. An additional 3 to 6 months is projected to start up the Riverbank and uplands injection wells along with the TCS and ER EW and TCS-IW system. These systems will involve balancing of the respective wells and injection points. In addition, if TOC needs to be added to the Riverbank well water, refinement and operation of the TOC injection components will be needed. There will be multiple wells to balance along with the existing network and system maintenance. Similar activities will be necessary for the ER-TCS loop.		Okay. Further evaluation will occur during the review of 60% design submittal.	Comment resolved.	See Section 7.3 of this BOD Report.
Tables									
217	DTSC-79	Table 3-1, Table 3-2, Table 3-3, Table 3-4		PG&E should provide more description for these tables to clarify if the well count column is also meant to describe the approximate well depth for each of those well? (e.g. Table 3-1, IRZ-1, 1 well with dual screens totaling 40 ft will be installed within the 64 foot layer 1 depth and another well with dual screens totaling 40 ft within the 126 feet layer 3 depth?) Are these proposal based on modeling or convenience since Table 3-1 are all within layers 1 and 3, while river bank extraction wells within Table 3-2 are all within layer 3? The rationale for selecting preliminary screen lengths should be discussed, as should the reason(s) for not establishing the preliminary lengths (well screen length identified as “TBD”) in select wells. What screen lengths were used in the groundwater model? What criteria will be followed for locating the particular screen length within the model layer with its specific thickness (especially if the layer thickness is significantly greater than the well screen length)? Clarification is also requested regarding Footnote “d” on Tables 3-2 and 3-3 that indicate all amended water may be replaced with freshwater. What triggers that decision?	Revised Tables 3-1 through 3-4 will be included in the 60% design submittal. The preliminary well count in Tables 3-1 through 3-4 denotes the number of wells are present in each well cluster. Each well location ID may consist of a well cluster of up to two wells. Per Table 3-1, IRZ-1 consists of two dual screen wells. The first well will be screened in the two shallow zones (Layer 1 and Layer 2) and the second well will be screened in the two deeper zones (Layer 3 and Layer 4). The injection flows at each of the injection intervals has been established through groundwater modeling to effectively distribute carbon within the IRZ, and the flow rate may therefore be much less than formation can accept, and a portion of the screen may see little or no flow. These stagnant areas provide ample surface area for unwanted biomass buildup that can exacerbate fouling issues, thus “oversizing” the screen can have a deleterious effect. Therefore, each screen will be a maximum of 40 feet long (a screen length that has been demonstrated to be effective for carbon amended injection). The placement of screens was chosen based on the portions of the aquifer containing contaminants requiring remediation and will likely be modified during the advancement of the remedy design and further modified in the field during installation activities. For the River Bank Extraction Wells only one well per	Okay pending review of 60% design submittal.		Comment resolved.	See Tables 3.2-1, 3.2-2, 3.2-3, and 3.3-1 and Appendix C (Design Bulletin: Remediation Well Design and Field Construction Approach).

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
					location is proposed. These wells will be a screened in Layers 3 and 4 to minimize the migration of manganese, iron, and other reduced species from the river's naturally occurring reducing rind, which is present in the shallower layers surrounding the river. The purpose of this is to minimize fouling of the extraction well and conveyance piping, as well as minimize the placement of manganese (and other species of concern) within the river's reducing rind into the upgradient groundwater plume via the inner loop injection well network. The rationale behind well screen lengths identified as "TBD" (Tables 3-2 to 3-4) is that the specifications for these future wells will be determined during the 60% design. For modeling purposes, the upland injection wells inject into model layers 1 through 4 (Appendix B, Section 4.4.3). The preliminary screen lengths were chosen based on the initial estimates of thickness of saturated sediments and the thickness of target contaminated zones within the saturated sediment. Well screen lengths will be included in place of "TBD" for the upland injection wells and east ravine extraction wells in the 60% design submittal. It will also be noted where field-encountered aquifer characteristics or other factors may affect the final screen lengths. Footnote "d" on Tables 3-2 and 3-3 attempts to explain that the aggregate minimum and maximum flow rates for each well network and will not be equal to the sum of individual well flow rates. It should be noted that some of the wells could be operating at maximum conditions, while others are operating near the minimum conditions (or not operating at all). Carbon-amended water injections may be replaced with freshwater injections at upgradient locations if it is found that a decrease in carbon dosage is necessary to reduce the mobilization of in-situ by products beyond the plume footprint.				

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
218	DOI-56	Table 7-3 Summary of Identified ARARs, Action Specific, Item No. 48		Please include a discussion of the current well design of the HNWR well in this paragraph.	Based on information provided in a November 24, 2010 electronic mail from Bradley Guay (USACE) to Curt Russell (PG&E), the HNWR well is 10-inch diameter well and extends to a depth of 156.5 ft below land surface with a stick up of approximately 2.75 feet. The upper 116 feet of the well is welded, 10-inch mild steel casing. Between 92 and 116 feet, the steel casing was perforated after installation to open this section of the well to the aquifer. Below 116 feet, a 0.030" slot well screen was installed. The type or material of well screen was specified in the information provided in the electronic mail. The test pump intake was set at a depth of 88 feet. There was no information provided about the grout or gravel pack in this well. Since HNWR well is an existing well, this information will be included in Section 3.3 (Freshwater Supply) of the 60% design submittal and the forthcoming Freshwater Supply Source Evaluation Technical Memorandum.	Okay pending review of 60% design submittal.	Noted. The upcoming report from the USFWS should be used to update the information provided in PG&E's response when it becomes available.	Comment resolved.	See Section 3.3 of this BOD Report
219	DOI-57	Table 7-3 Summary of Identified ARARs, Location Specific, Item Nos. 5 & 7		The "action" notation should include a reference to the DOI ROD, surnamed by BLM, BOR, FWS and BIA.	A reference to the DOI ROD will be added Table 7-3 as directed, in the 60% design submittal.		Okay pending review of 60% design submittal	Comment resolved.	See Table 6.2-1 of this BOD Report.
220	DOI-58	Table 7-3 Summary of Identified ARARs, Location Specific, Item Nos. 14, 17, & 22		Please update the "action" for the ARAR addressing the PA, Tribal Access Plan, and CHPMP. Additionally, it should be noted that a treatment plan will be developed throughout the design process.	The "action" column will be updated with current information in the 60% design submittal. Treatment measures are contained in the CHPMP and the EIR.		Okay pending review of 60% design submittal	Comment resolved.	See Table 6.2-1 of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
221	DTSC-80	Table 7-3 Summary of Compliance with Identified ARARs		Item 2, 52, 99, 100, 101, 32: Discuss the arsenic MCL and how arsenic concentrations above this level are currently proposed to be injected outside the contaminant plume in the last column on the table. Item 53, 99, 100, and 101: Discuss secondary MCLs of the byproduct manganese in the last column on the table. Item 35: Would this ARAR be in effect if a river intake structure were selected? Item 47: This item states, "Most of the groundwater that is withdrawn will be reinjected into the aquifer. Any groundwater that is withdrawn but not reinjected into the aquifer shall be put to reasonable and beneficial use." Please clarify/list the water uses of freshwater supply other than for reinjection. These uses do not seem to be accounted for in the design needs for the supply well which is only evaluated as a source for injection. Item 51: Mention that elevated arsenic in Arizona wells may require treatment.	**Item 2** – inserted text is shown in underline typeface, delete text is shown in ~~strikeout~~ typeface: Compliance with this requirement will be achieved by reducing the concentration of Cr(T) in the affected aquifer to a concentration below the federal maximum contaminant level (MCL) for Cr(T) of 100 µg/L. There is no federal MCL for Cr(VI) and the RAO of 32 µg/L (based on the regional background concentration) has been established at the conclusion of remedy implementation. ~~Although~~ ~~c~~ Concentrations of Cr(VI) and arsenic as in situ byproducts may fluctuate above baseline levels within the treatment area during remedy implementation. In addition, as part of the remedy fresh water from a well in Arizona will be injected west of the plume, within the project's Area of Potential Effects. The naturally occurring arsenic concentration in water from the well exceeds the MCL of 10ug/L, which is typical of water quality in the vicinity of Topock, Arizona . Modeling indicates that arsenic concentrations that may temporarily be elevated by ~~**a) the injection of this water and b)**~~ the generation from insitu remediation will attenuate under site conditions and return to pre-remedy baseline levels after the end of active remediation. Institutional controls will prevent use of affected groundwater as a drinking water source until the remedy is complete. Groundwater monitoring will be used to track performance of the remedy and verify that RAOs have been achieved at the conclusion of remedy implementation and prior to removing the institutional controls. **Item 32** This item states that "The preliminary (30%) design includes facilities in the jurisdictional water of the US (see Figure 2-16). PG&E will work with the USACE to ensure compliance with the substantive requirements of Section 404 per CERCLA Section 121(e)(1). It is anticipated that a wetland delineation will be conducted in the Spring of 2012." The DTSC comment does not appear to be relevant to this item. **Item 35** This ARAR applies if the river intake structure has the potential to affect navigable waters on the site.	Agree with Response pending review of the 60% design submittal. However, please note the following concerns : Item 2 – the comparison of UTL, which is the upper end of the background range, with generated concentrations of As above MCL must be carefully evaluated. While in nature, there will be natural variations and some concentration above MCL levels may exist (up to or exceeding UTL), This phenomenon should not be viewed as appropriate to leave chemicals above the MCL after active remediation beyond the current plume boundary because there is within a probability of detecting concentration at the UTL. If the generated concentrations are on par with the mean natural value and occasionally have detection reaching UTL, then the scenario is more like nature.		Comment resolved.	See Table 6.2-1 of this BOD Report. The text shown in bold strikeout typeface in PG&E Response to 30% Design Comment of this comment, is to reflect that in this 60% design, HNWR-1 water is pre-treated prior to injection.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
					Item 47 The 30% design states that the extracted groundwater is for freshwater injection and for Compressor Station operational use. The Compressor Station currently receives its water from well Topock-2 and 3 in Arizona. **Item 51** The Arizona Action-Specific ARAR (A.R.S 49-282.06(A)(2)) states that "To the extent practicable, provide for the control, management or cleanup of the hazardous substances in order to allow the maximum beneficial use of the waters of the state". PG&E understands that this ARAR applies to the control, management, or cleanup of hazardous substances in the State of Arizona. The 30% design does not involve treatment or cleanup in Arizona. The DTSC comment does not appear relevant to this item. **Item 52** – inserted text is shown in underline typeface, delete text is shown in ~~strikeout~~ typeface: Compliance with this requirement will be achieved by reducing the concentration of Cr(T) in the affected aquifer to a concentration below the state maximum contaminant level (MCL) for Cr(T) of 50 µg/L. There is no state MCL for Cr(VI) and the RAO of 32 µg/L (based on the regional background concentration) has been established at the conclusion of remedy implementation. ~~Although c~~ Concentrations of Cr(VI) and arsenic as an in situ byproduct may fluctuate above baseline levels within the treatment area during remedy implementation. In addition, as part of the remedy fresh water from a well in Arizona will be injected west of the plume, within the project's Area of Potential Effects. The naturally occurring arsenic concentration in water from the well exceeds the MCL of 10ug/L, which is typical of water quality in the vicinity of Topock, Arizona . Modeling indicates that arsenic concentrations that may temporarily be elevated by ~~**a) the injection of this water and b)**~~ the generation from insitu remediation will attenuate under site conditions and return to pre-remedy baseline levels after the end of active remediation. Institutional controls will prevent use of affected groundwater as a drinking water source until the remedy is complete.	Item 52 – The modeling result which suggests that Arsenic will attenuate and not be mobile in any extensive direction beyond the injection well remains to be proven. DTSC agrees that the pilot test appears to support that conclusion; however, it will become PG&E's liability if the remedy creates an Arsenic plume that does not attenuate with time or distance. PG&E must develop robust monitoring and contingency plans to ensure that arsenic will be under control during the remedy. PG&E's response is noted and DTSC will review the 60% design submittal when available.			

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
					Groundwater monitoring will be used to track performance of the remedy and verify that RAOs have been achieved at the conclusion of remedy implementation and prior to removing the institutional controls. **Item 53 –** inserted text is shown in underline typeface**:** There is no secondary MCL for Cr(VI) or Cr(T). Secondary MCLs are community acceptance standards for constituents that may adversely affect the taste, odor, or appearance of drinking water. Concentrations of insitu by-products (arsenic, manganese (secondary MCL of 50ug/L)) may fluctuate within the treatment area during remedy implementation. An institutional control will be enforced throughout the chromium plume area during implementation of the remedial action to prohibit use of the groundwater as drinking water source.	Item 53 - PG&E is correct that there is no secondary MCL for Cr(VI) or Cr(T). However, despite PG&E's statement that secondary MCLs are "community acceptance standards," they are nevertheless a regulatory standard for California drinking water. Although PG&E states that there will be ICs to prevent use of affected water for drinking water, the basin plan, which is an ARAR, dictates that the water is designated for beneficial uses. Therefore, ICs are not to change the designation of which the clean-up standards at remedy completion must be based.			
					Item 99 – inserted text is shown in underline typeface**:** Compliance with this requirement will be achieved by reducing the concentration of Cr(T) in the affected aquifer to a concentration below the federal and state MCLs of 100 µg/L and 50 mg/L respectively which represent the chemical concentrations in drinking water considered safe for human consumption. There are no MCLs or MCLGs for Cr(VI) and the RAO of 32 µg/L (based on the regional background concentration) has been established at the conclusion of remedy implementation. Concentrations of Cr(VI) and in situ byproducts (e.g., arsenic, manganese) may fluctuate above baseline levels within the treatment area during remedy implementation. In addition, as part of the remedy fresh water from a well in Arizona will be injected west of the plume, within the project's Area of Potential Effects. The naturally occurring arsenic concentration in water from the well exceeds the MCL of 10ug/L, which is typical of water quality in the vicinity of Topock, Arizona . Modeling indicates that arsenic concentrations that may temporarily be elevated by **~~a) the injection of this water and b)~~** the	Item 99 –The action specific ARAR designated the site ground water to be beneficial for municipal and domestic water supply. PG&E should ensure that the water quality will be properly restored to ambient conditions not just for Cr(VI) but also for any chemicals that will be generated or introduced.			

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
					generation from insitu remediation will attenuate under site conditions and return to pre-remedy baseline levels after the end of active remediation. Modeling also indicates that manganese generated from insitu remediation does not exceed the upper tolerance level of background manganese concentration at the site. The final groundwater remedy includes an institutional control to restrict use of the groundwater for potable use until the remedy is complete. Groundwater monitoring will be used to track performance of the remedy and verify that the RAOs have been achieved at the conclusion of remedy implementation and prior to removing the institutional control. **Item 100** – inserted text is shown in underline typeface: Surface water sampling in the Colorado River near the site show concentrations of Cr(T) less than the federal and state MCLs of 100 µg/L and 50 mg/L (drinking water supply standards). Surface water sampling in the Colorado River also show concentrations of Cr(VI) less than the California Toxics Rule criteria of 11 µg/L (protection of freshwater aquatic life). Reducing Cr(VI) concentrations in groundwater by implementation of the remedy will increase the level of certainty that surface water quality will continue to remain below these levels. PG&E will prepare an O&M Plan, Progress Reports, and a Corrective Measure/Remedial Action Completion Report. The remedy is intended to restore groundwater to the regional background Cr(VI) concentration of 32 µg/L, thereby addressing any contribution by PG&E affecting potential beneficial uses. The operation of the River Bank Extraction Wells will prevent migration of contaminants to the Colorado river that could impact beneficial uses or result in a failure to meet surface water quality objectives The remedy is also designed and will be implemented to control the generation and migration of insitu by-products (arsenic, manganese). The MCL for arsenic is 10ug/L and the secondary MCL for manganese is 50ug/L. In addition, as part of the remedy fresh water from a well in Arizona will be injected west of the plume, within the project's Area of Potential Effects. The naturally occurring arsenic concentration in	Item 100 - Similar to above, under basin plan and ARAR compliance, PG&E is also obligated to restore the groundwater to ambient conditions not just for Cr(VI) but also for any chemicals that will be generated or introduced.			

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
					water from the well exceeds the MCL of 10ug/L, which is typical of water quality in the vicinity of Topock, Arizona. Modeling indicates that arsenic concentrations that may temporarily be elevated by ~~**a) the injection of this water and b)**~~ the generation from insitu remediation will attenuate under site conditions and return to pre-remedy baseline levels after the end of active remediation. Modeling also indicates that manganese generated from insitu remediation does not exceed the upper tolerance level of background manganese concentration at the site. **Item 101 –** inserted text is shown in underline typeface: PG&E will prepare an O&M Plan, Progress Reports, and a Corrective Measure/Remedial Action Completion Report. Although concentrations of Cr(VI) and insitu by-products will fluctuate inside the footprint of the remedy during implementation, at the conclusion of the remedy the RAOs will be achieved. In addition, as part of the remedy fresh water from a well in Arizona will be injected west of the plume, within the project's Area of Potential Effects. The naturally occurring arsenic concentration in water from the well exceeds the MCL of 10ug/L, which is typical of water quality in the vicinity of Topock, Arizona. Modeling indicates that arsenic concentrations that may temporarily be elevated by ~~**a) the injection of this water and b)**~~ the generation from insitu remediation will attenuate under site conditions and return to pre-remedy baseline levels after the end of active remediation. Modeling also indicates that manganese generated from insitu remediation does not exceed the upper tolerance level of background manganese concentration at the site. Therefore, the remedy will comply with the substantive provisions of the SWRCB Resolution 68-16 that requires maintenance of the highest water quality consistent with maximum benefit to the people of the State, and with the substantive provisions of SWRCB Resolution 92-49 that require restoration of background water quality.				

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
222	DTSC-81	Table 8-1		DTSC understands that this is a cross reference table copied from the CMI/RD work plan. However, please note that the target dates for document submission have clearly changed. PG&E should update the table accordingly. Please also note that the table referenced other tables that are not in the 30% design (e.g., Table 4-5 for content of various design submissions). DTSC suggests a checklist format with locations within the document instead of the proposed table. The checklist can allow reviewers to know that the specific item has been completed and its location within the document at a glance.	PG&E will update the target dates in Tables 8-1 and 8-2 to reflect current schedule at the time the 60% design is submitted. In response to DTSC's comment, PG&E proposes to include a table similar to Exhibit 1-3 of the Revised CMI/RD Work Plan.	Okay pending review of the 60% design submittal.		Comment resolved.	See Tables 7.2-1, 7.2-2, and 7.2-3 of this BOD Report.
Figures									
223	DOI-59	Figure 2-17		This figure shows IRZ wells locations in the floodplain. Previous documents have noted that the wells would be located along the National Trails Highway (NTH) or possibly in the floodplain. Please justify the location of the wells within the floodplain area rather than along the NTH.	For safety reasons, PG&E has located the IRZ wells out of the NTH traffic lanes, on the road shoulder where available. Where road shoulder is not readily available, such as on the east side of NTH north of the MW-20 bench, PG&E has located wells in areas that minimize removal of vegetation and mature plants. The proposed well locations on Figure 2-17 accomplished both of these objectives.	Okay pending review of 60% design submittal.	Okay.	Comment resolved.	See Figures 2.4-6 and 3.0-1 of this BOD Report.
224	DOI-60	Figure 3-1		Building "M" is incorrectly labeled in the inset map according to the legend description which includes "L" but not "M". Please review and revise as necessary.	This figure will be revised in the 60% design submittal.	Okay	Okay pending review of the 60% design submittal.	Comment resolved.	See Figure 3.0-1 of this BOD Report.
225	DOI-61	Figure 3-1		Notes 1 and 3 should indicate Appendix D not C for the engineering drawings. Also, in the legend under Pipeline for Remedy, the words "pipeline" and "pipe" should end with (s) to indicate these may not be single pipelines.	This figure will be revised in the 60% design submittal.	Okay	Okay pending review of the 60% design submittal.	Comment resolved.	See Figure 3.0-1 of this BOD Report.
226	DTSC-82	Figure 3-1		Where would FW-INJ-3 (future well) potentially be located. Please summarize how this well came to be an optional well in the document.	See response to comment 155 DOI-37.	Okay pending review of 60% design submittal.		Comment resolved.	See Figure 3.0-1 of this BOD Report.
227	DOI-62	Figures 3-4 through 3-9		Please define the model layers on each figure.	The model layers will be further labeled to reflect the corresponding hydrogeologic units displayed in the cross-sections.		Okay pending review of the 60% design submittal.	Comment resolved.	See Figures 3.1-2 through 3.1-7.
Appendix B – Groundwater Modeling									
228	DOI-63	Appendix B Cross Sections		The proposed well screens should be identified on the cross sections.	Well screens will be added to the wells presented in the Appendix B cross-sections.	OK pending review of 60% design submittal.	OK pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Appendix B, Figures 6.4-3 to 6.4-8.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
229	HA-31			This appendix provides an overview of groundwater flow model development, but does not present sufficient detail to understand various decisions that were applied to arrive at the final model configuration on which the final remedy design was based. For example, how was the model calibrated, specifically what was the basis for assigning individual parameters over the range of available field data? What constraints were applied? What is the range of uncertainty? Between the time that the 2005 flow model was developed and the appearance of this new flow and transport model, little specific information on model development was presented to stakeholders, only the results. What configurations were considered to arrive at the design presented? What was/were the goal(s) of model optimization? Within these comments, the Tribe has emphasized the importance of siting to avoid impacts and desecration to sacred areas. Were any constraints applied to consider such avoidance? Were any scenarios considered that specifically addressed a startup strategy that would allow for a more rapid release of the IM3 WTP? Regardless of the answers to these questions, the Tribe is disappointed that the development of this model, the basis for design, was not communicated with the Tribes, Agencies, and Stakeholders in a transparent way. The Agencies should direct more open discussions and information exchange in this regard moving forward and particularly during remedy startup.	The calibration procedure was explained in CH2MHILL 2005 and describes the assignment of hydrogeologic parameters. The flow model was calibrated against (a) long term average groundwater levels, (b) average monthly floodplain levels responding to fluctuating river levels, (c) short-term responses to pump testing events, and (d) plume development over time. The autocalibration program PEST was employed to refine the calibration and to reduce effects of uncertainty in each calibration target. The solute transport model was based directly on the original flow model and honors all of the hydrogeologic parameters and boundary conditions. With respect to the uncertainty in the solute transport model, a sensitivity analysis was conducted with respect to the simulated parameters in section 6 of Appendix B. Text can be added to expand on the associated uncertainty. Several configurations were considered in the development of the groundwater flow and transport model. Well locations were carefully selected first by avoiding culturally or otherwise sensitive areas to minimize impact. This included closely evaluating delineated areas and avoiding sensitive areas during well placement. The next criteria was to optimize the well locations to minimize the number of necessary wells while still maintaining effective treatment to minimize the remedial timeframe. A careful balance of these criteria were evaluated until the optimal well layout was established. Several of these scenarios were presented prior to submittal of the 30% design report to reflect the reasoning We welcome open discussions and feedback regarding the remedial system design.	DTSC is perplexed as to the origin of the comment that the model development was not communicated with the Fort Mohave Indian Tribe. Based on review of our records, DTSC has facilitated several discussions on the model over the years so that questions associated with its development and use could be addressed. Some of these meetings held after the 2005 model calibration included the August 19, 2008 discussion on the use of the 5 layer models in the remedial selection process, the January 22, 2009 meeting at USGS office in San Diego, a two day meeting on September 1 and 2, 2011 on input parameters, and the October 18, 2011 meeting specifically on the modeling basis, uncertainties and results as it was applied to the remedy design. In addition, DTSC notes that we have responded to many questions raised by the FMIT via email on this same topic. However, DTSC acknowledges that the solute transport model included in the design is far more complex in nature than the original flow model, but such complexity is not unexpected. As always, DTSC will continue to facilitate meaningful discussions between PG&E and Tribes and/or Stakeholders regarding this matter.	Comment and response noted. DOI acknowledges the complexity of the fate and transport model, and to a lesser extent, the flow model and has requested the PG&E included further discussions in the forthcoming Fresh Water Technical Memorandum and the 60% design submittal. The agency encourages continued Tribal participation in the upcoming Consultative Working Group and Technical Working Group meetings planned throughout the design process.		See Appendix B, Section 4.
230	HA-32			Additionally, the Tribe notes that the TRC has provided a number of comments on model uncertainties, scenarios, etc. (Attachment A). The Tribe wishes to underscore these comments and approves them on behalf of the FMIT.	Comment noted. PG&E have responded to the TRC comments in Attachment A, and included those responses in this table.	Noted	Comment noted		

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
231	DOI-64	App. B, Section 2.2		The first paragraph of this section discusses the primary components of the groundwater flow system, citing five items. The conceptual hydrogeological site model should address each of these items in order to provide the framework necessary for development of the numerical flow model. DOI believes that it is important that the conceptual site model be thoroughly documented so that the basis of the subsequent mathematical model can be understood and critically assessed. This section, and in particular Section 2.2, is very abbreviated, with no discussion of several of the items called out in the first paragraph, and no basis for appreciating the hydrogeologic complexity of the site. Furthermore, while it is recognized that groundwater flow modeling has been ongoing at the site for many years, with comprehensive documentation, fate and transport modeling has not been previously presented. This model represents a significant revision warranting a more thorough discussion of the conceptual hydrogeologic and contaminant fate and transport site model as the basis for the numerical model in this section.	Conceptual model section will be expanded to provide a more thorough treatment of the subject at the beginning of the appendix for the 60% submittal.	OK pending review of 60% design submittal.	OK pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Appendix B, Section 2
232	DOI-65	App. B, Section 2.2, 2nd paragraph		This section mentions the occurrence of groundwater only in the alluvial aquifer at the site. Groundwater is also known to occur in consolidated bedrock. Previous to the discovery of contamination in bedrock groundwater in the East Ravine, bedrock groundwater was discounted as a potential contaminant migration pathway. With the East Ravine findings, the occurrence of groundwater in bedrock should be discussed in this section of the conceptual model. In doing so, it should be noted that limited information exists on the nature of the fracture flow and groundwater flow directions in the East Ravine area. Studies are ongoing. Also, with the recent findings at Site H in the East Ravine, PG&E should avoid statements that fracture flow in the bedrock is necessarily of limited flow rate and radius of influence.	Text will be added to discuss the groundwater in bedrock based upon the studies conducted to date. This will include discussions of how the bedrock groundwater behaves in the East Ravine area as well as conditions observed at Site H. Refer to response to comment #10 DOI-9.	Okay pending review of 60% design submittal.	Okay pending review of 60% design submittal.	Comment resolved.	See Appendix B, Section 2.2.
233	DOI-66	App. B, Section 3, 2nd paragraph, last sentence		This section of Appendix B refers the reader to Section 3.1 of the main report for a summary of the updates to the groundwater flow model, while Section 3.1 of the main report refers the reader to Appendix B for the same information. DOI recommends that the most detailed discussion of the modeling, including the conceptual hydrogeologic and fate and transport models, and the model code selection and implementation descriptions be presented in Appendix B, with the important concepts summarized in Section 3.1 of the main report.	The reference of the groundwater flow model details should have pointed to Hill 2005 and 2009. The solute transport model code selection and the groundwater submodel code selection are explained in detail in Appendix B. Further information with respect to the conceptual hydrogeologic and fate and transport models will be added to Appendix B. Appendix B will serve as a comprehensive documentation of the model. Section 3 will provide a summary level discussion that highlights primary design-related modeling conclusions.	OK pending review of 60% design submittal.	OK pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Section 3.1 of the BOD Text and Appendix B.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
234	DOI-67	App. B, Section 3.3, 1st paragraph, 2nd sentence		There appears to be a typographical error in this sentence. It appears "is' should be replace with "of".	Text will be edited.	Ok	Ok		See Appendix B, Section 4.3.
235	DOI-68	App. B, Section 3.3, 1st paragraph, 3rd sentence		It is not apparent that a north-south oriented grid is necessarily aligned with the direction of groundwater flow, which is northeastward over much of the area.	This sentence will be deleted in the 60% submittal.	OK.	OK pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Appendix B, Section 4.3.
236	DOI-69	App. B, Section 3.3, 1st paragraph, last sentence		This section states that the submodel domain boundaries are constant head boundaries, while Section 3.4 states that the boundaries are constant flux boundaries.	Text will be corrected. Boundary conditions are constant flux cells.	OK pending review of 60% design submittal.	OK pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Appendix B, Section 4.3.
237	DOI-70	App. B, Section 3.3 2nd paragraph		This section refers to the thickness of layers in the "solute transport submodel", but this section is actually discussing the groundwater flow submodel domain. This is potentially confusing. Also, it is unclear by what is meant by the statement that the upper four layers in the southern bedrock portion of the model "…no longer are consistent with the alluvial portions of these layers to the north". In what way are they not consistent? Please clarify.	Text will be revised to reflect a single flow and transport submodel. South of the bedrock contact, the upper four layers in the groundwater flow submodel represent bedrock, whereas to the north of the bedrock contact, the 4 layers represent the alluvial aquifer. Therefore the hydraulic conductivities vary within the layers to represent the different lithologies. Text will be changed to make this point more clear.	OK pending review of 60% design submittal.	OK pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Appendix B, Section 4.3.
238	DOI-71	App. B, Section 3.4		The use of constant flux boundaries seems reasonable if the distances from the boundaries to aquifer stressors (e.g., pumping and injection wells) are sufficient so as not to inappropriately constrain fluxes at the boundaries. In this regard, DOI would like assurance that the model is appropriately simulating boundary conditions under remedial action conditions in two areas; west and north of the fresh water injection wells and along the eastern boundary nearest the fresh water supply well in the HNWR. Also, please clarify what is meant by the statement "The final boundary conditions simulated in the submodel domain are the well cells which represent the proposed extraction and injection locations for the various remedial scenarios."	Because the submodel was extracted from the regional flow model, the boundary conditions reflect the actual pumping conditions within the model domain. Therefore the fluxes at the boundaries are not inappropriately constrained. The text will be modified to identify the three types of boundary conditions within the submodel. The sentence quoted in the comment represents the third type of boundary condition.	OK pending review of 60% design submittal.	OK pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Appendix B, Section 4.4.
239	DOI-72	App. B, Section 3.5, last sentence		Please revise the last sentence to say "All hydraulic conductivity values in the submodel were assigned on the basis of the ORIGINAL groundwater flow model properties", if in fact, this is the case.	The hydraulic conductivity values in the submodel are the exact same values in the regional groundwater flow model from which the submodel was extracted. Text in the 60% submittal will be edited to reflect the suggested sentence.	OK pending review of 60% design submittal.	OK pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Appendix B, Section 4.5.
240	DOI-73	App. B, Section 4.1, 3rd bullet		Change "on" to "of"	Text will be changed.	Okay	OK pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Appendix B, Section 6.1.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
241	DOI-74	App. B, Section 4.2.1		This section addresses mobile and immobile porosity. Please provide more support for this assumed value for this important parameter. Simply referring to the cited textbook is not sufficient. Please provide a detailed discussion of why a textbook value is reasonable for this model. Provide a discussion on how sensitive the model results are to this assumed parameter. If highly sensitive, which DOI expects, are there ways to better estimate the conditions for this site, rather than solely relying on textbook values?	Site in situ pilot tracer studies, along with breakthrough of IM3 injection water, were also used to estimate mobile porosity. Text will be added to document these site-specific sources of data and how they were used to estimate porosity.	OK pending review of 60% design submittal.	OK pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Appendix B, Section 6.2.1.
242	DOI-75	App. B, Section 4.2.2		DOI has previously been told by PG&E that calibration of the fate and transport model is infeasible because it is not possible to reliably simulate the generation of the current plume from its release in BCW. However, this section seems to be saying that the mass transfer coefficient parameter was somehow evaluated by adjusting it to produce “reasonable plume movement”. This concept is not clear and warrants further explanation.	It is correct that the calibration of the fate and transport model is infeasible because it is not possible to reliably simulate the generation of the current plume from its release in BCW wash. The mass transfer coefficient was developed based on literature values and models of similar dimensions and aquifer properties, and testing with the model. Small scale and short term plume movements were evaluated with a range of mass transfer coefficients. The text will be updated accordingly.	OK pending review of 60% design submittal.	OK pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Appendix B, Section 6.2.2.
243	DOI-76	App. B, Section 4.2.4		DOI had understood that this relationship of Cr (VI) degradation with TOC concentration was based on observations during the in-situ pilot tests, however no mention is made of that in this section. Please amplify on the basis for these critical assumptions and why 0.1 ppm is the point at which this process occurs. DOI has understood that the target TOC concentration for the IRZs is 100 ppm.	A section will be added to Appendix B discussing the results of in situ pilot tests and how these results were used in deriving a target TOC concentration for the remedy. A more detailed discussion of the various TOC target and trigger concentrations used in the model will be included in the 60% submittal.	OK pending review of 60% design submittal.	OK pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Appendix B, Section 3.4.1.
244	DTSC-83	Appendix B, Page 9, 4.2.4 Chromium Reduction	To account for this, the model assumed hexavalent chromium reduction/precipitation whenever the injected carbon exceeds a concentration of 0.1 parts per million (ppm). At the same time, a carbon half-life of 20 days was assigned to account for the degradation of the injected carbon over time.	Up to this point, Arcadis has provided a logical rationale for the parameters selected for the solute transport model. However, no rationale was provided for the parameters cited in the quoted text. This section should provide examples or reference specific sections of other documents that verify the 0.1 ppm carbon concentration is an appropriate value for the completion of chromium reduction (as well as the point at which arsenic and manganese begin to sorb and precipitate).	Refer to response to comment # 243, DOI-76. Additional detailed discussion of byproduct generation will be added to Section 4.2.6 of Appendix B and attenuation mechanisms will be detailed in 4.2.7 of Appendix B.	OK pending review of 60% design submittal.	OK pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Appendix B, Section 3.4.1.
245	DOI-77	App. B, Section 4.2.5, 3rd sentence		The sentence seems to have a typographical error. Is the intent of the sentence to say that, for initial conditions, the Cr (VI) concentrations in the mobile and immobile portions of the aquifer are in equilibrium?	Yes, the revised sentence is “The initialized hexavalent chromium distributions are the same in both the mobile and immobile aquifer portions.”	OK pending review of 60% design submittal.	OK pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Appendix B, Section 6.2.5.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
246	DTSC-84	Appendix B, Page 9, 4.2.5 Chromium Reduction		The initial hexavalent chromium contaminant plume maps (B-13 to 16) will need to be updated to include all recent data including the highest concentration detected to date in well MW-68-180 (22,000 ug/L) located on the compressor station. It will be interesting to see if this new concentration affects cleanup model runs.	Plume maps will be updated with plume characterization data collected through January 2012.	OK pending review of 60% design submittal.	OK pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Appendix B, Section 6.2.5. Plume maps were updated with plume characterization data collected through February 2012.
247	DOI-78	App. B, Section 4.2.6, last paragraph		The first sentence appears to actually be two separate sentences. The relationship of Cr (VI) reduction, Mn and As generation, and Mn and As persistence in dissolved form would benefit from a concentration versus TOC concentration plot that shows all three constituents. It appears from the various sections of text, and the referenced CMS-FS plots that Cr (VI) reduction begins when organic carbon concentration is above 0.1 ppm, Mn and As dissolution begins at about 10 ppm, and Mn and As precipitation begins at about 0.1 ppm.	Yes, it should be adjusted to two sentences and corrected. Within the model, both Mn and As generation/ dissolution will occur in the presence of any degrading TOC and is not limited by TOC concentration. However with respect to precipitation, Arsenic will not precipitate in the presence of TOC above a concentration of 0.1 ppm. Manganese will have active sorption in the aquifer independent of TOC concentration. The controlling function for Manganese sorption is Mn concentration as it is simulated using the Freundlich isotherm. In order to present conservative (worst-case) Mn transport, there is no active precipitation in the solute transport model to serve as a mechanism to remove Mn from solution. Additional detailed discussion of byproduct generation will be added to Section 4.2.6 of Appendix B and attenuation mechanisms will be detailed in 4.2.7 of Appendix B.	OK pending review of 60% design submittal.	OK pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Appendix B, Sections 3.4.3, 5.3, and 5.4.
248	DTSC-85	Appendix B, Page 10, 4.2.6 Byproduct Generation		The section discusses generation rates for byproduct arsenic based on organic carbon dosage during hexavalent chromium reduction. Mention of the specific arsenic species and geochemical mechanisms is requested to assist with understanding stable arsenic species in both reduced waters as well as aerobic. Please also discuss how arsenic is generated naturally in aerobic, nonreducing environments and what mechanisms and species exist in those environments.	Concepts presented in the response to comment #51, HA-7 will be provided in the text for the 60% submittal. Additional details on various arsenic species in other environments outside the IRZ will also be included.	OK pending review of 60% design submittal.	OK pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Appendix B, Sections 3.4.3 and 5.4.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
249	DOI-79	App. B, Section 4.2.6, 1st paragraph and Section 4.2.7, 1st paragraph, last paragraph		The assertion is made here that Mn migration will be limited outside the reactive zone where Cr (VI) is treated, and that the model-predicted attenuation profile is consistent with observed Mn attenuation across the floodplain. This concept has been often stated in discussions with PG&E consultants, i.e., that dissolved Mn is generated in the treatment zone but then will quickly adsorb outside the carbon area and dissolved concentrations will rapidly decline down gradient. However, the results of the fate and transport modeling depicted on Figures B-31 through B-34 do not seem to support this conclusion. The extent of the generated Mn plume grows continuously during the 30-year simulation period both within the floodplain and in the upland areas where carbon-amended water is injected. The plumes extend well beyond the areas where injected carbon is simulated to occur. Please reconcile these seemingly contradictory conclusions.	To introduce a level of conservatism, it is assumed that manganese sorption will occur, but manganese will not precipitate in groundwater. This will essentially retard the movement of manganese in groundwater, but will not remove manganese from groundwater. This allows the manganese to persist in the groundwater and only be minimized through dilution or remedial extraction. It is also important to note that the Mn represented in the model is also sourced from naturally occurring Mn in the rind which migrates into less reduced sediments in layers 3 and 4 and only attenuates by dilution and sorption – not via precipitation. This represents a conservative assumption that will be reconsidered in the 60% design. The rind concentrations will be reassessed and modified as necessary (refer to response to comment # 258, DTSC-91). Arsenic and manganese will be described separately in terms of attenuation and precipitation, with arsenic being more limited in overall mobility than manganese. More detail will be provided on the attenuation mechanisms for byproducts in Section 4.2.7 of Appendix B. The conceptual model, to be expanded at the beginning, of Appendix B will provide an overview of these concepts.	OK pending review of 60% design submittal.	OK pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Appendix B, Sections 5.3 and 5.4.
250	DOI-80	App. B, Section 4.2.7, Item c, page 13		Item (c) says that the concentrations of sorptive forms of iron were scaled back by three orders of magnitude from the measured values in fine-grained materials. Item (d) says that iron values measured for coarse-grained materials were slightly less but of the same order of magnitude as the fine-grained. It then concludes that “These results confirm selection of the strong and weak site iron concentrations as best representations of the iron concentration and form in the aquifer soil.” DOI is not clear on which results have been confirmed and are being used; the scaled-back values or the measured values for coarse-grained materials. If the scaled-back values are used, is this being done as a conservative measure?	Item (d) will be clarified to state that difference in iron concentration between the fine and coarse fractions was about three orders of magnitude, in agreement to the assumptions in item (c).	OK pending review of 60% design submittal.	OK pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	No longer applicable. See updated discussion in Section 5.3.2 of Appendix B.
251	DOI-81	App. B, Section 4.2.7, Item G		Please explain this sentence: “Field isotherms matched the model isotherms when sorptive iron was scaled back by 10% - field and model isotherms were for silt/clay soil.”	Field sorption isotherms were developed by measuring the concentration of manganese in the soil and in the groundwater for samples recovered from the alluvial aquifer fine grained soil. The sorption isotherm developed from this field data matched the modeled isotherm within 10%.	OK pending review of 60% design submittal.	OK pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Appendix B, Section 5.3.2.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
252	DTSC-86	Appendix B, Page 11, 4.2.7 Byproduct Adsorption and Precipitation	"Manganese and arsenic will sorb to iron minerals present naturally in the aquifer outside of the reactive zone, across the floodplain, and to these newly-formed iron minerals."	How then is arsenic stable at elevated concentrations in aerobic environments? Arizona wells have elevated arsenic above MCLs. Anomalously high arsenic concentrations are noted in aerobic well MW-12 coexisting with the chromium contaminant plume. Will the model allow the elevated arsenic that is measured at MW-12 and in Arizona (e.g., Sanders well) to persist in model results?	Arsenic is stable in aerobic environments due to natural geochemical equilibrium established over an extended time period, and in the presence of a continual ongoing source of arsenic (such as due to hydrothermal activity in AZ). This ongoing source over geologic time periods can result in saturation of arsenic sorption capacity in the aquifer. The text from Appendix B that this comment refers to discusses arsenic generated by the transient geochemical conditions in the IRZ. The solute transport model is designed to simulate the relative effect of arsenic generated by the biogeochemical conditions induced by the NTH IRZ, and also to simulate the fate of the arsenic naturally present in the freshwater supply well that is injected into the freshwater injection wells. The model does not include anomalously high arsenic concentrations at MW-12 or the Sanders well.	Okay		Comment resolved.	Note that as directed by DTSC on December 31, 2012, PG&E added into the 60% design, a pre-treatment system to polish Arizona groundwater to California standards prior to injection. Therefore, the fate and transport of naturally-occurring arsenic associated with freshwater injection is no longer applicable, as the freshwater source will be treated for arsenic, and has been removed from the 60% design.
253	DTSC-87	Appendix B, Page 12, 4.2.7 Byproduct Adsorption and Precipitation, Paragraph 1, Line 1.		Please cite the wells being evaluated for manganese so the reader can follow along and evaluate the assessment presented here.	The wells that were evaluated for Mn attenuation include MW-20 (adjacent to the river), MW-39, MW-30, MW-36, and MW-31 (away from the river). The concentrations of manganese and iron were evaluated in these wells under IM-3 pumping conditions. These wells will be identified in the 60% design document update to Appendix B.	Okay pending review of 60% design submittal.		Comment resolved.	See Appendix B, Section 5.3.
254	DTSC-88	Appendix B, Page 12, 4.2.7 Byproduct Adsorption and Precipitation	"The field data provides a validation of the conceptual model used as the basis for attenuation in the byproduct fate and transport model."	The section must also then cite that field data also raises concern with manganese due to its long term persistence.	The long-term persistence of manganese is generally associated with persistent reducing conditions. Under less reducing conditions, manganese concentrations decline gradually with time. The field data demonstrates this. The text in the 60% design will include this expanded discussion.	Okay pending review of 60% design submittal.		Comment resolved.	See Appendix B, Section 5.3.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
255	DTSC-89	Appendix B, Page 13, 4.2.7 Byproduct Adsorption and Precipitation, Item (e).		The section indicates that manganese and arsenic were added to the model at low to high concentrations to simulate conditions. It seems that actual concentrations should have been utilized. The document should include a listing of the actual concentrations used in the model to allow for review and ensure they are representative.	The naturally occurring Mn and As simulated in the model was discussed on page 15 section 4.2.8. These values were average representative values that will be refined in the 60% design.	Okay pending review of 60% design submittal.		Comment resolved.	See Appendix B, Section 6.2.8, for discussion of manganese. Note that as directed by DTSC on December 31, 2012, PG&E added into the 60% design, a pre-treatment system to polish Arizona groundwater to California standards prior to injection. Therefore, the fate and transport of naturally-occurring arsenic associated with freshwater injection is no longer applicable, as the freshwater source will be treated for arsenic, and has been removed from the 60% design.
256	DTSC-90	Appendix B, Page 15, 4.2.7 Byproduct Adsorption and Precipitation	"An evaluation of the concentration trends for manganese across a transect of wells from the east (along the river) to the west (toward National Trails Highway) shows that as groundwater moves through less reducing geochemical conditions (away from the river), the concentration of manganese attenuates. The attenuation profile is simulated in the model by an analysis of manganese concentrations along a similar transect, moving from west (along the IRZ at National Trails Highway) to the east (toward the river)."	The first sentence indicates that manganese attenuates away from the river (away from less reducing conditions). The second sentence seems to say that manganese attenuation will occur towards the river. Clarification is requested.	Text will be clarified to indicate that manganese more readily attenuates in less reducing conditions. In this case, the discussion compares Mn attenuation away from the river (under IM-3 pumping conditions, where the gradient direction is reversed and Mn in the reducing zone adjacent to the river is pulled into a more oxic environment away from the river, and deeper) to the Mn attenuation simulated under IRZ conditions (where Mn generated in the IRZ migrates downgradient into a more oxic zone toward the river). This appears to be contradictory but the discussion compares current observations of Mn attenuation (under IM-3 pumping conditions) to Mn attenuation under IRZ conditions.	Okay pending review of 60% design submittal.		Comment resolved.	See Appendix B, Section 5.3.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
257	DOI-82	App. B, Section 4.2.8		It appears from the discussion that the evaluation considered only naturally occurring Mn in the floodplain and not As. Please explain why the naturally occurring As component was limited only to the fresh water injection sites in the simulations. Why is As treated differently from Mn?	The mechanisms that govern arsenic mobility were analyzed in the same way in both freshwater injection wells and in IRZ injection wells. The difference lies in the predicted behavior of arsenic in these two areas, rather than the way in which they were analyzed. In the freshwater injection areas, arsenic from the freshwater supply is injected into the wells and the model predicts its attenuation with distance from the injection points. In the IRZ areas, arsenic is generated as organic carbon is consumed, and then attenuates within the organic carbon footprint via the same mechanisms that it attenuates with away from the freshwater injection wells. Any arsenic generated in the NTH IRZ is readily precipitated outside of the carbon footprint or once the carbon is consumed. The model predicts that byproduct arsenic will not reach the Colorado River or the river bank extraction wells.		Comment and response noted. Further evaluation will occur during the review of 60% design submittal.	Comment resolved.	Note that as directed by DTSC on December 31, 2012, PG&E added into the 60% design, a pre-treatment system to polish Arizona groundwater to California standards prior to injection. Therefore, the fate and transport of naturally-occurring arsenic associated with freshwater injection is no longer applicable, as the freshwater source will be treated for arsenic, and has been removed from the 60% design.
258	DTSC-91	Appendix B, Page 15/16, 4.2.8 Naturally occurring Manganese and Arsenic	"To simulate a naturally occurring conservative manganese concentration distribution in the rind, an additional simulation was performed under ambient (nonpumping) conditions. This assumed the rind was present in model layers 1 and 2, and extends approximately 250 ft on either side of the surface water features, as well as under the surface water features and marshland."	There appears to be no basis for utilizing the manganese rind simulation as exiting data do not support a manganese rind extending 250 feet away from the river in model layers 1 and 2. Fluvial wells nearest the river (MW-28-25, MW-28-90, MW-34-55, MW-34-80, MW-34-100, MW-52S, MW-52M, MW-52D, MW-53M, MW-54-85, MW-54-140, MW-56S, MW-56M, MW-56D, etc.) do not yield the high manganese (> 2 mg/L Mn) that is depicted adjacent to the river and under the marsh in modeling figures (e.g., Figure B-31). Figure 2-8 of the report also shows the lack of high (> 2 mg/L) manganese. Wells with elevated manganese near the river (e.g., MW-22, MW-32-035, MW-53D) are associated with highly brackish, saline (and even brine) waters atypical of site conditions. Figure 2-8 suggests that elevated manganese may be a function of depth and, therefore, related to the chemically stratified nature of the aquifer. The model must be modified to represent site conditions and the section rewritten.	Elevated concentrations of both Mn (Figure 2.8) and Fe (Figure 2.9) indicate the presence of a reducing zone extending away from the river. Anaerobic core study data suggest that although this area is generally reducing, the reducing conditions are naturally distributed with pockets of weaker and stronger reducing activity. Also, manganese content of the fluvial matrix is variable, so that in some areas that indicate reducing conditions that would support dissolved manganese(indicated by strongly negative ORP and the absence of Cr(VI)) , the observed Mn concentrations are relatively low. It is also possible that Mn concentrations are lower in parts of the shallow zone immediately adjacent to the river due to the presence of the hyporheic zone (groundwater/surface water mixing zone), which serves to deliver oxic river water that can dilute aqueous Mn concentrations and/or oxidatively precipitate Mn. A more in-depth analysis of the spatial distribution of the reducing rind, including spatial distribution of geochemical indicators, will be considered for the 60% design to more fully illustrate the extent of the reducing zone. The Mn transport model results indicate generated-byproduct Mn concentrations within the range naturally measured in the floodplain. The text will be modified in the 60% design to place this in better context with the actual background Mn concentrations observed. Additionally, a	Okay pending review of the 60% design submittal.		Comment resolved.	See Appendix B, Sections 2.3, 6.2.8, and 8.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
					one-dimensional hyporheic zone model for Mn is also being developed for the 60% design, which will be used to evaluate geochemical/hydrological processes governing manganese behavior near the groundwater-river water interface as groundwater flows toward the river.				
259	DTSC-92	Appendix B, Page 16, 4.2.8 Naturally occurring Manganese and Arsenic	"With respect to arsenic, the primary naturally occurring arsenic that was simulated was associated with the proposed freshwater injection. Groundwater extracted from HNWR-1 located in Arizona was assumed to have a naturally occurring arsenic concentration of 17 ppb. This concentration was continuously applied to all of the simulated freshwater injection wells to evaluate the potential impact of the naturally occurring arsenic."	Why was 17 ppb arsenic used for HNWR-1 when Exhibit 3-1 and Appendix A1 state a value of 15 ppb? Recommend updating this value after a robust data set is attained. Please indicate if the model, if applied in its current form, would conclude that injected arsenic would attenuate within the aquifer if reinjected back into the HNWR-1 area.	The freshwater arsenic concentration will be updated to reflect all available data for future solute transport modeling runs. The solute transport model was developed as a tool to analyze the relative impact of arsenic potentially generated by the NTH IRZ and the introduction of a freshwater water source with a known arsenic concentration into the upgradient freshwater injection wells. This solute transport model is not designed to be a tool to evaluate background arsenic behavior in the vicinity of HNWR-1. Also refer to response to comment #252 DTSC-86.	OK pending review of 60% design submittal.		Comment resolved.	Note that as directed by DTSC on December 31, 2012, PG&E added into the 60% design, a pre-treatment system to polish Arizona groundwater to California standards prior to injection. Therefore, the fate and transport of naturally-occurring arsenic associated with freshwater injection is no longer applicable, as the freshwater source will be treated for arsenic, and has been removed from the 60% design.
260	DOI-83	App. B, Sections 4.4 and Figures B-17, B-18, and B-20		The text and figures are very confusing in this section. The text appears to talk about two different optional configurations of NTH wells, one with a 150-foot spacing and one with a 75-foot spacing. The figures jump from one configuration to the other with no explanation. The figure titles speak only of the "conceptual remedy" or "remediation design locations", without distinguishing between the two apparent options discussed in the text. DOI understands from the text that PG&E is proposing the 150-foot spacing configuration design as the remediation design. The text and figures need to be revised to clearly distinguish between the remediation design and the alternative option considered but not selected. DOI recommends that Figure B-17 show the remediation design configuration of 150-foot well spacing, and that the cross section location figure (B-18) and the cross section (B-20) depict this remediation design configuration. A separate new figure can then be introduced showing the 75-foot well spacing configuration, with the title clearly stating this is as optional layout that was considered but not selected.	The text and corresponding figures will be clarified with respect to the NTH IRZ well spacing. The provisional wells will be removed from Figures B-18 and B-20. Figure B-20 will be brought to Section 3 with the provisional wells included.	OK pending review of 60% design submittal.	OK pending review of 60% design submittal.	Resolved pending review of 60% design submittal.	See Appendix B, Section 6.4, and Figures 6.4-1 to 6.4-8.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
261	DTSC-93	Appendix B, Page 17, 4.4 Remediation Design		Request adding contoured chromium plume to cross-sections (Figures B-18 through B-24). Identify the natural reductive zone on Figures B-19 and possibly B-20. Illustrate the actual screened zones that were used in the model run to allow comparison to Tables 3-1 to 3-4 and eventually to actual emplaced screen depths. What criteria will guide screen placement during drilling? Figure B-17: The flow rates associated with the IRZ wells pictured on Figure B-17 are not the same as those rates called out in Table 3-1. This difference should be discussed or corrected.	The cross-sections will be updated to reflect the chromium plume delineation and proposed screen intervals. Screen placement will be guided by the lithology encountered during drilling. Screening over the more permeable sections of the aquifer will produce better flow and encourage development of the IRZ. The IRZ well flow rates shown on Figure B-17 will be corrected to correspond to the nominal rates in Table 3-1. Flow rates will be reviewed for consistency and explanations will be included in the 60% design submittal.	Okay pending review of 60% design submittal.		Comment resolved.	See Appendix B and Table 3.2-1 of the BOD Report.
262	DOI-84	App. B, Section 4.4.1		The discussion of fresh water injection wells conflicts with DOI's understanding of the different purposes of the FW-INJ wells and the UPGRAD-INJ wells. DOI understood that the FW-INJ wells receive only fresh water, while the UPGRAD-INJ wells receive both carbon-amended water and fresh water. The text of 4.4.1 identifies wells UPGRAD-INJ-3 and UPGRAD-INJ-4 as fresh water injection wells. In reviewing the design document, DOI could find no information that suggests that wells UPGRAD-INJ-3 and UPGRAD-INJ-4 would be used differently than the other UPGRAD-INJ wells.	The well names can be updated to reflect their function in the model and the text will be clarified. Because the FW-INJ well located within I-40 was no longer a viable option, it was relocated to the UPRAD-INJ-4 location. The two northernmost upgradient injection wells (UPGRAD-1 and 2) receive the water extracted from the riverbank extraction wells. The freshwater injection wells (FW-INJ-1, 2 & 4, and UPGRAD-INJ-3 & 4) receive freshwater from HNWR-1. Additional modeling can be conducted to evaluate the impact of using different patterns of freshwater and riverbank water injections into UPGRAD-INJ-1, 2, 3, & 4. Please see Exhibit 3-4 footnote c indicating that wells UPGRAD-INJ-1 and UPGRAD-INJ-2 may be used for injecting carbon-amended water or freshwater. The remaining upland wells will be used as freshwater injection wells. The proposed setup is expected to successfully create proper hydraulic conditions, so that the chromium plume moves through the treatment zone at the designed direction and rate.	Okay pending review of 60% design submittal.	Okay pending review of 60% design submittals.	Comment resolved.	See Appendix B (Section 6.4) and Section 3 of the BOD Report.
263	DOI-85	App. B, Section 4.4.1		Editorial Comment. The new section entitled "Freshwater Injection" should be included within the text between the current 4.4.1 and 4.4.2.	The text will be updated.		Okay pending review of 60% design submittals.	Comment resolved.	See Appendix B, Section 6.4.7.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
264	DTSC-94	Appendix B, Page 17, 4.4.1 National Trails Highway IRZ	"By extracting at these locations the natural west to east flow gradient is generally preserved to encourage flow through the reduced groundwater."	Extracting 200 gpm at the northern end of the IRZ would seem to have a significant effect on east-west flow. Section 3.3 indicates that pumping a remote well at Park Moabi would have adverse effects on the remedy. Please provide figures with flow lines to help visualize system flow. Please indicate why dual screen recirculation wells were no longer considered for the IRZ. They would generate no net flow along shorter segments of the NTH IRZ.	Extracting 200 gpm from the northern portion of the NTH IRZ, and 100 gpm from the central portion of the NTH IRZ allows the groundwater to flow from west to east to encourage flow through the NTH IRZ. Injection of fresh water upgradient of the IRZ, coupled with extraction from the AZ side of the river, forms the greatest flushing force through the IRZ. Switching the fresh water source to the Park Moabi area would diminish the flushing force through the IRZ, as the pull from the east would be lost and the pull from the west would lower the eastward flux of injected water to some degree. This will be explained more thoroughly in the freshwater supply evaluation technical memorandum and summarized in the 60% submittal. A more detailed discussion regarding dual-screen recirculation wells is included in the response to comment #94 (DTSC-31): As discussed in the final pilot report, the findings of the study indicated potential issues with distribution of organic carbon substrate in this recirculation design, due to vertical short circuiting between injection and extraction intervals that limited lateral distribution at the middle and deep intervals. Based on this information, the recirculation system for the final remedy does not include recirculation wells with injection and extraction intervals at the same location.	Okay pending review of tech memo and 60% design submittal.		Comment resolved.	See Appendix J of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
265	DTSC-95	Appendix B, Page 19, 4.4.1 National Trails Highway IRZ	"A conservative simulated arsenic concentration of 17 ppb was introduced into all 5 freshwater injection wells. Due to the relatively high precipitation potential in this aquifer, the footprint of the impacted groundwater in the vicinity of the freshwater injection wells is fairly limited and actually reaches steady state conditions after several years where the arsenic footprint no longer expands. "	The section calls out "high precipitation potential". Please define this term. Will precipitation of the arsenic lead to well fouling? Details of the simulated arsenic precipitation model should be shared in the document. What transformations are occurring to specific arsenic species? Will pH adjustment of the freshwater be needed as originally envisioned in the 2009 CMS/FS? Angled borings/wells should be considered for this project due to logistical and cultural constraints. Angled wells for FW-INJ-3 do not appear to have been considered.	The high precipitation potential refers to the potential for arsenic to be removed from groundwater through interaction with the aquifer matrix minerals upon injection of the freshwater. This will be clarified in an update to Appendix B. Details of the arsenic precipitation model will be provided in an updated conceptual model discussion to be added to Appendix B for the 60% design. pH adjustment is not considered necessary for the freshwater injection. In the 2009 document, the need for pH adjustment was mentioned as a design consideration. Angle drilling of large diameter wells presents many serious difficulties. The drilling equipment for large diameter boreholes is not designed to drill at anything other than very slight angles off of vertical. At slight angles, the horizontal offset between the well head and the screened interval would be a few tens of feet. Other problems include difficulty in keeping a straight borehole, keeping the borehole from caving, placement of annular materials, installation of pumps and injection tubing, and rehabilitation of the well using swabs and bailers. A more complete discussion of the possible advantages and drawbacks of angle wells will be provided in the 60% design.	Okay pending review of 60% submittal.		Comment resolved.	Note that as directed by DTSC on December 31, 2012, PG&E added into the 60% design, a pre-treatment system to polish Arizona groundwater to California standards prior to injection. Therefore, the fate and transport of naturally-occurring arsenic associated with freshwater injection is no longer applicable, as the freshwater source will be treated for arsenic, and has been removed from the 60% design.
266	DOI-86	App. B, Section 4.4.2		DOI has concerns about the proposal to construct the riverbank extraction wells with capability of only extracting from the deeper portions of the aquifer. While it is understood that contaminated groundwater in the floodplain area is predominantly deep, there are areas where Cr (VI) contamination is present in samples from shallow wells east of NTH (Figure 2-3a). In DOI's view, one of the important reasons to incorporate the riverbank extraction wells in the selected remedy was to provide a "backstop" to the in-situ remedy that could be operated to capture any contaminated water that might otherwise reach the river. While it may prove to be unnecessary to extract water from the shallow zone, DOI would prefer to preserve the option of doing so without additional well installation later if it proves to be necessary. PG&E should evaluate well construction options for the riverbank extraction wells that would allow for pumping of water from the shallow intervals if deemed necessary in the future during system operation and monitoring.	While there is Cr(VI) present east of the NTH IRZ, it is anticipated that this impacted water will be readily treated in the existing shallow reducing rind. This is only applicable to existing Cr concentrations east of the NTH IRZ line, the Cr concentrations upgradient (west) of the NTH IRZ is anticipated to be treated by the NTH IRZ. The riverbank extraction wells were originally designed to be a backstop for the deep groundwater below the reducing rind. Screening wells in the reducing rind could lead to potential well fouling by the naturally occurring Mn. However, the riverbank extraction wells can be constructed in a manner that would allow them to be modified if observed conditions suggest it is necessary to control Cr6 migration. One approach would be to build the well so that the casing in the shallow unit could be perforated if water needed to be pumped from the shallow zone. Alternative designs will be considered and one selected and presented in the 60% design.	Okay pending review of 60% design submittal.	Okay pending review of 60% design submittals.	Comment resolved.	See Section 3.2, Appendix D2, and Appendix B (Section 6.4.2).

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
267	DOI-87	App. B, Sections 4.4.2 and 4.4.3		This section states that reinjection of the water extracted from the riverbank extraction wells would be limited to two injections wells, presumably UPGRAD-INJ-1 and UPGRAD-INJ-2, although not specifically identified by number in the text. DOI understood that all of the UPGRAD-INJ wells would receive both carbon-amended water from the riverbank extraction wells and fresh water. In reviewing the design document, DOI could find no information that suggests that wells UPGRAD-INJ-1 and UPGRAD-INJ-2 would be used differently than the other UPGRAD-INJ wells. Why was injection of the riverbank well water limited to only these two wells in the simulations?	The text will be clarified to explain the function of the proposed wells. It is currently simulated that only the northern 2 upgradient injection wells (UPGRAD-INJ-1 & 2) will receive riverbank extraction water. The remaining two wells will receive freshwater injections. Alternative injection approaches are being considered as part of the 60% design and will be presented in the 60% document.	Okay pending review of 60% design submittal.	Okay pending review of the 60% design submittals.	Comment resolved.	See Appendix B, Section 6.4.
268	DTSC-96	Appendix B, Page 19, 4.4.2 Riverbank Extraction	"Along the west side of the Colorado River, a series of extraction wells were simulated with the goal of both accelerating groundwater through the NTH IRZ and to also capture any hexavalent chromium located downgradient of the NTH IRZ. The proposed layout of the riverbank extraction wells consists of 4 wells screened in model layers 3 and 4 (beneath the naturally occurring rind) with the option to add a fifth well if necessary. The simulated total extraction rate of 150 gpm was utilized for the solute transport model runs."	Please provide capture zone analysis, including associated figures, for the riverbank system for all layers modeled. Is the riverbank system capturing the entire plume east of the floodplain during the life of the remedy? Also document that the riverbank extractors were created to capture any generated byproducts throughout the life of the remedy. The document should discuss higher pumping rates up to 640 gpm as originally envisioned for the riverbank system in the 2009 CMS/FS. Why send imported freshwater to the inner recirculation loop when site water is available and higher rates should achieve cleanup faster? Layers 3 and 4 are proposed for pumping, presumably since they are beneath the "naturally occurring rind". The reductive zone must be clearly defined and carefully plotted on maps and cross-sections to ensure that systems are properly designed. The rind appears to be part of the remedy, yet is not properly addressed in the document. What will trigger adding a fifth well? Why was the fifth well eliminated from the original design?	Capture zone figures and an expanded discussion for the Riverbank Extraction wells will be provided with the 60% design. Pumping rates were reduced in the Riverbank Extraction wells in an attempt to reduce the impact on the naturally occurring shallow reducing rind and to minimize pumping stress on the NTH IRZ caused by higher flowrates in the floodplain. Higher pumping rates in the floodplain proximal to the NTH IRZ will lead to faster groundwater velocities between the IRZ and the Riverbank Extraction wells. This increases the hydraulic stress on the NTH IRZ in the direction of groundwater flow and increases the potential for an incomplete remedial barrier, as demonstrated in the 300 gpm model run (Figure B-46). Pumping the Riverbank Extraction wells at a reduced rate increases the potential for a comprehensive IRZ to develop along the NTH IRZ to enhance remediation of the Cr(VI) impacted groundwater. The extent of the naturally occurring reducing zone will be delineated in both plan view and cross-section in the 60% design. The fifth riverbank extraction well will be considered based on the hydraulic performance of the other 4 Riverbank Extraction wells and monitoring well data. The fifth well is not operated in the 30% design because adequate capture was achieved by just operating the other 4 extraction wells.	Okay pending review of 60% design submittal.		Comment resolved.	See Appendix B, Section 6.5.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
269	DTSC-97	Appendix B, Page 19, 4.4.2 Riverbank Extraction	"These wells will potentially pull down the groundwater from the naturally occurring rind, so consideration was taken to keep the extraction rate at a reasonable level."	Clarify why pulling down shallow water with the deeper extractors should be minimized/kept to "reasonable levels".	There are two major reasons for minimizing the downward pull of the riverbank wells. 1. The naturally occurring reducing rind typically contains elevated manganese and iron concentrations that could contribute to well fouling and provide a source of manganese and iron into layers 3 and 4. 2. The naturally occurring reducing rind provides ideal conditions for Cr(VI) precipitation in the event there is breakthrough past the NTH IRZ in Layers 1 and 2. Thus the riverbank extraction wells are designed with due consideration given to minimizing potential impacts to the naturally occurring reducing rind.	Okay		Comment resolved.	
270	DTSC-98	Appendix B, Page 20, 4.4.3 Uplands Injection		Briefly describe how fouling in amended wells will be mitigated.	Wells will be periodically rehabilitated to physically or chemically remove fouling deposits on the well screen, filter pack and/ or in the near well formation. Well fouling mitigation procedures are addressed in more detail in Sections 3.2.1.1, 3.2.2.1, and 3.2.3.1 for the different components of the in-situ remediation system. In addition, proactive backwashing of the wells will be used to control fouling before it occurs.	Okay.		Comment resolved.	
271	DOI-88	App. B, Section 4.4.4		Please identify the four extraction wells and two injection wells by number in the text. DOI presumes they are Mid-EX-1 through -4 and comp-inJ-1 and comp-inJ-2, shown on Figure B-18. While this may seem obvious in this case, the previous discussions of the UPGRAD-INJ injection wells led to confusion. This can be avoided by explicitly identifying wells by number when discussing them.	Text will be clarified to reflect how the simulated wells will be operated.		Okay pending review of 60% design submittals.	Comment resolved.	See Appendix B, Section 6.4.2.
272	DOI-89	App. B, Section 4.4.5		Identify the extraction wells by number in the text. DOI presumes they are RAV-EXT-1 through RAV-EXT-4.	Text will be updated to reflect the associated well names.		Okay pending review of 60% design submittals.	Comment resolved.	See Appendix B, Section 6.4.5.
273	DOI-90	App. B, Section 4.4.6		Identify the injection wells by number in the text. DOI presumes they are comp-inJ-1 and comp-inJ-2, and FW-INJ-4.	Text will be updated to reflect the associated well names.		Okay pending review of 60% design submittals.	Comment resolved.	See Appendix B, Section 6.4.6.
274	DTSC-99	Appendix B, Page 21, 4.4.6 Topock Compressor Station Injection	"Water from the extraction wells northeast of the Compressor Station and the East Ravine Extraction wells is treated and injected into two wells located in the immediate vicinity of the TCS."	Briefly describe how extracted water is being treated prior to injection.	The water extracted from the TCS and East Ravine wells will undergo carbon substrate amendment addition prior to being re-injected. The word "treated" will be revised to "amended with carbon substrate".	Okay.		Comment resolved.	See Appendix B, Section 6.4.6.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
275	DOI-91	App. B, Section 4.5, 2nd sentence		This section states that groundwater flow under ambient conditions is primarily west to east, however, flow over much of the plume area is north to northeastward toward the river based on the contours on Figure B-25.	The sentence will be deleted.		Okay pending review of 60% design submittal	Comment resolved.	See Appendix B, Section 6.5.
276	DTSC-100	Appendix B, Page 21, 4.5 Flow Conditions		Figure B-25 illustrates simulated groundwater contours, but it is not clear which model layer is being presented. Separate figures for each model layer are required. Flow line figures are also requested for each layer.	Figure B-25 is for Layer 1. Flow figure for each layer will be provided in the 60% design report.	Okay pending review of 60% design submittal.		Comment resolved.	See Appendix B, Section 6.5.
277	DOI-92	App. B, Figure B-28		Figure B-28 is missing. Figure B-27 is included twice.	Correct, Figure B-28 will be provided to show the Layer 2 simulated Cr results.	Okay pending review of 60% design submittal.	Okay pending review of 60% design submittals.	Comment resolved.	See Appendix B.
278	DTSC-101	Appendix B, Page 22, 5. Solute Transport Results 5.1 Hexavalent Chromium	"By year 30 of the simulated transport run, the majority of the hexavalent chromium plume in all four model layers has been remediated. The only exception by year 30 is the portion of the hexavalent chromium that is initialized in the bedrock in the vicinity of the East Ravine extraction wells."	The design documents should indicate what the total estimated time is to clean up (meet RAOs) based on the results of the most current model run. Modeling times should be extended until RAOs are met. The document should also mention that the "Year 30" runs for all layers do not show complete cleanup to RAOs in the alluvial aquifer.	In the 60% design, the model runs will be continued until RAOs are achieved in the alluvial aquifer. Total projected time to cleanup for the alluvial aquifer in each layer will be presented.	Okay pending review of 60% design submittal.		Comment resolved.	See Appendix B, Section 7.1.
279	DOI-93	App. B, Section 5.1, 2nd sentence		There are no results shown for 5 years.	Agreed, the 5 year reference will be removed from the text.	Okay	Okay pending review of 60% design submittals.	Comment resolved.	See Appendix B, Section 7.1.
280	DOI-94	App. B, Section 5.1 and Figure B-29		It is not clear why the NTH IRZ fails to control Cr (VI) plume migration at the northern end. Please explain why the system cannot be adjusted to correct for this without having to rely on the riverbank extraction wells.	The northern end of the NTH IRZ consists of 3 extraction wells. These wells both supply the NTH IRZ injection wells and also maintain the eastward flow component towards the Colorado River. They are screened in the lowest concentration portion of the plume and hydraulically control the plume when they are actively pumping. When the IRZ "rests" for 18 months between TOC injection events, these wells are not pumping and the low concentration plume migrates a short distance past the wells. The low concentration mass that progresses past the northern NTH IRZ in model layers 3 and 4 is readily captured by the riverbank extraction well and is diluted below 32 ppb with the other riverbank extraction wells before it is injected into the upgradient wells. Model simulations will be conducted in the 60% design to analyze alternatives to better control migration of the Cr(VI) plume to the north end of the IRZ.	Okay pending review of 60% design submittal.	Okay pending review of 60% design submittal.	Comment resolved.	See Appendix B, Sections 7.1 and 10.9.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
281	DTSC-102	Appendix B, Page 22, 5.1 Hexavalent Chromium, and Figures B-27 to B-30	The sections of the plume that are initialized on the east side of the NTH IRZ and the low hexavalent chromium concentrations in the vicinity of the NTH IRZ wells that are not treated by the NTH IRZ, are hydraulically controlled by the riverbank extraction wells.	The validity of this statement is difficult to determine based on the representative snap shots of the model provided in Figures B-27 to B-30. One might expect that the northern NTH IRZ extraction wells would be able to adequately intercept the hexavalent chromium plume, however, as demonstrated in the transport model figures, a sizable portion, albeit at low concentrations, does escape past the extraction wells towards the river and Arizona between 18 months and Year 20. Perhaps, PG&E should use particle tracking and resulting flow lines to illustrate the anticipated hydraulic movements surrounding the Northern portion of the IRZ. DTSC also recommends showing the current plume outline on these figures for reference.	Refer to response to comment #280 DOI-94. The NTH IRZ extraction wells only operate for 6 months during a two year period and are not designed to fully hydraulically control the low concentration northern Cr plume. The northernmost riverbank extraction well assists in capturing the northern tip of the Cr(VI) plume.	Okay pending review of 60% design submittal.		Comment resolved.	See Appendix B, Section 7.1.
282	DTSC-103	Appendix B, 5.2 Manganese		The section or elsewhere in the document should discuss the manganese secondary MCL as well as USEPA's 2004 health advisory for manganese to provide significance to the manganese discussion. Is there an ecological risk associated with manganese? PG&E should mention some contingency measures being utilized at Hinkley to control manganese byproduct migration (i.e., pumping impacted manganese wells and injection into dry wells or infiltration gallery to precipitate manganese within vadose zone soils).	Manganese was one of 13 general chemical parameters evaluated for potential risk in the GWRA and was not identified as posing a potential ecological risk, based on data available at the time of that evaluation (ARCADIS 2009). The SMCL and USEPA's 2004 health advisory for manganese are both below the UTL of the naturally occurring concentration of 1.32 mg/L manganese in groundwater and the range of average concentrations up to 9.26 mg/L found in the floodplain. In this situation where the naturally occurring concentration is higher than a concentration protective of human health and ecological receptors, any activities conducted that maintain conditions consistent with the naturally occurring background concentration would not result in any increase in site related potential adverse impacts to either human or ecological populations Concentration is the key to evaluating potential adverse impacts to biological species. Concentration is a function of the amount of manganese present (i.e. – mass) along with the flow rate and volume of water carrying that manganese. The proposed design and associated modeling indicates that manganese generated will not increase the concentration of manganese in groundwater to exceed the UTL of background concentrations. Therefore, implementing the proposed design would not create additional adverse impact (exceeding background conditions) to species potentially contacting the manganese concentrations in groundwater. Because the proposed treatment does not increase concentrations above naturally occurring background, the proposed	Okay pending review of 60% design submittal.		Comment resolved.	See Appendix L (O&M Manual).

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
					treatment does not present a concern for additional adverse impacts for either direct contact by humans consuming groundwater, or for indirect contact by humans or ecological species contacting manganese discharged from groundwater to surface water. As suggested, a discussion of contingency measures will be included in the 60 percent design in the event that manganese concentrations exceed naturally occurring concentrations.				
283	DTSC-104	Appendix B, Page 22, 5.2 Manganese		The manganese figures and text need to be revised. See previous comment on Appendix B, 4.2.8 Naturally occurring Manganese and Arsenic, Page 15/16. DTSC does not concur with the current write up. Based on existing data presented, the section should conclude that manganese byproduct formation will occur and impact upland areas around amended injection wells as well as the majority of the floodplain with elevated concentrations for greater than 30 years. Figure 3-34 (Layer 4 Simulated Manganese Transport) suggests that the manganese plume is still expanding after 30 years. Would manganese concentrations and plume footprint continue to expand after 30 years? Include model runs that show when manganese levels return to baseline conditions.	Manganese is continuously generated in the presence of carbon. Additionally, the simulated sorption of Mn only retards the movement of Mn in the aquifer, there is no mechanism that removes Mn from groundwater in the solute transport model. In the 60% design the manganese behavior in the solute transport model will be evaluated to reflect the potential of Mn oxidation.	Okay pending review of 60% design submittal.		Comment resolved.	See Appendix B, Section 5.3.3.
284	DTSC-105	Appendix B, Page 22, 5.2 Manganese, and Figures B-31 to B-34	The manganese runs take into account both the simulated naturally occurring manganese as well as potential manganese generated as a byproduct from carbon amended injection wells.	This presentation is simply confusing. Although it is PG&E's hypothesis that there would be a potential for high concentrations of manganese in the fluvial sequence, there is little objective data to support this "simulated naturally occurring manganese." If it is PG&E's intention to show the effect of Mn flux resulting from remediation, PG&E should begin with actual measured data and simulate the sequence over time as with Cr(VI). Although PG&E would also like to conclude that the remedy would not increase "the load" of manganese in the formation, it is questionable if these graphics would accomplish that either.	The simulated naturally occurring manganese distribution was meant to represent an average naturally occurring Mn distribution. Observed concentrations ranged from 1 to 9 ppm. The manganese distribution will be re-evaluated based on available site data to refine the solute transport modeling. Due to the limited data density, in particular to the east of the river, assumptions have to be made based on the observed concentration data and the operating conceptual model that explains the presence of Mn in the floodplain sediments.	Okay pending review of 60% design submittal.		Comment resolved.	See Appendix B, Section 7.2.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
285	DOI-95	App. B, Sections 4.2.7, 5.3 and 6.5		Section 4.2.7 discusses arsenic attenuation and states that arsenic attenuates primarily through sorption processes. However, Sections 5.3 and 6.5 refer to arsenic precipitation in discussing the rapid As plume attenuation. In general, the discussions of Mn and As generation and attenuation must better explain why they behave similarly or differently during transport, and provide the basis for why they are being simulated differently. Also, DOI requests that the results of the As simulations be provide for the 0.5xBase precipitation simulation in map form so that the potential As plume could be assessed.	Text will be clarified to explain how arsenic and manganese are simulated. Results for the 0.5 X Base precipitation for Arsenic will be provided.	Okay pending review of 60% design submittal.	Okay pending review of 60% design submittal.	Comment resolved.	Note that as directed by DTSC on December 31, 2012, PG&E added into the 60% design, a pre-treatment system to polish Arizona groundwater to California standards prior to injection. Therefore, the fate and transport of naturally-occurring arsenic associated with freshwater injection is no longer applicable, as the freshwater source will be treated for arsenic, and has been removed from the 60% design.
286	DTSC-106	Appendix B, Page 23, 5.3 Arsenic		See previous comments regarding arsenic. Include model runs that show when arsenic levels return to baseline conditions. As with all modeling, appropriate monitoring will need to be conducted to verify model results. Contingency measures will need to be identified in the event that modeling proves inadequate.	Additional figures will be generated to show the recovery of the arsenic levels to baseline conditions after the active remediation is completed. Contingencies will be discussed in the 60% design document.	Okay pending review of 60% design submittal.		Comment resolved.	Note that as directed by DTSC on December 31, 2012, PG&E added into the 60% design, a pre-treatment system to polish Arizona groundwater to California standards prior to injection. Therefore, the fate and transport of naturally-occurring arsenic associated with freshwater injection is no longer applicable, as the freshwater source will be treated for arsenic, and has been removed from the 60% design.
287	DTSC-107	Appendix B, Page 23, 6. Sensitivity Analysis		The rationale for conducting sensitivity analysis 10 years out should be stated. An analysis near the end of cleanup (end goal) would also seem appropriate.	The 10 year timeframe for the sensitivity analysis was selected because it provided a reasonable snapshot of the influence of the varied parameter on the plume transport. Analyzing the sensitivity at early or late times in the run potentially masks the impact of the parameter variance. Simulation results toward the end of the remedial timeframe where plume mass is still present (approximately 30 years of simulated transport) will be provided in the 60% design in order to summarize the long term impact associated with parameter variations.	Okay pending review of 60% design submittal.		Comment resolved.	See Appendix B, Section 10.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
288	DTSC-109	Appendix B, Page 25, 6.3 Riverbank Extraction Rates		A range of 0 to 300 gpm riverbank extraction rates were evaluated. Please also evaluate 640 gpm as originally proposed for Alternative E in the 2009 CMS Report.	Increasing to 640 gpm will significantly increase the byproduct impact in the uplands as can be seen in the comparison of the 150 gpm and 300 gpm runs.	Okay.		Comment resolved.	
289	Hualapai-9			In the modeling portion of the 30% design report (Appendix B), the time frame for clean-up of the Cr(VI) plume was modeled to be 30 years. Parameters for input to the remedy model came partly from the ISPTs at the Topock Compressor Station. During the different ISPT studies, carbon concentrations in the injected fluid ranged from 1,000 to 10,000 mg/L. In contrast, carbon concentrations in the remedy model ranged from 50 to 100 mg/L (many orders of magnitude lower). Therefore, the modeled results really cannot be compared to the ISPT results. The groundwater remedy, when constructed, will be a large experiment with many unknown parameters. This might be expected given the geochemical and hydrological complexities at the site. However, the Tribes and stakeholders should be made aware of the uncertainties that exist in the project, and a range of dates should be presented, rather than a promise for a 30-year completion.	A more detailed discussion of the uncertainties will be added to the text.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		See Appendix B, Section 11.
290	Hualapai-1 and TRC-1			<u>Addressing Uncertainty</u> The modeling discussion does not address or evaluate predictive uncertainty. The fact that the modeling report does not mention “uncertainty” suggests that an integral part of the modeling evaluation is missing here. It is important to utilize the model to address the uncertainty of model inputs (such as porosity, hydraulic conductivity, storage, river leakage, sorption, dispersion, Cr(VI) reduction rates, etc.) which could be evaluated in terms of variations in number of remediation wells, impacts from by-products, and estimated total duration of the cleanup. **TRC Recommendation:** It is anticipated that a reasonably detailed discussion of how uncertainly has been evaluated would be included in the 60% design report.	As with all mathematical models of natural systems, it is limited by factors such as scale, accuracies in estimated hydraulic properties and/or boundary conditions, and the underlying simplifications and assumptions incorporated into the models. These factors result in limitations to the model’s appropriate uses and to the interpretations that may be made of simulation results. The flow model calibration procedure was explained in CH2MHILL 2005 and describes the assignment of hydrogeologic parameters. The flow model was calibrated against (a) long term average groundwater levels, (b) average monthly floodplain levels responding to fluctuating river levels, (c) short-term responses to pump testing events, and (d) plume development over time. The autocalibration program PEST was employed to refine the calibration and to reduce effects of uncertainty in each calibration target. This calibration procedure resulted in a highly heterogeneous distribution of hydraulic conductivity to represent the natural system. With respect to the solute transport model, uncertainty was addressed by conducting a detailed sensitivity analysis on various solute transport parameters. This sensitivity analyses can be utilized to address the uncertainty in the model by providing a range of remedial timeframes associated	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		See Appendix B, Section 11.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
					and relative impacts of by-products. Additional text can be added to the 60% design report to expand on the uncertainty associated of the predictive model.				
291	Hualapai-2 and TRC-2			<u>Addressing Uncertainty</u> Certainly one expects deviations between model simulated and actual system responses in drawdown, groundwater flow direction and gradient. Has the model been utilized to evaluate contingencies (aside from simply adding wells) to respond to potential changes in the system outside of those specifically shown by current model results? **TRC Recommendation:** Using a range of possible flow parameters in the model runs may illustrate potential responses in the actual groundwater system which should be monitored for during initial operation and startup. If this has already been done or is ongoing, a discussion of this analysis and results should be included in the 60% design.	The calibrated groundwater flow model provided a representative highly heterogeneous representation of the natural system. This calibration processed was described in detail in CH2MHILL 2005. Therefore, additional calibration will not be performed. Several different remedial alternatives were evaluated using the groundwater flow and solute transport model. By varying the remedial scenarios based on the amount of wells, well locations, flow rates, and well spacing, the effectiveness of the different layouts could be compared. For example, numerous runs were conducted with respect to the NTH IRZ where the system was optimized to minimize the potential for the plume to migrate past the NTH IRZ. Additional text can be added to the 60% design report to expand on the various components that were evaluated in order to arrive at the optimized remedial strategy.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		See Appendix B, Sections 6.4 and 10.
292	Hualapai-3			<u>Evaluating Effects of Local-scale Geologic Heterogeneity Using the Model</u> Local-scale geologic heterogeneity will likely dominate the effectiveness of the simulated proposed carbon injection treatment. This is typical and even expected in most groundwater cleanups, especially in fluvial systems. It does not appear that the current model incorporates the representative elementary volume (REV) to capture the local heterogeneities in confining layers, etc., especially using Mod-Flow. The model should be used to generate a range of probable cleanup times. Modeling parameter estimation tools such as PEST could be used to help estimate at least the effects of parameter uncertainty on predicted cleanup times.	The concept of REV is defined as the minimum volume over which aquifer parameters reflect their macroscopic values and do not fluctuate over small-scale changes in matrix properties (Bear, 1972). The model cells contain macroscopic average values that were originally estimated during flow model calibration (CH2M HILL 2005 and response to comment 116), and therefore support the REV concept. There is no continuous confining layer documented in the numerous well logs compiled for the site and presented in the RFI Volume 2 report, but there are heterogeneities inherent in the alluvial and fluvial materials. PEST was used in the original flow model calibration to help account for these heterogeneities. Clarifications about the modeling parameters will be provided in the 60% design. Transport parameters will be further evaluated through a sensitivity analysis to represent uncertainty in the transport model to provide a range of cleanup times in the 60% Design Report.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		See Appendix B, Sections 4, 10, and 11.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
293	Hualapai-4 and TRC-3			Evaluating Effects of Local-scale Geologic Heterogeneity Using the Model A thorough discussion is needed to address the uncertainties associated with subsurface heterogeneity and model parameterization and the associated confidence ranges for the number of wells, duration of cleanup and by-product concentrations over impacted areas. **TRC Recommendation:** It is anticipated that a reasonably detailed discussion of how uncertainly has been evaluated would be included in the 60% design report. Questions to address in refining the accuracy and precision of the model include: what are the geological, geochemical, or hydrologic heterogeneities that might be anticipated? How would these affect the design details? What are the reasonable ranges of time to achieve clean up the plume?	Heterogeneity is addressed in the groundwater flow model by a variable hydraulic conductivity distribution established during the groundwater flow model calibration process. This distribution was based on observed field data and further refined through parameter estimation (PEST). Documentation with respect to the groundwater flow model is presented in Hill 2005 and 2009. Heterogeneity is also addressed in the solute transport model by simulating the system as a dual domain model. This allows for interaction between the mobile and immobile porosities. Additional discussions regarding uncertainty will be included in the 60% design.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		See Appendix B, Sections 4 and 11.
294	Hualapai-5 and TRC-4			Evaluating Effects of Local-scale Geologic Heterogeneity Using the Model With any drawdown scenario, it is reasonable to anticipate that the system will be stressed beyond the conditions against which it has been calibrated likely causing deviations between the simulated and actual conditions. **TRC Recommendation:** In the subsequent design documents, there should be discussion on contingencies in the remedial design (other than additional wells) to account for the reasonably anticipated deviations. This may include a discussion on how predicted drawdown, and extent, magnitude, flow direction and/or gradient may differ from actual drawdown impacts (especially at distance from the injection/ extraction wells) using a range of possible flow parameter values.	The system has not been under the proposed stresses simulated in the model so we cannot calibrate to these proposed conditions. By calibrating to the current conditions a baseline is established to build upon. The model is just used as a tool to guide decisions, not to be used as a factual predictor. As the remedy is put in place, the system should be carefully monitored to evaluate the effectiveness.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		
295	Hualapai-11 and TRC-7			Addressing Uncertainties in Model Parameters and Assumptions The current flow model assumes steady-state flow conditions, and appears to assume that the seasonal water table fluctuations from such factors such as variable recharge, river leakage and variations in time and distance between gaining and losing areas are not important. **TRC Recommendation:** The model should be used to assess transient boundary conditions on the simulated predictions and model simulation runs.	While there are variations in such parameters recharge and river stage, the pattern of groundwater flow is consistent. By developing a long term steady state average condition, the model is able to take into account the fluctuations in the system	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
296	Hualapai-12			Addressing Uncertainties in Model Parameters and Assumptions A uniform model grid of 25x25 feet is specified throughout the entire sub-model domain. Given that injection and extraction well points will be on the order of one foot, corrections need to be made to the simulated heads at and near these injection/extraction wells to account for these differences. It is not clear that the current model account for this.	Focused figures were not generated to display water levels at the well points. For the purpose of solute transport modeling, the head is averaged over the entire cell to demonstrate the hydraulic influence. While water levels at the exact location of the well will vary based on injection or extraction rates, the model averages the hydraulic impact over the cell to simulate the hydraulic influence.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		
297	Hualapai-13 and TRC-8	Modeling		Addressing Uncertainties in Model Parameters and Assumptions Density dependent flows were not simulated, yet groundwater levels are typically corrected for both temperature and salinity (which DOES increase with depth at Topock). Would the operation and performance of the proposed remedial system (i.e. number and distribution of wells, pumping rates, etc.) be different if temperature and salinity effects were considered in the modeling? **TRC Recommendation:** Salinity differences should be accounted for in the modeling for the 60% design. At a minimum, a discussion should be included if it is anticipated that salinity variation will not be a factor, based on sensitivity calculations.	Language will be added to the 60% design explaining how temperature and salinity differences will have a negligible impact on the proposed remediation system. The flow of water will be more controlled by the natural heterogeneity of the aquifer, not the potential deviations in temperature and salinity.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		See Appendix B, Section 11.
298	Hualapai-14 and TRC-9			Addressing Uncertainties in Number of Installed Wells Discussion on page 18 of the Appendix B: "Development of a Groundwater Flow and Solute Transport Model" indicates that one of the driving forces behind the potential increase in the number of wells installed within the NTH (National Trails Highway) IRZ is based upon reducing the production of by-product: *"the spacing of the NTH IRZ wells is decreased, the carbon injection concentrations can potentially be lowered as well to reduce generated byproducts"* This statement indirectly addresses uncertainty in the system and raises concerns that additional wells will be placed prior to a thorough evaluation that additional wells will be effective. **TRC Recommendation:** A discussion of the rationale and decision points to be used to install additional NTH IRZ wells should be included in the 60% report. This discussion should include how the IRZ installation and/or monitoring data will be used in this decision process.	Text will be expanded in the 60% design to further explain the sensitivity analyses conducted to optimize the well locations, rates, and carbon concentrations. A balanced system that will optimize the Cr(VI) reduction while minimizing the potential for byproducts, and minimizing the remedial system footprint is the goal of the transport modeling.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		See Appendix B, Sections 6.4 and 10.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
299	Hualapai-15			Addressing Uncertainties in Number of Installed Wells For example, monitor well 3-D within the ISPT floodplain study indicated that chromium reduction was not efficient until carbon levels above 100 mg/L where achieved. This raises doubt about the effectiveness of lower carbon concentrations in sufficiently reducing Cr(VI). In addition, multiple examples from the ISPT data indicate that sustained chromium concentrations can persist in the presence of lower TOC concentrations. A thorough analysis of the correlations of TOC levels, achieved ORP values and Cr(VI) concentrations measured during the ISPT studies would provide insight into the range of carbon injection concentrations that are capable of reducing Cr(VI) and preventing undesirable concentrations of byproducts from forming. Prior to implementation of additional remedial wells, modeling efforts could be used to understand how additional extraction wells would impact byproducts produced in the NTH IRZ. Results from such an analysis could be used to determine appropriate byproduct action thresholds which would be used justify additional remedial wells.	This topic was discussed at the January 6 and January 19, 2012 TWG meetings. A discussion of the pilot test data will be included in a detailed response to comments in the 60% design document. Detailed discussion of the monitoring plan and how data is used will be in 60% documents.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		See Appendix B (Section 3.4) and Appendix L (O&M Manual).
300	Hualapai-16 and TRC-10			Evaluation of the Impact of River Bank Extraction on the Organic Rind In 30% Design Modeling Appendix B, sensitivity analysis of riverbank extraction wells showed that the clean-up time was not affected by riverbank extraction rates of zero. Are the riverbank extraction wells just a contingency in case Cr(VI) is detected in the Colorado River, or can the remediation proceed with zero riverbank extraction rates.*[Next four sentences appear only in the comment letter]* The potential for destruction of the organic rind would be much less if the riverbank extraction wells did not stress the groundwater system near the river. Operation of the riverbank extraction wells will certainly pull oxidized river water through the rind, which over time could reduce the ability of the rind to naturally reduce Cr(VI). In addition, Anaerobic core tests show that there is sufficient reducing capacity in the “rind” to remove a significant portion of Cr(VI) in the plume. Long-term impacts of flushing were not described **TRC Recommendation:** It may be appropriate to discuss this during a TWG meeting. A more detailed discussion of scenarios where the river bank extraction wells will (or will not) be utilized would be anticipated in the 60% design report.	The riverbank extraction wells are not a contingency in case Cr(VI) is detected in the Colorado River. Riverbank extraction wells will both facilitate the groundwater flow through the IRZ and capture Cr(VI) located in the floodplain downgradient of the NTH IRZ. The riverbank extraction wells are also designed to control NTH IRZ generated byproducts in the deeper portion of the aquifer. The riverbank wells are designed to be screened beneath the naturally occurring reducing rind to minimize potential negative hydraulic impacts on the reducing rind and reduce the potential for well fouling in the riverbank extraction wells caused by the presence of dissolved minerals in the naturally reduced groundwater in the rind. Hydraulic analyses indicate the riverbank extraction wells primarily pull water from the deep aquifer (Model Layers 3 and 4) below the river and reducing rind. Limited extracted water comes from the shallow aquifer (Model Layers 1 and 2) and the largest fraction of captured shallow groundwater comes from upgradient (west) of the riverbank extraction wells. As per comment to DTSC-96, capture zone figures and an expanded discussion for the	Comment and response noted.	Comment and response noted. Further evaluation will occur during the review of 60% design submittal.		See Appendix B, Section 6.5.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
					riverbank extraction wells will be provided in the 60% design. The naturally occurring reducing rind provides ideal conditions for Cr(VI) precipitation in the event there is breakthrough past the NTH IRZ in the shallow portion of the aquifer. Thus the riverbank extraction wells are designed with consideration given to minimizing potential impacts to the naturally occurring reducing rind.				
Appendix C – Design Criteria									
301	DOI-96	Appendix C.7		This section should identify criteria for selecting above ground versus underground piping.	The criteria will be added to this section in the 60% design submittal.		Okay pending review of 60% design submittals.	Comment resolved.	
302	DOI-97	Appendix C, Attachment A		This attachment shows general respiratory and fermentative reactions but it should also discuss 1) how substrate dose relates to lowering redox potential, causing fermentation processes that are critical to hexavalent chromium reduction, 2) how an optimal dose can achieve hexavalent chromium reduction while minimizing byproduct production (reduced manganese and arsenic), 3) arsenic reduction and increased mobility of arsenic, and 4) that the primary mechanism for hexavalent chromium reduction is abiotic reactions with ferrous iron and sulfide.	Appendix C (Attachment A) will be expanded to capture the following points: Within an IRZ, many reductive processes will be stimulated. The amount of organic carbon substrate applied to the injection points is determined by the amount needed to achieve lateral distribution. Concentrations of TOC will be highest at the injection point and decrease with distance, and the arsenic and manganese generated is a consequence of that distribution of organic carbon, as discussed in detail in Appendix G of the 2009 CMS/FS. It is agreed that abiotic pathways such as reduction by Fe(II) may be faster than direct biotic mechanisms for Cr(VI) reduction (e.g., Wielinga et al., Environmental Science and Technology, 2001). Fe reduction is expected to occur under active Cr(VI) reduction conditions, producing mixed Fe/Cr precipitates that sequester Cr(VI). Thus, we do expect that both Cr(VI) reduction mechanisms will be occurring simultaneously. To optimize the tradeoff between organic carbon distribution and byproduct generation, design parameters such as well spacing, recirculation flowrates, and injection concentrations can be varied. The first step of this process was taken with the reactive transport modeling that supported the IRZ design (Appendix B). This optimization process will continue during operation as monitoring data is collected, evaluated, and used to modify operations of the system. A monitoring plan detailing how this will be done will be included in the 60 percent design.	Okay pending review of 60% design submittal.	Okay pending review of 60% design submittal.	Comment resolved.	

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
303	DTSC-110	Appendix C, Page C-2, 3rd Bullet	Non-mechanical excavating methods within TCS are mandatory and requirements will be described in more detail in the intermediate design submittal.	PG&E has asserted that this is a company policy for years and DTSC has been requesting this policy to be documented for nearly as long. DTSC does not understand why the inclusion of this policy should be deferred to the 60% design.	Comment noted.	DTSC awaits submittal of the PG&E policy.		Comment resolved.	
304	DTSC-111	Appendix C, Page C-3, C.1.4 Concrete Vaults	Vaults will be precast concrete sections conforming to PG&E Standard K-35.	What is this standard? PG&E should provide all design standards, in whole, if they are applicable to the remedy.	The draft technical specifications (part of the 60% design submittal) will list applicable standards (e.g., ASTM, ANSI, PG&E), applicable codes (e.g., Uniform Building Code, Uniform Fire Code) and other requirements. There are more than 120 specification sections and each section references one or more standards. PG&E Standard K-35 is a standard for concrete vault cover.	Okay pending review of information to be submitted in the 60% design submittal.		Comment resolved.	
305	DTSC-112	Appendix C, Page C-7, C.4.1 Piping	piping materials will be compatible with the characteristic of the conveying fluids and will be single walled unless the pipe is used to convey: (1) groundwater or remedy-produced water that is California Hazardous waste; or (2) concentrated carbon substrate. In these cases, double-walled piping will be used.	As stated earlier, because of the cultural concerns associated with the project area and the incomplete soil investigation, DTSC would prefer that double wall pipes be used for any untreated water conveyance.	Based on modeling, groundwater with Cr>5 ppm could be extracted from the IRZ extraction well, IRZ-23. Additional information about the subsurface conditions will be obtained as we start to install remediation wells. With regards to the suggested use of double walled piping for management of extracted water (that are below hazardous waste characteristic level) to protect against leaks due to concerns over the possibility of contamination leaching from the soils (which have not been investigated) to the groundwater, it should be noted that soil data do exist for the AOCs that overlap with the remedy infrastructure as shown in Figure 2-15. Supplemental soil sampling is being planned to complete the soil investigation and current schedule shows completion of the investigation prior to the start of groundwater remedy construction. Further, baseline soil samples will be collected to document baseline site conditions at the time of remedy construction. In addition, the overlapped AOCs are located within the plume footprint for which an active remediation will be implemented for decades. Additional evaluation of the potential for leaks and methods of leak detection and control will be performed and included in the 60% design.	DTSC will review evaluation of 60% design submittal.		Comment resolved.	

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
306	DTSC-113	Appendix C, Page C-9, C.4.5 Secondary Containment	Where required, secondary containment systems will be sized and designed in conformance with applicable codes and standards.	When will this be defined? Since the locations of major infrastructures have already been proposed in the 30% design, PG&E should be able, at this point, to decide what components will need and where these secondary containment systems will be required.	Example elements defined with secondary containment in the 30% design submittal are: - The solid/liquid separator area (see dwgs A-7 and M-7) - The remedy produced water conditioning building containment is discussed in Appendix C, Section C.4.5 - The influent water storage tanks (see dwgs C-17 and C-18) - The truck loading/unloading area at the MW-20 bench (see dwg C-9) - The truck loading/unloading area at the Transwestern Bench (see dwg C-10) f) Carbon amendment process buildings (see dwgs C-9 and C-10) h) Carbon substrate tanks (See Section 3.2, p-3-4) Additional details will be provided in the 60% design.	Okay pending review of 60% design submittal.		Comment resolved.	See Section C.5.5 of Appendix C (Design Criteria) and Appendix D (Engineering Drawings)
307	DTSC-114	Appendix C.11 Construction Requirements		DTSC recognize that more detailed sequence will be in the 60% design, however, it would be helpful to have a general idea of the construction sequence.	An updated project schedule with more detailed sequence will be provided in the 60% design submittal.	Okay pending review of 60% design submittal.			

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
308	Hualapai-36 and TRC-18			Considerations for Implementation and Construction Presently, the project site is impacted by noise from the compressor station, river traffic noise, the interstate highway (I-40) and the BNSF railway (and possibly other less significant sources). At many, but perhaps not all locations, the additional noise from groundwater contamination remedy implementation will not be problematic. However, there may be locations of cultural significance and use where this is not the case. The existing noise standards quoted in the 30% BOD Appendix C (Design Criteria), indicate, for CA facilities, that based on San Bernardino County criteria, a noise level of 70 dB is permissible. We take issue with this, as the 70 dB A-weighted equivalent energy level of 70 dB as stated in the San Bernardino County Development Code of 2007 (Section 83.01) is for an affected land use that is industrial. **TRC Recommendation:** This design criterion may be appropriate for areas such as the existing compressor station itself. However for other land uses, this criterion needs to be re-examined and likely revised downward.	PG&E appreciates the Tribe's comment and notes the TRC's recommendation. PG&E has not completed the detailed project design at this stage. In the 30% design, major process equipments were located within buildings which will attenuate process equipment sound emissions. Pumping equipments were also located in belowground concrete vaults which will attenuate the sound emissions. PG&E will continue to evaluate potential means and methods to further lower noise emissions by the remedy as the design progresses and throughout the equipment procurement process. Additional information will be provided in the 60% design, As stated in the Tribe's comment, the noise environment at the project site is currently dominated by a number of noise sources, and "at many, but perhaps not all locations, the additional noise from groundwater contamination remedy implementation will not be problematic." For other areas, PG&E does not anticipate off-site sound levels from long term remedy operation to result in a substantial permanent increase in ambient noise levels above existing noise levels (see Section 4.91.5 of the Final EIR). In fact, in some areas, a source of noise will be eliminated when the IM facilities are decommissioned and the land is restored, as part of implementing this remedy. PG&E will implement the EIR mitigation measures on noise (NOISE-1, NOISE-2, and NOISE-3) and incorporate them in the project design, construction, and operational phases. These measures include best management practices for reducing noise levels during construction and a method to inform/ communicate to alert Tribes and nearby receptors of project activities that could generate noise, and to manage/ resolve any complaints. The EIR notes that implementation of NOISE-3 would achieve the normally acceptable exterior noise standards for places of worship. The San Bernardino County Development Code 83.01.08 establishes the exterior noise standards for land uses as a place of worship at 55 dB Leq daytime and 45 dB Leq nighttime (Leq is the equivalent average hourly noise level). The noise criteria in the EIR were appropriate.	Comment and response noted.	Comment and response noted.		

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
Appendix D – Plans (Engineering Drawings)									
309	DOI-98	Appendix D, Drawing G-6		There is an influent flow from the Bat Cave Wash Remedy. This is not discussed anywhere in the design package. Influent wastewater flow from the TCS and East Ravine systems is not shown. Why are solids transferred to the liquid/solid phase separators by vacuum truck? Would this process not be continuous enough to warrant dedicated piping?	The remedy produced water main that runs through Bat Cave Wash is shown on drawing G-6 (Appendix D), at the upper left hand corner. There is a parallel main that runs along National Trails Highway. A cross reference to site plans will be added in the drawings. There is no produced water pipe from the East Ravine extraction wells since those will not be backwashed automatically. The TCS injection wells (COMP-INJ-1/-2) are shown on the drawing connected to the produced water pipe. The solids loadings are anticipated to be low; therefore vacuum truck was designed for transferring solids. If actual operating conditions differ, automation could be considered.	Okay pending review of 60% design submittals.	Okay pending review of 60% design submittals.	Comment resolved.	
310	DOI-99	Appendix D, Drawing G-6A		Although small in volume (0.1 MG/yr), extraction well rehab water should be shown in the table for completeness.	This will be added to drawing G-6A in the 60% design submittal.		Okay pending review of 60% design submittals.	Comment resolved.	
311	DOI-100	Appendix D, Drawing G-9		It appears CIP water can be directly used in carbon amended injection wells. Under what conditions?	CIP water will be treated like first flush rehabilitation water. Because the characteristics of the wastewater will not be known until it is pumped back out of the well, some of this water will likely be hauled by a truck to the central treatment system initially (versus transporting through pipelines). Possible reuse scenarios will be examined after water quality is determined.		Okay pending review of 60% design submittals.	Comment resolved.	
312	DOI-101	Appendix D, Drawing -10		It appears Line 202 (third from the top of the drawing) should be North NTH IRZ Injection Leg 1 – 23.	The comment on Line 202 is duly noted. The label should read “North Nth IRZ Injection Leg 1-23”. However, it must be noted that IRZ-1, IRZ-5 and IRZ-9 and IRZ -23 are designated as extraction wells (See Figure 3-1 and Section 3.2.1) and will not be used to inject carbon-amended water into the aquifer.		Okay pending review of 60% design submittals.	Comment resolved.	
313	DOI-102	Appendix D, Drawing C-4		Injection wells should be shown on the drawing (the symbol is in the legend).	The change will be made in the 60% design.		Okay pending review of 60% design submittals.	Comment resolved.	
314	DOI-103	Appendix D, Drawings C-25 and 26		The pipeline profiles are missing on the drawings.	The profiles will be shown in the 60% design submittal.		Okay pending review of 60% design submittals.	Comment resolved.	
315	DOI-104	Appendix D, Drawings I-5, I-10-, I-13, and I-15		DOI reviewed the fresh water system P&ID (Drawing I-5), which showed freshwater output going to facilities on Drawings I-10, I-13, and I-15. Drawings I-10 and I-14 identified no inflow from Drawing I-5, but I-13 did. One of these lines should go to the freshwater injection P&ID, which does not exists.	These drawings will be clarified in the 60% design submittal.		Okay pending review of 60% design submittals.	Comment resolved.	

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
316	DOI-105	Appendix D, Drawing M-11A		Where is the influent line? Also, please explain the notation “future borehole dia after re-drill”. Is the drawing depicting potential future well diameters as wells are periodically replaced in the same location?	The influent line is shown in the center of the diagram (the backwash and injection share a common line that join together outside the well casing). For clarity, a call out will be added in the 60% design submittal. The wells will be drilled in two passes because of the size and depth of the boring – 1) a pilot hole to record the lithology and perform geophysics; 2) reaming the boring to place the casing and filter/gravel pack.		Okay pending review of 60% design submittals.	Comment resolved.	
317	DOI-106	Appendix D, Drawing M-13A		According to Table 3-1, all single screened wells are for layer 1, and dual screened wells are for layers 1 and 3. Why is packer shown above layer 1 for the single screen well but not the dual screen well?	For the single screen injection wells, the packer is used to help support and centralize the down-well piping and appurtenances. In the dual screen wells, the primary purpose of the packer is to isolate the two target zones of the aquifer (while providing the support and centralization as a secondary purpose). Standardization of the packer equipment simplifies the spare parts inventory.		Okay.	Comment resolved.	
318	DOI-107	Appendix D, Drawing M-13D		Has this sheet been put in as a place holder to be completed in the 60% design? Please explain.	That is correct. Details will be added in the 60% design package.		Okay pending review of 60% design submittals.	Comment resolved.	
Appendix F – Remedy-produced Water Management Technical Memorandum and Response to Comments									
319	DTSC-115	Appendix F, Remedy Produced Water Management		Can PG&E define the rehabilitation event – In a common rehabilitation event – you have acid washing then swabbing and jetting. Do you anticipate equipment replacement? What is the respective down time of that well?	Over time, wells will exhibit a progressive loss in specific injectivity and specific capacity. If routine backwashing does not correct the decline or loss, more extensive or aggressive rehabilitation will be required. A common rehabilitation event consists of first, using various tools and techniques to agitate the well to remove and loosen the plugging material, such as wire brushing, swabbing, surging and the use of acids/chemicals and second, removing the plugging material from the well by airlifting or pumping. In addition, testing can also be conducted before and after a rehabilitation event to identify the zones that are most plugged (before the event) and to understand the effectiveness of the rehabilitation (after the event). Testing techniques could include video surveys, spinner surveys, and aquifer tests. At the start of a rehabilitation event, the equipment (pump, connecting pipe) will be removed from the well and will be replaced if significant wear or corrosion is noted; otherwise, equipment will be replaced based on a replacement schedule developed in the O&M plan. A well could be out of service for 1 to 2 weeks during a rehabilitation event. Down time is usually dependent on the ease of access to the well, the ability to efficiently manage	Okay pending review of the 60% design and O&M Plan submittal.		Comment resolved.	See Appendix F of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
					produced water, the well depth and diameter, the amount of pre and post testing that is required, the severity of capacity loss or plugging, and the number of rehabilitation techniques utilized during the event.				
320	Hualapai-37	Appendix F		1. Evaluate how the remedy-produced water management system will perform in relation to how much time the remediation process will take; i.e. 30 years – 60 years. Appendix F provides a list of options for disposing of the remedy-produced water, and no definitive water management alternatives were presented. Given the uncertainties, it is difficult to describe the anticipated performance of the remedy-produced water management system. Infrastructure such as pipelines, pumps, and valves would be expected to wear out, and these components would be replaced as part of routine maintenance. However, the expected life of the injection and IRZ wells cannot be predicted over the 30 to 60 years of the remediation project. It is possible that re-injection of unclean water (i.e. remedy-produced water that has not been fully treated or cleaned) might reduce the overall life of the wells, requiring the drilling of replacement wells, thereby prolonging the time period necessary to complete the groundwater remediation.	Appendix F presents a management plan that is flexible to support, and not constrain the remedy over the anticipated multiple decades of operation. Having more than one reuse and/or disposal option available is critical for this remedy over the long haul. The design basis for the remedy produced water conditioning system is 30 years. A Draft O&M manual will be included in the 60% submittal with information about routine maintenance activities, sampling, testing, equipment replacement schedule, etc. for the conditioning system as well as maintenance activities for wells (backwash, well rehab). Injection well performance will be monitored (e.g., specific injectivity) and evaluated, and well maintenance will be performed in a timely manner to prevent reduced well life	Comment and response noted.	Comment and response noted pending review of the 60% design, including the groundwater monitoring and contingency plans.		See Appendix F and the draft O&M Manual of this BOD Report.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
321	Hualapai-38	Appendix F		2. Are the stated estimates for required conditioned water (7.3 MG per year referenced on Table F1) viable for the remediation remedy? According to the document (page F-2) "a variable that will have a significant impact on the volumes produced is the frequency of backwash events…" Please review data for reliability. What are the consequences of increased backwashing to the existing water tables with a projected run-time of 30 to 60 years? The estimated annual volume of remedy produced water is shown to be 7.3 million gallons per year (Mgal/yr). This translates to about 22.4 acre-feet per year (af/yr). There is a significant amount of uncertainty in the number of IRZ wells and frequency of backwash and well-rehabilitation events; therefore, it seems that the design should consider a range of values. In any case, 22.4 af/yr is a significant amount of water, considering that the groundwater flow model (CH2M HILL, 2005) indicates that 10 af/yr of groundwater flows into the west side of the model domain, the subsurface outflow from the Mohave Basin is 5 af/yr, and Mohave Basin discharge to the Colorado River is 603 af/yr. If the remedy-produced water were removed from the Mohave Basin water budget (for example, on page F-9 by trucking off-site or evaporation through TCS ponds), the loss of water to the aquifer would represent a substantial loss of the water budget. Accordingly, PG&E should ensure that every measure is exercised to minimize this water loss.	The groundwater levels at the Topock site are controlled by the Colorado river. The quantity of water being discussed as remedy produced water is insignificant in comparison to the water available from the Colorado River. The average annual flow of the river below David Dam is nearly 10 million af/yr. The river is in communication with the aquifer at Topock. If the aquifer were drawn down below the level of the river, recharge from the river would rapidly replenish the aquifer. Note that PG&E currently pumps over 200 af/yr from the IM-3 wells on the river bank just to maintain a minimum landward gradient. The aquifer reaches steady state within a matter of hours to days when IM-3 pumping is started or stopped. Even though the volume of water generated by well maintenance is insignificant in terms of the basin-wide water balance, it is PG&E's desire to minimize the volume of water trucked away or discharged to the evaporation ponds.	Comment and response noted. DTSC agrees that water is a valuable resource and should be preserved within the local water basin to the maximum extent possible.	Comment and response noted pending review of the 60% design, including the groundwater monitoring and contingency plans.		See Appendix F of this BOD Report and the draft O&M Manual, Volume 2, Sampling and Monitoring Plan and Volume 3, Contingency Plan.
322	Hualapai-39	Appendix F		3. Please evaluate backwash byproducts as they relate to remedy-produced water (conditioning) that is possibly reused by blending it with carbon-amended water and then injecting back into carbon-amended IRZ wells as described on page F-13. The document indicates that the backwash water will have elevated concentrations of Cr(VI) and byproducts (As, Fe, and Mn). It is further indicated that the well-rehabilitation water will have pH values potentially less than 2. It is proposed that this remedy water will be re-injected into IRZ wells after pH neutralization and filtration of solids. However, there does not appear to be a contingency plan addressing the potential for handling remedy-produced water that could contain high concentrations of contaminants. Approaches outlined in Appendix F assume that the remedy-produced water will be non-hazardous and can be re-cycled.	Please note that the text that this comment refers states that the wells, receiving the injected water, will have elevated levels of byproducts, carbon, and possibly chromium. Injection wells need similar water to the formation water to not cause adverse geochemical reaction. Therefore, pH adjustment of water generated during acid treatments is anticipated to be required. Removal of dissolved constituents (byproducts and low levels of chromium) will not be needed because after blending backwash water with the water from the riverbank wells, the injected water quality will be similar to the aquifer water quality in/near the injection wells. Injection well performance will be monitored (e.g., specific injectivity) and evaluated, and well maintenance will be performed in a timely manner to prevent reduced well life. Based on experience at Topock and Hinkley, PG&E anticipates that the routine backwash water will be non-hazardous. This will be verified and confirmed via monitoring at startup and during operations.	Comment and response noted.	Comment and response noted pending review of the 60% design, including the groundwater monitoring and contingency plans.		See Appendix F of this BOD Report and the draft O&M Manual, Volume 2, Sampling and Monitoring Plan and Volume 3, Contingency Plan.

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

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					Well rehab water can be thought of as having two distinct water quality characteristics – one at the beginning (first flush) and the other at the end of the rehabilitation process. The first flush water can be low in pH (acid is used to dissolve mineral deposits), and contain high concentrations of solid materials and rehabilitation chemicals. As the flushing continues, the water quality becomes more similar to backwash water. By careful management of the acidification process, it is possible to maintain pH >2 in the first flush water so that no hazardous waste is expected to be generated. Note that the preference for disposal of first flush rehab water are the TCS evaporation ponds or off-site disposal (trucking offsite to permitted disposal facility is an approach presented in Appendix F). However, monitoring of water quality will be conducted during rehabilitation events. Care will be taken to maximize recycling/reusing of produced water onsite and minimize the amount of water needed to be trucked offsite.				
				In addition, re-use by blending with carbon-amended water could consume carbon that is intended for remediation of the Cr(VI) due to the presence of byproducts such as ferrous iron and sulfide; therefore, target carbon concentrations might not be achieved in the remedial system.	Ferrous iron in the injected water will not consume the amount of organic carbon needed for the remediation of Cr(VI), in fact it is a product of the carbon injection. Carbon would be consumed by oxidized species, not by reduced species such as ferrous iron and sulfide. As discussed in response to comment #51 HA-7, the combination of iron reduction and organic carbon oxidation that produce the reducing conditions in the IRZ for remediation of Cr(VI) will occur thermodynamically as follows: $Fe(OH)_3(s) + 3H^+ + e^- \rightarrow Fe^{2+} + 3H_2O$ $1/12\ C_2H_6O + 1/4\ H_2O \rightarrow 1/6\ CO_2 + H^+ + e^-$ where C_2H_6O is ethanol, the form of organic carbon to be injected in the IRZ.				
				As with any engineering design, the remedy-produced water treatment system should be designed for the worst-case scenario.	It is not clear as to “the worst case scenario” mentioned in this comment. It is typical that groundwater remediation systems are designed to anticipated conditions and, through the use of contingency planning, provided with adequate flexibility for adjustment after startup and operations.				
				At the top of page F-15, “if strict water quality requirements are mandated for re-injection options, removal of dissolved constituents (such as arsenic, manganese, iron, calcium and	See 1st paragraph of this response.				

APPENDIX I
Response to Comments on Draft Basis of Design Report/Preliminary (30%) Design
Groundwater Remedy Revised Basis of Design Report/Intermediate (60%) Design
PG&E Topock Compressor Station, Needles, California

Item	Comment Number*	Section/Page	Reference Text	30% Design Comment	PG&E Response to 30% Design Comment	DTSC Response to 30% Design Comment	DOI Response to 30% Design Comment	Final Comment Resolution	Where Responses are Reflected in the 60% Design Documents**
				selenium) may be required." Note that Cr(VI) is not mentioned in this list of constituents. As described above, re-injection of unclean water (i.e. remedy-produced water that has not been fully treated or cleaned) might reduce the overall life of the wells, requiring the drilling of replacement wells.					
323	Hualapai-40	Appendix F		4. If Cr(VI) is not effectively removed from the aquifer, what is the contingency plan if the backwash contains high concentrations of Cr(VI)? If the backwash contains Cr(VI), Appendix F proposes to add carbon (ethanol) to the backwash water before re-injection, which will supposedly reduce Cr(VI) to Cr(III) after re-injection. However, with an automated backwash and re-injection system (as proposed), it is not clear whether there would be monitoring of Cr(VI) concentrations in backwash water. A contingency plan was not presented for treatment of backwash water containing Cr(VI) concentrations.	Backwash water quality will be monitored; the draft O&M Manual will propose a monitoring frequency. As indicated in response to comment #321 Hualapai-39, removal or treatment of dissolved constituents (including Cr(VI)) in the injected water will not be required because after blending with water from the river bank wells, the injected water quality will be similar to the aquifer water quality in/near the injection wells. Because the water is being injected along with carbon amendment in to an already reduced geochemical environment around the injection wells, any Cr(VI) in the injected water will be rapidly reduced within a short distance of the injection well. Injection well performance will be monitored (e.g., specific injectivity) and evaluated, and well maintenance will be performed in a timely manner to prevent reduced well life.	Comment and response noted. DTSC agrees that the pending contingency plan is an important document that will require careful evaluation.	Comment and response noted pending review of the 60% design, including the groundwater monitoring and contingency plans.		See Appendix F of this BOD Report and the draft O&M Manual, Volume 2, Sampling and Monitoring Plan and Volume 3, Contingency Plan.

Notes:

* Comment number is denoted by commenter name (or abbreviation, see below) followed by the order of the comments received.

** This column indicates where changes as a result of comment resolution, if applicable, are reflected in the design documents. The design documents include the 60% BOD Report, the Engineering Drawings/Plans (Appendix D of the BOD), and the draft O&M Manual (Appendix L of the BOD).

DOI = U.S. Department of the Interior
DTSC = California Department of Substances Control
Hualapai = Hualapai Department of Cultural Resources
HA = Hargis + Associates, Inc. (on behalf of Fort Mojave Indian Tribe)
MWD = Metropolitan Water District
TRC = Technical Review Committee.

Appendix J
Freshwater Supply Technical Memorandum and Responses to Comments

Pacific Gas and Electric Company

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April 27, 2012

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Subject: Submittal of Freshwater Source Evaluation Technical Memorandum

Dear Aaron and Pam:

In response to comments from the California Department of Substances Control on the Preliminary (30%) Design document, Pacific Gas and Electric (PG&E) has prepared the attached technical memorandum that discusses the three potential sources of fresh water, their advantages and limitations, and PG&E's preferred option. These potential sources were each presented in the project's Corrective Measures Study/Feasibility Study (CMS/FS), and they are consistent with the water supply options in the certified Environmental Impact Report (EIR). The criteria used to evaluate fresh water sources was included as part of the Preliminary (30%) Remedy Design.

The three potential fresh water sources outlined in the memo – and a brief discussion of the advantages and disadvantages of each – are as follows:

1. An existing well (HNWR-1) in Arizona

Advantages

- Proven water source
- Capacity of nearby wells not impacted
- Existing well means reduced installation impact

Disadvantages

- Naturally occurring arsenic in water supply wells in Topock, Arizona above MCL (10μg/L). Geochemical modeling indicates that arsenic will not migrate far from the injection points in California and will dissipate at the end of remediation. Monitoring will be conducted to verify

modeling results. Water treatment facilities to remove arsenic could be installed if arsenic does not behave as predicted

2. A new well or wells located in proximity to the site in California (near Moabi Regional Park)

Advantages

- Lower concentration of arsenic, compared to Arizona well(s)
- Nearby electric power and pipeline route facilitate delivery to project site

Disadvantages

- Smaller capacity of aquifer at Moabi Regional Park means use of multiple wells and increased installation impact
- Pumping large volumes from a well or wells near Park Moabi could impact capacity, water quality in nearby existing Moabi Regional Park wells
- Water treatment facilities would likely be required to remove iron and manganese prior to injection to protect wells
- Salinity of water from a high capacity well at Park Moabi may be above the range considered potable by the Regional Water Quality Control Board

3. The Colorado River

Advantages

- Sufficient capacity
- Low concentrations of arsenic and dissolved salts

Disadvantages

- Implementability issues due to special status fish species that occur in the Topock area, specifically the razorback sucker and the bonytail chub. Both are federally-listed and state-listed as endangered; the razorback sucker is also a California Fully Protected Species. Preliminary discussion with the California Department of Fish and Game (CDFG) indicated that approval of a fish screen and intake structure that would avoid incidental take of the razorback sucker may be difficult to obtain. This issue will need to be explored further, may not be feasible, and would likely add more time to the project
- Environmental and sustainability considerations related to implementation and operation of a river intake structure
- Potentially susceptible to future contamination as a result of upstream discharges or spills
- Water treatment facilities to remove suspended solids, potentially organic carbon, and disinfection to remove microbes required prior to injection to protect wells

The use of the existing well in Arizona is the preferred freshwater supply option for the remedial action, as it is a proven well that can provide adequate water quality and quantity, presents less disturbance of

the site, less uncertainty, and less risk to project schedule. The basis for this conclusion, along with a comprehensive review of each option, is presented in detail in this tech memo.

Sincerely,

Yvonne Meeks
Topock Project Manager

Enclosure
Freshwater Source Evaluation Technical Memorandum

cc:

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Freshwater Source Evaluation, PG&E Topock Compressor Station, Needles, California

PREPARED FOR: Pacific Gas and Electric Company

PREPARED BY: CH2M HILL

DATE: April 27, 2012

1.0 Introduction

A major component of the selected groundwater remedy at the Pacific Gas and Electric Company (PG&E) Topock Compressor Station (TCS, or the Compressor Station) is freshwater injection. The primary objectives of the freshwater injection are to assist with flushing the chromium plume through the *In Situ* Reactive Zone (IRZ) located along the National Trails Highway (NTH) and to constrain westward spread of carbon-amended water and in-situ byproducts from the Inner Recirculation Loop.

The potential sources of fresh water were originally presented in the Corrective Measures Study/Feasibility Study (CMS/FS) (CH2M HILL 2009a). The CMS/FS considered three potential sources of fresh water: a well or wells in Arizona (in proximity to the project site), a well or wells in California (in proximity to the project site), and water from the Colorado River. These potential sources are consistent with the water supply options in the certified Environmental Impact Report (EIR) (AECOM 2011). An initial evaluation of these options was presented in the Corrective Measure Implementation/ Remedial Design (CMI/RD) Work Plan (CH2M HILL 2011a). Further evaluation was conducted during the development of the design documents, and the results were presented in the Draft Basis of Design (BOD) Report/Preliminary (30%) Design (CH2M HILL 2011b).

In response to specific comments on the preliminary (30%) design (comments #142 DTSC-55 through #153 DTSC-66), this Technical Memorandum (TM) provides additional details and analysis and is organized as follows:

- **Section 2.0** describes the quantity of water required for remedy performance derived from the modeling and the desired water quality for freshwater injection.
- **Section 3.0** compares the three freshwater sources to the evaluation criteria identified below.
- **Section 4.0** summarizes the rationale for selection of the preferred alternative.
- **Section 5.0** includes a list of references cited in this TM.
- **Attachment A** contains three reports from Moabi Regional Park's consultant LeRoy Crandall and Associates.
- **Attachment B** contains a TM on the preliminary engineering survey/evaluation of river intake and fish screen.
- Subsequent to the 30% design, changes were made to the groundwater transport model to improve the accuracy of manganese and arsenic simulations. The revised model was then used to evaluate the different freshwater alternatives with regard to chromium removal and manganese/arsenic migration. **Attachment C** provides a brief summary of the changes to the model and the results of model simulations conducted to support the evaluation of freshwater sources.

The following criteria are used to evaluate the freshwater supply options in this TM:

1. Influence of freshwater pumping on remedy performance
2. Quantity of water available
3. Water quality and potential need for conditioning of water prior to injection
4. Implementability and sustainability considerations

The first three criteria were identified in the preliminary (30%) design. A fourth criterion, "Disturbance associated with construction," was also identified in the 30% design. The California Department of Toxic Substances Control (DTSC) also requested that a contingency criterion be added to the evaluation. Both the disturbance and the contingency criteria have been incorporated, along with additional considerations, into criterion no. 4 (Implementability and sustainability considerations).

2.0 Water Quantity and Quality

This section describes the quantity of fresh water required for remedy performance and the desired water quality for freshwater injection.

2.1 Water Quantity

The groundwater remedy is designed to move the chromium plume across the NTH IRZ line in an easterly direction by injecting water to the west and pumping from wells near the river bank. The freshwater injection system is designed to provide a hydraulic barrier to prevent movement of chromium or *in situ* byproducts beyond the plume footprint to the north and west and provide the hydraulic gradient needed to push the plume across the IRZ. The current design and modeled flow rate for freshwater extraction is 600 gallons per minute (gpm). However, the potential maximum flow rate for freshwater injection is 1,200 gpm, which includes the maximum aggregate flow rate for the entire Outer Loop injection well network (including FW-INJ-4) of 600 gpm and the maximum aggregate freshwater flow rate for the Inner Loop injection well network (e.g., UPGRAD-INJ-2, UPGRAD-INJ-3, and UPGRAD-INJ-4 are receiving fresh water at the maximum flow rate) of 600 gpm.

It is necessary to obtain a sufficient supply of water that will be reliable over the long term. There should be excess capacity in the freshwater source to offset future declines in well efficiency and allow for adjustment of freshwater injection rates to optimize the performance of the remedy. During remedy implementation, several of the freshwater injection wells will be installed in areas where no previous wells have been drilled and hydrogeologic conditions are unknown. If the aquifer is more transmissive than anticipated in these areas, additional fresh water would be needed to create the gradient necessary for remedy operation. On the other hand, if the aquifer is less transmissive than anticipated, less water would be needed.

2.2 Water Quality

This section discusses desired water quality for the freshwater injection system. There are several water quality parameters that need to be considered for the freshwater source in order to prevent plugging of the injection wells and the aquifer as well as degradation of the water quality in the aquifer.

2.2.1 Prevention of Well and Aquifer Plugging

Well and aquifer plugging could be caused by geochemical reactions between the injected water and the native water or aquifer materials or by the presence of suspended solids in the injected water. Well plugging could also be caused by microbial growth in the injection wells. Prevention of aquifer plugging is essential to remedy performance. Prevention of well plugging is critical to good well health and long well life. Examples of potential clogging characteristics that may be present in sources of injected water near the Topock site include the following:

- Dissolved iron and/or manganese content that could result in precipitation of iron/manganese oxides on the well screen
- Very low total dissolved solids (TDS) that could dissolve minerals such as gypsum and calcite adjacent to the well screen and reprecipitate these minerals in a narrow zone downgradient from the injection well, reducing porosity to a degree that could result in production loss
- High total suspended solids (TSS) in the injection water that could eventually plug the screen openings
- Water with dissolved organic carbon content that could produce biofouling of the well

Dissolved Iron and Manganese

Iron and manganese are soluble in reduced geochemical conditions, such as are found in the reducing rind around the river and across much of the shallower portions of the floodplain. When reduced water containing dissolved iron and manganese is exposed to oxygen, the iron and manganese precipitate, in the case of iron very rapidly. This can cause very rapid fouling of injection wells. If the source of fresh water contains dissolved iron and manganese, pretreatment would be required to remove the precipitates prior to injection. Based on experience of well maintenance at Interim Measure No. 3 (IM3), the ideal concentrations of dissolved iron and dissolved manganese in injected water are 20 micrograms per liter (μg/L) and <10 μg/L, respectively.

Total Dissolved Solids

Water with very low concentrations of TDS tends to dissolve some of the minerals that are present in an aquifer matrix. Minerals such as gypsum and anhydrite can be dissolved from the area around the well and then re-precipitate as the low-TDS water moves outward from the well and begins to equilibrate with the native water in the aquifer. This re-precipitation can cause plugging of the aquifer. This was a concern when IM3 was designed and is one of the reasons that IM-3 was designed to produce water that matches the average TDS of the middle and lower zones of the aquifer where the IM-3 injection wells are screened.

The freshwater sources from the HNWR-1 well and from the river have average TDS of about 500 milligrams per liter (mg/L) and 680 mg/L, respectively. There was some concern initially that the low TDS of these freshwater sources may have the potential to cause diminished injection productivity due to the mechanism described above. A geochemical model simulation was performed using the U.S. Geological Survey's (USGS's) PHAST code (Parkhurst et al. 2010), in which injection of water chemistry from HNWR-1 (the lower TDS of the two waters) into the alluvial aquifer was simulated in a simplified model. The purpose was to calculate the mass of salts that would be re-precipitated at various distances from the injection well, and assess whether the volume of this mass would block a significant portion of the aquifer porosity. The simulation showed that less than one percent of the available porosity was blocked by re-precipitation. This was considered to be insignificant from a water production standpoint. These results were expected, since the native groundwater in the freshwater injection area is undersaturated with respect to gypsum and anhydrite, the calcium sulfate minerals that are most often associated with this mechanism of production loss through re-precipitation. The undersaturation indicates that gypsum is either absent or in negligible quantity in the aquifer matrix. Based on these simulation results, it is anticipated that surface or groundwater sources in the southern Mojave Basin will not be an issue for plugging due to low TDS.

Total Suspended Solids

Suspended solids are particulate matter that is small enough to remain suspended in water. These particulates can be large enough to plug the pore spaces in the aquifer near the well, resulting in well plugging. Most properly designed and developed water wells produce water that is very low in suspended solids (TSS <1-2 mg/L) and therefore suitable for injection. Wells that have poorly designed screens and gravel packs or screens that have corroded and become compromised can produce suspended solids. Surface water sources, including river water, typically have higher TSS which in most cases needs to be removed through filtration prior to injection.

Dissolved Organic Carbon Content

With the exception of iron bacteria that use dissolved iron as an energy source, the microbes associated with well fouling require some kind of organic carbon as an energy source. Under aerobic conditions organic carbon in the injected water can support growth of microbes in and near the well and result in rapid plugging of an injection well. Dissolved organic carbon is typically very low in natural groundwater. Dissolved organic carbon has been non-detect (<1 mg/L) in the HNWR-1 well and averages about 1.3 mg/L in the existing wells (PM-03 and PM-04) at Moabi Regional Park. If wells were used as a freshwater source, there would likely not be enough organic carbon in the injected water to cause biofouling in the injection wells. Based on data provided by Metropolitan Water District of Southern California (MWD), the average dissolved organic carbon content in the Colorado River near Topock is 9 mg/L. While this is considered low for a surface water source, it is considerably higher than the groundwater sources being considered and might be enough carbon to contribute to injection well fouling. The

fouling potential of the river water would depend on the bio-availability of the dissolved carbon present. If the carbon is relatively resistant to microbial uptake, the microbes would not be able to readily utilize it and there would be less potential for well fouling. If the carbon was in a form that the microbes could readily use, microbial growth could occur within or near the well and fouling would be more of a concern. If the river were selected as the freshwater source, laboratory tests would need to be conducted to determine the nature of the dissolved carbon present and whether or not it would be likely to cause problems with well fouling.

2.2.2 Protection of Aquifer Water Quality

In order to attain the remedial action objectives (RAOs) for hexavalent chromium (Cr[VI]) at the Topock site, substantial movement of groundwater in the target remediation area – either through natural or induced measures – will be necessary, and under active treatment for Cr(VI), it is expected that significant mixing of groundwater in the target remediation area would occur both vertically and horizontally. As a result, temporary fluctuations in water quality (up to or exceeding the upper tolerance limit [UTL]) will occur during remedy implementation prior to achieving RAOs, i.e., water quality and concentrations measured at individual monitoring wells are expected to change during the course of the remediation from concentrations present today.

The RAO for Cr(VI) at the conclusion of remedy implementation has been established as 32 µg/L based on the regional background concentration. There is no state or federal Maximum Contaminant Level (MCL) for Cr(VI). Concentrations of Cr(VI) and arsenic as an *in situ* byproduct may fluctuate above baseline levels within the treatment area during remedy implementation. In addition, as part of the preliminary (30%) design, fresh water from the Refuge well (HNWR-1) in Arizona is designed to be injected west of the plume, within the project's Area of Potential Effects (APE). The naturally occurring arsenic concentration in water from this well exceeds the MCL for arsenic of 10 µg/L. During the Topock Background Study, arsenic concentrations above the MCL were found in water supply wells in the vicinity of the Topock Marina, Arizona. Modeling indicates that arsenic concentrations that may temporarily be elevated by a) the injection of this water from Arizona and b) the generation from *in situ* remediation will attenuate under site conditions and return to pre-remedy baseline levels after the end of remediation (see Figures 3-9 through 3-12). Modeling also indicates that manganese generated from *in situ* remediation may be temporarily elevated at concentrations that fall within the range of naturally-occurring concentrations historically measured within the shallow fluvial aquifer. Monitoring will be performed during remedy implementation to verify the above modeling results, and appropriate adjustments will be made to remedy operations as needed.

Given the goal to restore the water quality to ambient conditions for Cr(VI) and any chemicals that could potentially be generated or introduced by the remediation, the following are examples of characteristics of injected water that could be a concern from a water quality perspective:

- TDS above 3,000 mg/L
- Constituents introduced at concentrations above site background or above water quality standards that do not attenuate after the end of remediation
- Emerging contaminants not yet identified

Total Dissolved Solids

The basin plan prepared by the Colorado River Basin RWQCB considers groundwater with less than 3,000 mg/L of TDS to be potable (RWQCB 2006). The TDS in groundwater in the upper portions of the aquifer at the Topock site is generally below 3,000 mg/L while the groundwater in the lower portion of the aquifer has TDS of 10,000 mg/L or greater. In order to flush the chromium plume efficiently through the IRZ, the freshwater injection wells are planned to be screened across the entire aquifer thickness. The TDS in the shallow zone of the aquifer near the planned injection wells ranges from about 900 mg/L to about 2,800 mg/L. Over the decades of remedy operations, most of the aquifer within the plume footprint will be flushed with fresh water from the injection wells. If the injected water has a TDS above 3,000 mg/L, portions of the aquifer that are currently below 3,000 mg/L and therefore considered potable would likely be above 3,000 mg/L for many decades . To preserve

the potable status of the upper zone water, it would therefore be desirable to have a freshwater source with a TDS less than 3,000 mg/L.

Note that for the IM-3 injected water, the TDS target was set at 4,200 mg/L. The IM-3 wells are selectively screened in the lower portion of the aquifer and this TDS target is consistent with that deeper zone. The IM-3 injection wells were not intended to flush the chromium plume, so there was no need to screen the shallow portion of the aquifer. Injecting water with TDS of 4,200 mg/L into the lower zone does not degrade the existing water quality and was therefore allowed for the IM-3 system.

Constituents Introduced Above Site Background or Above Water Quality Standards that Do Not Attenuate After the End of Remediation

Water quality at the Topock site could be compromised if the injected water contains persistent and mobile constituents at concentrations that are greater than site background or above applicable water quality standards. This could be particularly problematic for those constituents that do not attenuate after the end of remediation. The degree to which the water quality is compromised would depend on the toxicity, concentration, mobility, and persistence of the constituent in question.

As discussed above, modeling indicates that arsenic concentrations that may temporarily be elevated by injection of HNWR-1 well water (with naturally occurring arsenic level of 15µg/L, which is below site background of 24.3µg/L but above the MCL of 10µg/L) will attenuate under site conditions and return to pre-remedy baseline levels after the end of remediation (see Figures 3-9 through 3-12). Monitoring will be performed during remedy implementation to verify the above modeling results, and appropriate adjustments will be made to remedy operations as needed.

It should be noted that naturally occurring chromium (VI) in the fresh water used for injection will be at concentrations at or below the site background of 32µg/L. Any residual CrVI) introduced with the fresh water is expected to be persistent in the aerobic portions of the aquifer, but would continue to be attenuated in the natural reducing conditions in fluvial sediments adjacent to and beneath the river after the remedial action is complete.

Emerging Contaminants

Perchlorate and 1,4-dioxane are two of the more common emerging contaminants that have been identified in groundwater and surface water at other sites in recent years. Others on the list include endrocrine disrupting compounds and various types of pharmaceuticals. There have been several large-scale groundwater remediation projects where treated groundwater was injected back into the aquifer and then later found to contain an emerging contaminant that was not previously identified as harmful. Examples of this include the Tucson Airport Area Superfund site, where it was discovered in 2002 that 1,4-dioxane had been passing undetected through the air strippers since 1987and was injected into a previously uncontaminated portion of the aquifer. A similar problem occurred at the Aerojet site in Rancho Cordova, CA, where perchlorate passed undetected through air strippers and was injected into a clean portion of an aquifer. By the time perchlorate was recognized as a contaminant, it had already reached one of the municipal wells that the remediation system was intended to protect. Because the water in the Colorado River is used and reused several times in municipal and agricultural water supplies before it reaches Topock, it contains compounds that may become emerging contaminants in the future. Based on data provided by MWD, compounds considered to be pharmaceutical or personal care products that have been detected in the river below Davis Dam include caffeine, carbamazepine, N,N-Diethyl-meta-toluamide (DEET), ibuprofen, 4-n-Nonylphenol, Primidone, Sulfamethoxazole, Mitotane (o,p-DDD), Methylparaben, tris(2-carboxyethyl)phosphine (TCEP), acetaminophen, and Azithromycin. As the Colorado River basin becomes more populated, many of these compounds, along with others, are expected to become more prevalent. As analytical techniques improve, additional compounds may be detected that are present but below current detection limits. Because the river provides the primary source of water for the Mojave Valley, many of the compounds present in the river water will eventually be present in groundwater, but it may take many years for them to move from the river to a nearby well. Some of these emerging contaminant compounds are not mobile in the subsurface and may never move far from the river. If fresh water were obtained from a well rather

than from the river, this travel time from the river to a well would provide a buffer that might allow for mitigation measures to be implemented prior to injecting an emerging contaminant and having it spread across the site.

3.0 Evaluation of Freshwater Sources

This section presents a description of the evaluation criteria identified in Section 1.0. These criteria are used to assess the three freshwater sources. The various analysis factors and considerations associated with each criterion are shown in Exhibit 3-1. Each of these criteria is discussed below.

EXHIBIT 3-1
Alternative Evaluation Criteria
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

Evaluation Criteria	Analysis Factors and Considerations
1. Influence of Freshwater Pumping on Remedy Performance	• Quantitative description of hydraulic effect on plume due to pumping
2. Quantity of Water Available	• Quantity of water available • Quantity of backup and contingency water supplies • Current demand of existing wells and how the current and future water demands of those wells will be met
3. Water Quality/Potential Need for Conditioning Prior to Injection	• Comparison of source water quality to target water quality • The need for conditioning of water prior to reinjection
4. Implementability Considerations (including Disturbance from Construction and Contingency)	• Significance and type of disturbance - Volume of soil disturbed, aesthetics, construction duration, new facilities - Number and size of components such as wells, pipes, access roads, treatment and support facilities - Infrastructure footprint - Ability to make use of existing facilities • Administrative requirements - Substantive permitting requirements/Approvals, access easements, compliance with ARARs and EIR mitigation measures • Maintenance requirements of facilities • Ease of replacement or redundancy, or implementation of potential contingencies • Flexibility of design - Ability to handle changes in flow and quality

3.1 Evaluation Criterion #1 -- Influence of Freshwater Pumping on Remedy Performance

Solute transport model simulations were conducted to evaluate the effects on remedy performance for pumping 600 gpm from the three freshwater sources (HNWR-1 well, hypothetical well at Moabi Regional Park, and the Colorado River). Figure 3-1 shows the general locations of the three sources. Note that the location of the river intake structure/fish screen is not relevant to the hydraulic evaluation because pumping 600 gpm of water from the river has no effect on river or groundwater levels. The results of the transport model simulations that show the effects of the different fresh water supply options on the remedy are provided in Figures 3-2 and 3-3. These figures show the Cr(VI) concentrations remaining after 30 years of remedial operations in model layers 1 and 3. (The alluvial aquifer is broken into 4 layers in the model with Layer 1 being the uppermost and Layer 4 being the deepest). As shown, there is very little observable difference between the three freshwater sources. Therefore, the choice of freshwater source between HNWR-1, Park Moabi, or the river will have negligible effects on the effectiveness of the remedy. Note that there was no attempt to optimize the remedy in these simulations. The

flow rates in the model were held constant throughout the entire 30 year active remedy period. During the application of the remedy, it is anticipated that ongoing remedial process optimization will be applied to accelerate cleanup in recalcitrant areas of the plume, shortening the overall cleanup time.

As requested by DTSC, particle tracking simulations were conducted using the flow model to evaluate the effects of the three freshwater sources on the flow field in the vicinity of the remediation area. The results of these simulations are provided in Figures 3-4 and 3-5. These figures show the flowlines emanating from the freshwater injection wells after 30 years, in model layers 1 and 3. The flowlines for the HNWR-1 option and the river intake option are very similar, indicating that HNWR-1 pumping has only a minor effect on gradients. Pumping from Moabi Regional Park, however, has a noticeable effect on the direction of groundwater flow in the western portion of the site, where flowlines are drawn toward the hypothetical pumping well. While this has negligible effects on the rate of Cr(VI) removal, it could be important if there were some objectionable characteristic in the injected water because it is likely that some of the injected water would be drawn back close to or possibly within Park Moabi by the end of the active remedial action.

3.1.1 Conclusion

Based on the solute transport model simulations, there are negligible differences between the three freshwater sources from a hydraulic perspective.

3.2 Evaluation Criterion #2 - Quantity of Water Available

As stated in Section 2.0, based on modeling, the minimum quantity of fresh water required for the remedy is 600 gpm. However, the maximum case could be as much as 1,200 gpm. For this evaluation criterion, the Colorado River is the obvious best option amongst the three sources due to its plentiful supply (for all options, PG&E has water rights in excess of the amount of water required, as set forth in Chapter 4.12 of the certified EIR). However, the following discussion provides due consideration to the Arizona and California groundwater sources and addresses comments received on the preliminary (30%) design on this topic.

3.2.1 Well or Wells in Arizona

Table 3-1 (all tables are presented at the end of this TM) lists identified wells near Topock Marina, Arizona along with their construction data (if known). Each of the identified wells is discussed below. Note that in response to comment #134 DTSC-52, PG&E performed a well search in the Arizona Department of Water Resources (ADWR) Imaged Records Database but was unable to identify any additional wells in the area beyond those which were already known. Using the Earth Point Townships layer in Google Earth, the cadastral location of the Topock Marina area was determined. This included only Quadrant B, Township 15 North, Range 21 West, Section 3, as all other surrounding property on the Arizona side were determined to belong to the Havasu National Wildlife Refuge. This cadastral location was used to conduct the well search in the ADWR database records. The ADWR database is current as of December 13, 2011, as stated on the ADWR website. Available information regarding wells and their corresponding files in the section that includes the Topock Marina were downloaded from the database and reviewed. These wells were then compared to PG&E's current database of wells in that location. No new wells existed in the ADWR database that is not already in PG&E's database. PG&E recently learned from the Topock Marina Resort that no onsite well is currently planned and that water will be purchased from an existing water purveyor. PG&E will continue to inquire about the Resort's planned water use. New information, if any, obtained will be provided.

HNWR-1 Well

HNWR-1 is a 10-inch diameter well completed to a depth of 157 feet and screened over the interval from 92 to 157 feet. The bottom 40 feet of the well is wire-wrapped screen and the interval from 92 to 116 feet is steel casing that was perforated in place after the well was built. Sand and gravel was logged from 35 to 157 feet. The only fine grained silt or clays noted were interbedded with sand in a thin zone between 75 and 82 feet. The HNWR-1 well encountered a thicker and more consistent interval of sand and gravel than has been logged in any of the wells drilled at the Topock site or at Moabi Regional Park on the California side of the river. The high production rate at HNWR-1 is consistent with the coarse grained nature of the aquifer observed in this well.

In November 2010, the HNWR tested the well for a period of 24 hours at an average flow rate of approximately 900 gpm, which resulted in a sustained pumping water level at about 80 feet below the well head. When HNWR was operating this well to provide irrigation water for the Sacramento Wash Revegetation Project, it was intermittently operated at flow rates near or slightly above 1,000 gpm. Short-term capacity testing conducted at the well during recent sampling events indicate that when utilizing the existing pump setup, a maximum pumping rate of about 1,030 gpm can be achieved with a pumping level of approximately 82 feet below the well head. The feasibility of conducting a longer-term constant-rate extraction test at HNWR-1 well is still under evaluation. PG&E is coordinating with the Refuge regarding their planned use for this well and to confirm that the well has sufficient capacity to meet this use and that of the remedy.

Topock-2 and Topock-3 Wells

The Topock-2 and Topock-3 wells are operated by Southwest Water and supply water to the compressor station, the Topock Marina, and a few other nearby customers. Topock-2 is a 140 foot deep well that was drilled in 1980 as a replacement for the original Topock-2 well. Topock-3 was drilled in 1974. It was originally completed to a depth of 250 feet but it produced poor quality water. The bottom 100 feet of the well were plugged with cement and the water quality improved. A video log of Topock-3 was conducted by ADEQ during their Topock Groundwater Study (ADEQ 2006). It showed the well casing to be heavily corroded and in very poor condition. The bottom 20 feet of the casing appears to have collapsed. The well is blocked at a depth of 127 feet. The condition of Topock 2 is unknown.

Even though it is in poor condition, Topock-3 is far more productive than Topock-2. PG&E recently conducted some short term pumping tests at Topock-2 and Topock-3 wells. The results of these tests will be included in the intermediate (60%) design. The specific capacity of Topock-2 was about 11 gallons per min per foot (gpm/ft) while the specific capacity of Topock-3 was about 30 gpm/ft. The pumps currently installed in the Topock-2 and Topock-3 wells produce about 200 gpm max each. The wells themselves may be capable of producing more, but there is a risk of collapse in Topock-3 if it is pumped at rates that would produce excessive drawdown. There is also a risk of pulling the poor quality water up from depth if the Topock-2 and Topock-3 wells were over pumped. The average concentration of arsenic in the Topock-2 well during the Topock Background Study was 12.3μg/L, similar to that in HNWR-1. The Topock-2 and Topock-3 wells do not offer any advantages over the use of HNWR-1 because there are not currently significant differences in the water quality, and there is greater uncertainty about the future water quality as well as the quantity of water available. Therefore, these wells will only be considered as a backup source for HNWR-1 and/or be used to augment the flow needed for the remedy, as applicable.

There was a request in comment #142 DTSC-55 to state the reason for why Topock-1/2 were abandoned and replaced by Topock-2/3. The reason is not known to PG&E.

MW-55 Well Cluster, Sanders, PG&E-9S (Topock Marina Area)

There is sufficient area to install a well at the Topock Marina. MW-55 well clusters had arsenic concentrations of 4.7-5.2 μg/L (from a sample collected on 4/3/2012), Cr(VI) less than 7μg/L, and manganese ranges from less than 100 to 1,230μg/L. The nearby Sanders and PG&E 9S wells both had arsenic concentrations above 30μg/L. It is considered doubtful that the aquifer at MW-55 could provide a sufficient quantity of water for the remedy. The log of MW-55 shows predominantly silt and silty sand down to a depth of 137 feet, where bedrock was encountered. So the aquifer appears to be relatively thin and predominantly fine grained in this area. Lastly, it is likely that a high capacity well at the Topock Marina would create substantial drawdown at the nearby Smith and Sanders wells, and possibly limit those well owners ability to pump water. As mentioned above, PG&E recently learned from the Topock Marina Resort that no onsite well is currently planned and that water will be purchased from an existing water purveyor. PG&E will continue to contact the Topock Marina Resort to inquire about their planned water usage. New information, if any, obtained will be provided.

Using a well from the Topock Marina area does not offer any advantages over the use of HNWR-1 because there is greater uncertainty about the quantity of water available. Therefore, a well in this area is not considered further as an alternative for using a well or wells in Arizona as the freshwater supply source.

MW-54 Well Cluster

The MW-54 well cluster is located on the peninsula that separates the river channel from the Topock Marsh. The aquifer at MW-54 is predominately coarse grained and would appear to be potentially capable of providing a sufficient quantity of water. However, the water quality at MW-54 is poor. TDS is over 12,000 mg/L in the deep well (MW-54-195) and over 6,000 mg/L in the shallow MW-54-85 well. The average TDS from all three MW-54 wells is about 8,800 mg/L. If this water were used as fresh water for the Topock remedy, a large area of the aquifer beneath the Topock site would become non-potable due to high TDS for many decades after the chromium was removed. All three of the wells in the MW-54 cluster contain significant concentrations of dissolved iron and manganese, which would require pre-treatment prior to use in an injection well. The location of MW-54 is also problematic. To access to this area by road requires crossing the river at Needles, then driving south along the dike road through the refuge. The last several miles are on an unimproved dirt road. Drive time from the Topock Compressor Station is over an hour. To provide piping and power to the MW-54 location within the boundaries of the Project Area would require boring under the Colorado River or under the outlet to the Topock Marsh. The MW-54 area is also close to sensitive habitat, so there might be seasonal restrictions on some types of activity such as drilling and well maintenance during nesting seasons. Lastly, drawdown from pumping fresh water near MW-54 might adversely affect the ability of the river bank wells to provide capture for the chromium plume on the floodplain. MW-54 is just across the river from the floodplain extraction wells and there would undoubtedly be interference. Because of the significant disadvantages associated with a well from the MW-54 area, a well in this area is not considered further as an alternative for using a well or wells in Arizona as the freshwater supply source.

Conclusion for Arizona Groundwater Option

Based on the considerations described above for the available well options near Topock Marina, Arizona, it is unlikely that there is a suitable location within or even close to the Project Area on the Arizona side of the river where PG&E could construct a well that would provide a sufficient quantity of groundwater of suitable quality for injection without pretreatment and with arsenic concentrations much lower than at well HNWR-1. Well HNWR-1 appears to be the best option for a groundwater supply within or close to the Project Area in Arizona. As a result, the evaluation presented in this TM includes the HNWR-1 well as the source of fresh water from Arizona.

3.2.2 Well or Wells in California

Table 3-1 provides a listing of water wells, test boring, and infiltration gallery in or near Moabi Regional Park and their construction data (if known). As shown in Table 3-1, of the 6 wells or test borings drilled at Moabi Regional Park, only 2 were able to produce more than 100 gpm. In hopes of finding a better supply with better quality, Moabi Regional Park commissioned LeRoy Crandall and Associates to conduct an evaluation of the water supply options in 1986. Three reports are available that document this evaluation. The first report provides a summary of the available data on the groundwater conditions at the park (Crandall 1986a). The second report documents the results of an exploratory drilling program consisting of collection of geologic information and depth specific groundwater samples from three exploratory boreholes (Crandall 1986b). The third report documents the construction and testing of well PM-03, one of the two supply wells currently in use at the park (Crandall 1986c). All three Crandall reports are included in Attachment A of this TM.

Based on the available data from the driller's log, former well PM-01 was tested at a flow rate of 300 gpm with a specific capacity of about 16 gpm/ft. Well PM-01 was used for several years, but reportedly produced water with a TDS concentration of 3,000 mg/L. Former well PM-02 was tested at 430 gpm but there was no record of the drawdown so no estimate of specific capacity could be made. Both of these two wells had mineralized water. The water from well PM-02 was so saline that it was considered unusable and the well was apparently never put into production (Crandall 1986a).

The wells currently in use at Moabi Regional Park (PM-03 and PM-04) produce water with lower mineral content, but at rates of only 40 to 60 gpm. Attempts were made (by parties other than PG&E) to develop water supplies at two other locations near Moabi Regional Park. An exploratory boring was installed (by parties other than PG&E) south of the park entrance, near the present day location of the Moabi Regional Park water storage tank (along

Park Moabi road about 500 feet north of Interstate I-40). This boring was extended to a depth of over 500 feet but produced only a small volume of water and was never completed as a well. Another well was drilled about a half mile west of Moabi Regional Park to supply water for the construction of I-40. This well reportedly produced less than 5gpm (Crandall 1986a). Based on this information, the capacity of the aquifer to support a 600 gpm well in the areas south or west of Moabi Regional Park appears doubtful. Wells previously drilled within Moabi Regional Park have produced as much as 430gpm, however these high-volume wells have exhibited relatively high mineral content. Wells that have produced better quality water in or near the park have exhibited low pumping capacity.

The conceptual model expressed by LeRoy Crandall and Associates is that "the best quality ground water in the vicinity of the Park occurs in the shallow alluvial deposits that traverse a large portion of the Park, and extend southwesterly toward the Chemehuevi Mountains" (Crandall 1986a). Apparently, the higher quality water that is presently used at Park Moabi is limited to a relatively thin subsurface zone. Existing wells completed in this zone of higher-quality water cannot sustain rates of more than about 70-80 gpm.

DTCS asked whether it would be possible to install multiple wells at Moabi Regional Park to obtain the necessary capacity for the remedy. It might be possible to get an adequate quantity of water from two or more wells, however these wells would need to be located far enough apart to avoid interference with each other. The separation distance would depend primarily on the transmissivity of the aquifer. Based on the transmissivity estimates currently in the model (5,700 gpd/ft), two wells pumping 275 gpm each and screened across the upper 200 feet of the aquifer would need to be at least 1,000 feet apart to minimize interference effects. This would result in more than 100 feet of drawdown at each well. The drawdown created by these two hypothetical wells could also affect the ability of Moabi Regional Park to obtain adequate amounts of water from their existing wells.

There was a suggestion that hydraulic data be collected from former wells PM-01 and PM-02 due to their higher yields (#142 DTSC-55). The location of the PM-02 well is unknown (Crandall 1986a). During a subsequent 1986 investigation, LeRoy Crandall and Associates reported that the bottom 90 feet of the PM-01 well was cemented shut in an attempt to improve the water quality in the well (Crandall 1986b). After cementing, PM-01 was only open to a depth of 100 feet below surface. The report does not mention what effect this had on the capacity of the well, but it had relatively little effect on water quality. The current condition or even existence of the PM-01 well is unknown. Therefore, it is not clear what an aquifer test at PM-01 would determine, particularly because the well is likely in poor condition due to age and disuse and has been partially cemented shut.

In comments on the 30% design report (#142 DTSC-55), DTSC requested that the best place for a water supply well in California be identified. Because it appears the aquifer at Moabi Regional Park would not be able to supply a sufficient quantity of good quality water to simultaneously meet the needs of the remediation project and the Park, the best location for a production well would likely be outside the APE to the north or northwest. Based on current understanding of the geology and water quality at the Topock site, there is little possibility that a well with sufficient capacity and quality could be located between Moabi Regional Park and the Compressor Station, so it would need to be located further away. The presence of the Bouse formation is considered a limiting factor for both quantity and quality of water in the Needles area (Metzger and Loeltz 1973). The Bouse contains brackish water and generally does not yield large quantities of water. The Bouse overlies the Miocene Fanglomerate and older alluvium, neither of which is considered likely targets for large capacity, high quality wells. Drilling through the Bouse in hopes of finding better quality below is not likely to be successful. The best chance of finding a high capacity well with low TDS is in a location where the Bouse formation has been eroded away and the channel has been backfilled with a coarse sequence of recent sand and gravel. The erosion of the Bouse formation occurred in drainages when sea level was lowered during the ice ages. If a sizeable gravel-filled paleo channel in the Bouse can be located, a well completed in it might be able to provide sufficient quantity and quality for the remedial action.

The Bouse formation outcrops at the surface just north of Moabi Regional Park. It was also encountered in all of the Park Moabi wells. It is therefore unlikely that a large paleo channel exists between Moabi Regional Park and the surface outcrop to the north. For that reason, the best place to prospect for a water supply well appears to be in the next drainage to the north of Park Moabi. This is a sizeable drainage with no surficial outcrop of Bouse present. The Bouse may have been eroded beneath this wash, and the paleo channel may have been filled with

sand and gravel rather than clay and silt. The proposed locations for 4 exploratory borings in this wash are shown on Figures 3-6 and 3-7. There no known existing wells in this area. The closest known well is the California Ag Station well, which is between 1 and 2 miles from any of the proposed well locations. Exploratory drilling would be required to determine whether any of the locations to the north of Park Moabi could yield a sufficient quantity and quality of water for the remedy.

Conclusion for California Groundwater Option

Written reports produced by Moabi Regional Park's consultant, LeRoy Crandall and Associates, present a conceptual model that states "the best quality ground water in the vicinity of the Park occurs in the shallow alluvial deposits that traverse a large portion of the Park, and extend southwesterly toward the Chemehuevi Mountains". Existing wells completed in this zone of higher-quality water cannot sustain rates of more than about 70-80 gpm and Crandall concluded that higher pumping rates from the existing PM-03 well would likely result in degradation of water quality as poor quality water was drawn vertically up from below or laterally in from near the river.

Another consideration in determining new extraction well location is compliance with EIR mitigation measure (WATER-1), which requires no substantial effects on production rates of existing nearby wells. Using a simple Theis analysis based on the transmissivity in the groundwater model, a well pumping 600 gpm at Park Moabi would produce 25 feet of drawdown at a radius of 2,500 feet. It is therefore unlikely that a high capacity well within Park Moabi could demonstrate compliance with mitigation measure WATER-1.

Based on available data, it appears unlikely that a well or wells could be sited within the APE in California that would supply an adequate quantity of water for the remedial action while insuring the protection of the quantity and quality of water from the existing wells at Moabi Regional Park.

3.2.3 Conclusion

For criterion #2 (Quantity of Water Available), the Colorado River is the obvious best option amongst the three sources due to its plentiful supply. Without additional exploratory drilling in California, the Arizona groundwater option (existing HNWR-1 well) is more favorable than the California option (Moabi Regional Park wells). As previously mentioned, PG&E is coordinating with the Refuge on the demand for water from the HNWR-1 well and to confirm the well capacity to meet this and other needs (note that Topock-2 and -3 wells can be used to augment the flow needed for the remedy, as applicable). The necessity for and feasibility of a longer-term constant-rate extraction test at HNWR-1 well is still under evaluation at this time.

3.3 Evaluation Criterion #3 - Quality of Water/Potential Need for Conditioning of Water Prior to Injection

This criterion evaluates and compares the three freshwater sources from a water quality perspective and the potential need for conditioning prior to injection.

3.3.1 Well or Wells in Arizona

Table 3-1 summarizes the available data from wells near Topock Marina, Arizona and each of these wells (HNWR-1, Topock-2/3, MW-54/MW-55 Well Clusters, Sanders, and PG&E-9S) is discussed below.

HNWR-1 Well

Table 3-2 presents the HNWR-1 well sample results collected since November 2010. Based on data collected to date, arsenic is the only compound that exceeded an MCL. A discussion about this naturally occurring arsenic (in Topock, Arizona) and the fate and transport modeling is presented below. TDS, total dissolved chromium, and hexavalent chromium are also discussed.

Arsenic

As shown in Table 3-2, arsenic is present in HNWR-1 at concentrations ranges from 15 to 16µg/L, below the site background level of 24.3µg/L (CH2M HILL 2009b). The naturally occurring arsenic concentration exceeds the MCL of 10µg/L, which is typical of water quality in water supply wells in the vicinity of Topock, Arizona. This water is

likely the result of a hydrothermal source to the east and its elevated temperature (95-97 °F). Elevated arsenic concentrations are commonly associated geothermal waters (Hem 1986). Temperatures up to 100 degrees F were noted in the water from the Topock-2 and-3 wells during the Topock Groundwater Background Study. Average arsenic concentration in Topock-2 was about 12µg/L, based on the six samples collected for the Background Study. Water at a temperature of about 115 degrees F was encountered in well MTS-2 at the Mohave Topock Compressor Station, about a mile northeast of the HNWR-1 well, during the Topock Groundwater Study (ADEQ 2006). ADEQ did not analyze the samples from MTS-2 for arsenic. However, ADEQ did conduct a study of the ambient groundwater quality in the Sacramento Valley Groundwater Basin (immediately east of the Mohave Valley basin where the Topock Site and HNWR-1 are located) and found the average arsenic concentration to be about 14 µg/L, similar to that in HNWR-1 (ADEQ 2001). Based on all available information, arsenic in HNWR-1 and nearby wells is the result of natural conditions in the Sacramento Valley. Figure 3-6 shows the average arsenic concentrations in wells sampled as part of the Topock Background Study.

Figure 3-8 shows the maximum arsenic concentrations in wells at the Topock site. In the upland area near the planned freshwater injection wells, arsenic concentrations are generally less than 5µg/L, however arsenic has been detected at concentrations between 5.2 µg/L and 14.4µg/L in the vicinity of the current IM-3 injection wells. Elsewhere across the Topock site it is not unusual to find arsenic concentrations above the MCL of 10 µg/L. Concentrations similar to or above the 15 µg/L measured in the HNWR-1 well have been observed in wells near the river, bedrock wells, and near the current evaporation ponds. Thus, the concentration of arsenic in water from HNWR-1 is within the range of arsenic concentrations found at the Topock site and well below the background concentration of 24.3µg/L.

Model simulation of HNWR-1 water injection into California was performed to evaluate the fate and transport of arsenic over time. Geochemical modeling was done with the same simplified PHAST model described above, along with the current site transport model (MODFLOW/MT3D/PHT3D) have shown that arsenic concentrations above the MCL of 10µg/L would be limited to areas within a few hundred feet of the injection wells during the course of the remedy (Figures 3-9 and 3-10). This is due to the abundance of iron oxide minerals in the aquifer matrix in California. Amorphous iron oxide mineral concentrations used in the model were based on measured concentrations from the Aerobic Core Study (CH2M HILL 2005a) and the *in situ* pilot studies conducted by ARCADIS at Topock. Modeled arsenic adsorption to these iron oxides was based on published arsenic adsorption constants on iron oxides contained in the PHREEQC database (Parkhurst and Appelo, 1999; Dzombak and Morel, 1990). Following the end of active remediation, the model simulations predict that the remaining “halos” surrounding the injection wells are dispersed and adsorbed to downgradient iron oxides (Figures 3-11 and 3-12). In summary, although the arsenic in the HNWR-1 well source is above the MCL, transport modeling predicts that the arsenic will not be mobile in the environment surrounding the proposed injection wells and will attenuate under site conditions and return to pre-remedy baseline levels after the end of active remediation.

There was a comment as to why dissolved arsenic is stable in aerobic waters withdrawn from well HNWR-1, but would become unstable when injected into aerobic waters in California (#147 DTSC-60). The most likely explanation is that iron oxide minerals, effective adsorbers of arsenic, are undoubtedly present in the aquifer matrix in Arizona, however, long-term exposure to the groundwater with naturally occurring arsenic has saturated all the adsorption sites on these minerals. There are a finite number of adsorption sites for matrix minerals, and if the groundwater has excess concentration of an adsorbing constituent (such as arsenic), then the matrix minerals and groundwater will form an equilibrium state, with the adsorption sites at capacity (Schindler 1991, Stumm 1992). By contrast, groundwater on the California side of the river does not have a similar hydrothermal source, and has markedly lower arsenic concentrations in the oxidized portions of the alluvial aquifer. Arsenic in areas surrounding the proposed injection is generally below 10 µg/L. The iron oxides in these areas are not saturated with arsenic, and may act as effective adsorbers where arsenic is introduced.

The potential well fouling associated with arsenic in HNWR-1 water was also evaluated (#147 DTSC-60). Arsenic from the proposed fresh water source is geochemically favored to adsorb to iron oxide minerals present throughout the alluvial aquifer matrix. Based on measured concentrations of iron oxides from core samples and published geochemical relationships for arsenic adsorption (Dzombak and Morel, 1990), the injected arsenic is not

expected to persist in groundwater more than a few hundred feet away from the injection wells. The adsorption occurs via a chemical bond between the negatively charged arsenate ion to positively charged sites on the iron oxide surface. There are a finite number of such sites on each iron oxide crystal, so when those sites are saturated with arsenate ions, newly introduced arsenate will travel to the next available crystal with open sites. This results in a thin layer of adsorbed arsenate ions on the surface of the iron oxide in aquifer matrix. Because it is an adsorption reaction and not a precipitation reaction, there is no solid phase being formed that would preclude the movement of water through the pores of the aquifer matrix. The thin layer of arsenic ions sorbed to the iron oxide would not measurably change the effective porosity of the aquifer.

Evaluation of water from areas with lower arsenic outside the influence of hydrothermal activities

There was a concern about injecting HNWR-1 water because it contains chromium above the localized concentrations in the upland injection wells and arsenic level above the MCL of 10 µg/L (#134 DTSC-52). DTSC has requested that areas with lower arsenic outside the influence of hydrothermal activities also be evaluated for freshwater supply (#146 DTSC-59).

Figure 3-6 shows the distribution of arsenic in wells sampled in Arizona and California. The geothermal conditions on the Arizona side of the river are likely associated with the recent volcanic activity that formed the Black Mountains. It is noteworthy that the wash to the north of Sacramento Wash is named Warm Springs Wash. This wash flows directly out of the Black Mountains about 1.5 miles north of the Sacramento Wash. The extent of the geothermal area is not well defined. Temperature data from wells included in the Topock Background Study were provided in the Step 2 Background Study Report (CH2M HILL 2005b). The warmest wells sampled in the Background Study were Topock-2 and Topock-3 with temperatures around 100 degrees F. The third warmest well was TMLP-2, with a temperature of about 93 degrees F. TMLP-2 is located more than 5 miles up the Sacramento Wash from Topock-2 and Topock-3. Three of the Golden Shores wells had temperatures above 90 degrees F, suggesting that geothermal effects may extend to several miles to the north as well as east from Topock.

If it becomes necessary to develop a water supply from a well in Arizona other than HNWR-1, it would likely be from a well outside the APE to the north. There are two wells north of HNWR-1 for which some information exists. Well GSRV-2 is located along Highway 95 just south of Warm Springs Wash, approximately 1.6 miles north of HNWR-1. Approximately 0.4 miles further to the north along Highway 95 is the Serrano landscaping well. Figures 3-6 and 3-7 show the locations of these wells. Based on the well logs for these wells provided in the ADEQ report (ADEQ 2006), the geology in this area appears to be favorable for a high capacity well, with sand gravel logged down to a depth of about 250 feet. The capacity of the existing GSRV and Serrano wells has not been assessed. Without data on the aquifer properties, pumping rates, and pumping water levels in the GSRV-2 and Serrano wells, it is not possible to predict whether a new production well to supply the remedy would have adverse effects on the existing Serrano wells.

The water temperature in GSRV-2 was about 88 degrees F, indicating it may be mildly affected by geothermal conditions. This well was sampled 7 times during the Topock Background Study. At the direction of DTSC, one of these samples was excluded for the purposes of calculating background statistics. Although, this sample was excluded from the background calculations, it represents a valid sample result and should therefore be considered in the freshwater source evaluation. Based on the 7 available samples, the mean arsenic concentration was 5.6 µg/L, which is considerably lower than HNWR-1. The maximum and average Cr(VI) concentrations were 38.6 and 27.1 µg/L, respectively. Based on the results from GSRV-2, it is possible that a water supply well near GSRV-2 could produce Cr(VI) in excess of the established background for the Topock site. The Serrano well was sampled during the ADEQ Topock Groundwater Study (ADEQ 2006) and contained Cr(VI) at 26.2 µg/L. ADEQ did not analyze for arsenic. Both GSRV-2 and Serrano wells are located near or within Warm Springs Wash. The elevated Cr(VI) in area may be associated with the volcanic rocks in the recharge area for these wells, along the channel of Warm Springs Wash and in the Black Mountains to the east.

Exploratory drilling would need to be conducted in order to evaluate the quantity and quality of water that could be provided by a new production well to the north of HNWR-1. Some preliminary potential locations for exploration boreholes are show on Figures 3-6 and 3-7. These locations have not been field checked and property ownership has not been determined. The southernmost location is about 0.6 miles north of HNWR-1. The

northernmost is about 2 miles, by road. If wells were developed in these locations, piping would need to be extended to these locations.

Total Dissolved Solids (TDS)

Well HNWR-1 produces water with TDS (about 500 mg/L) lower than the Colorado River (about 680 mg/L). There was some concern initially that the low TDS of HNWR-1 water may have the potential to cause diminished injection productivity and aquifer plugging. A geochemical model simulation was performed using the U.S. Geological Survey's PHAST code (Parkhurst et al., 2010), in which injection of water chemistry from HNWR-1 (the lower TDS of the two waters) into the alluvial aquifer was simulated in a simplified model. The purpose was to calculate the mass of salts that would be re-precipitated at various distances from the injection well, and assess whether the volume of this mass would block a significant portion of the aquifer porosity. The simulation showed that less than one percent of the available porosity was blocked by re-precipitation. This was considered to be insignificant from a water production standpoint. These results were expected, since the native groundwater in the freshwater injection area is undersaturated with respect to gypsum and anhydrite, the calcium sulfate minerals that are most often associated with this mechanism of production loss through re-precipitation. The undersaturation indicates that gypsum is either absent or in negligible quantity in the aquifer matrix.

According to Bradley Guay of the U.S. Army Corps of Engineers (USACE), who supervised the installation and testing of HNWR-1 and authored a PhD dissertation titled "Hydroglogic Investigation of Topock Marsh," the isotopic signature of the water from HNWR-1 is more similar to other wells further up Sacramento Wash than to the Colorado River (personal communication between Bradley Guay and other representatives of DOI and representatives of PG&E, November 19, 2010). At present, it appears that HNWR-1 does not draw a lot of water from the river, but rather intercepts groundwater moving down the Sacramento Wash. This conclusion is also supported by the fact that the temperature of the water pumped from HNWR-1 is 95-97 degrees F, much warmer than the water in the river.

The estimated volume of groundwater to be moving down Sacramento Wash is about 100 acre-feet per year, or approximately 60 gpm. Thus, there is likely not enough water being provided by the Sacramento Wash drainage to supply the minimum 600 gpm needed for the remedy. It is likely that HNWR-1 would draw increasing amounts of water from the Topock Marsh over time. There are no wells between HNWR-1 and the marsh, so the groundwater quality in this area is unknown. Similarly, it is not known how far below the bottom of HNWR-1 the high TDS water lies. It is therefore not possible to predict what changes might occur in water quality at HNWR-1 over time with any degree of certainty. It is likely that the TDS will increase as more river water is pulled in.

Total Dissolved Chromium and Hexavalent Chromium

Based on data collected to date, HNWR-1 well contains about 16-19.2 μg/L total dissolved chromium and 15-18 μg/L Cr(VI), both below the site background levels for chromium of 34.1 μg/L and Cr(VI) of 31.8 μg/L (CH2M HILL 2009). The total chromium level is also below the MCL of 50μg/L.

There was a comment that the HNWR-1 well should be noted that it exhibits a Cr(VI) concentration about double PMM-Supply (#145DTSC-58). PMM-Supply is PM-03. The level of Cr(VI) in PM-03 ranges from 0.23 μg/L (in a sample collected in 2003) to 12 μg/L (in a sample collected in 2010) (Table 3-3 and PG&E 2012). While the Cr(VI) level in HNWR-1 is higher than PMM-Supply (or PM-03), it cannot be stated that the level in HNWR-1 well is double that in PMM-Supply, as suggested in the comment. In fact, Cr(VI) level in Moabi Regional Park water supply well PM-04 (13 to 21.4 μg/) is slightly higher than HNWR-1 (Table 3-3 and PG&E 2012). These levels are consistent with the range of concentrations found in other Topock area wells that contain naturally occurring ("background") chromium concentrations. See Section 3.3.2 for additional discussion on water quality for Moabi Regional Park wells.

Topock-2/3 Wells

As shown in Table 3-1, Topock-2/3 wells contain TDS of 800-900 mg/L, Cr(VI) of 7-11 μg/L, and arsenic of 12-14 μg/L. Manganese in Topock-2 averages around 3.1 μg/L. Similar to HNWR-1 well, the arsenic level in these wells is also above the MCL of 10 μg/L.

MW-55 Well Cluster, Sanders, PG&E-9S (Topock Marina Area)

There is sufficient area to install a well at the Topock Marina. MW-55 well had arsenic concentration of 4.7-5.2 μg/L (from a sample collected on 4/3/2012), Cr(VI) less than 7μg/L, and manganese ranges from less than 100 to 1,230μg/L. The nearby Sanders and PG&E 9S wells both had arsenic concentrations above 34 μg/L and manganese above 99μg/L.

MW-54 Well Cluster

The MW-54 well cluster is located on the peninsula that separates the river channel from the Topock Marsh. The aquifer at MW-54 is predominately coarse grained and would appear to be potentially capable of providing a sufficient quantity of water. However, TDS at MW-54 is over 12,000 mg/L in the deep well (MW-54-195) and over 6,000 mg/L in the shallow MW-54-85 well. The average TDS from all three MW-54 wells is about 8,800 mg/L. If this water were used as fresh water for the Topock remedy, a large area of the aquifer beneath the Topock site would become non-potable due to high TDS for many decades after the chromium was removed. Arsenic at MW-54 ranges from non-detect to 4.5μg/L. All three of the wells in the MW-54 cluster contain significant concentrations of dissolved iron and manganese, which would require pre-treatment prior to use in an injection well.

Conclusion for Arizona Groundwater Option

Based on the information presented above, naturally occurring arsenic levels in past and current water supply wells (HNWR-1, Topock-2/3, Sanders, and PGE-9S) are all above the MCL. Arsenic data from existing monitoring well clusters (MW-54 and MW-55), though limited, are below the MCL. Cr(VI) in both supply and monitoring wells are well below the Topock site background level of 31.8 μg/L. TDS is low in all wells, with the exception of MW-54 clusters.

With regard to arsenic level above the MCL, transport modeling predicts that the arsenic will not be mobile in the environment surrounding the proposed remedy injection wells and will attenuate under site conditions and return to pre-remedy baseline levels after the end of active remediation. Therefore, it is PG&E's assessment that treatment of arsenic is not needed. Monitoring will be implemented during remedy implementation to verify the modeling results and adjustments will be made as needed. Potential contingency actions include adding ex-situ arsenic treatment or switching to another source (see Section 3.4).

At DTSC's request, the following discusses potential options to reduce arsenic in HNWR-1 water from 15μg/L to less than the MCL of 10μg/L, prior to injection. For the purpose of this discussion, it is assumed that the arsenic would be reduced to 5μg/L. The target concentration of 5μg/L was selected to provide a factor of safety below the MCL.

Potential Options for Reducing Arsenic Concentrations in HNWR-1 Water Prior to Injection

Blending with water sources with lower arsenic (River water, Moabi Regional Park well water)

River water has low concentrations of arsenic – using data provided by MWD (January 2008-April 2011) – the average value from this data set is 2.7 μg/L, with a maximum of 3 μg/L. If the maximum arsenic value is assumed, a blending ratio of 5 to 1 of river water to HNWR-1 water is required to produce a blended stream with 5μg/L arsenic. Because the blended water will be overwhelmingly dominated by the river water, the treatment considerations and footprint required for this option are essentially the same as they would be for conditioning of the river water (see Section 3.3.3, Colorado River). Therefore, this blending option does not offer any advantages over obtaining all the water from the river. In fact, blending will require additional infrastructure (piping and power to HNWR-1) and create additional disturbance that are not needed.

There is limited, current arsenic data for the Moabi Regional Park water supply wells (PM-03 and PM-04). Available data showed low levels of arsenic ranging from ND to 2μg/L, similar to or lower than the arsenic in the river water. If the maximum arsenic value is assumed, a blending ratio of 5 to 1 or higher of Moabi Regional Park well water to HNWR-1 water is required to produce a blended stream with 5μg/L arsenic. Because the blended water will be overwhelmingly dominated by Moabi Regional Park well water, the treatment considerations and

footprint required for this option are essentially the same as they would be for the California option (see Section 3.3.2, Well or Wells in California). In addition, it is doubtful that adequate volume of water could be obtained from the relatively thin zone of higher quality water tapped by PM-01 and PM-04. Arsenic concentrations from a hypothetical high capacity well at Park Moabi are unknown. Therefore, this blending option does not offer any advantages over not blending. In fact, blending will require additional infrastructure and create additional disturbance that are not needed.

***In situ* arsenic treatment**

At DTSC's request, PG&E has reviewed a Scientific Investigations Report published by the USGS regarding a possible method for *in situ* treatment of arsenic (USGS 2010). This report documents a pilot scale test of an experimental *in situ* arsenic removal technology. The technology involves several above ground treatment steps that are similar to conventional arsenic treatment; however the actual arsenic precipitation occurs in the aquifer. The principal advantage of the technology over conventional above-ground treatment is the absence of a solid waste stream from the iron/arsenic precipitation process. Because much of the treatment is above ground, the footprint of this *in situ* technology could be similar to a conventional above-ground arsenic removal process. In addition, depending on how the technology was applied, there would either be a need for several more injection wells near the HNWR-1 well, or the life of the remedy freshwater injection wells could be shortened.

During the first USGS test, the injection wells plugged within an hour. In the second test, the injection wells plugged within 3 to 4 hours and the filters needed to be backwashed every 30 minutes. The cause of this plugging was suspected to be air entrainment. The USGS report noted that: "Switching injection or air-lifting among wells and filters may alleviate many problems; however, the maintenance of such a system may be substantial."

The process tested by the USGS involves several steps. First, the water is aerated, which was accomplished through airlift pumping in the USGS test. Air lift pumping would not be practical at the 600 to 1,200 gpm design flow rates required in the final remedy, so the aeration step would be done after the water was pumped from the well. Following aeration, chlorine was added to further oxidize the arsenic. Then the water was passed through carbon filters to remove the chlorine. Next, hydrochloric acid was added to reduce the pH to 5.5. In the last step just prior to injection, ferric chloride was added. The low pH of the water was necessary in order to prevent the ferric iron from precipitating until the water moved out of the injection well bore and into the surrounding aquifer. Under the normal pH of the water at Topock, ferric iron will precipitate in a matter of minutes when oxygen is present. Arsenic is removed through co-precipitation with the ferric iron in the aquifer near the injection wells.

The USGS pilot test was designed to control arsenic in a production well by injecting iron in nearby injection wells and creating an *in situ* remediation zone (IRZ) around the pumping well. If PG&E were to apply this technology in the same way at Topock, it would involve installation of three or four injection wells in the vicinity of HNWR-1. A portion of the water pumped from HNWR-1 would be passed through an aboveground treatment facility and returned to the aquifer in the injection wells. A process flow diagram for this is provided in Exhibit 3-2. In theory, only a fraction of the water pumped from HNWR-1 would need to be returned to the aquifer near the well to maintain the IRZ, however the USGS paper does not provide enough data to estimate what that fraction would be. Additional water quality and process analysis and a pilot test would be needed to develop operational parameters for the application of this experimental technology at HNWR-1. The size of the above ground treatment plant needed at HNWR-1 would be dependent on the amount of water that needed to be treated and returned to the injection wells.

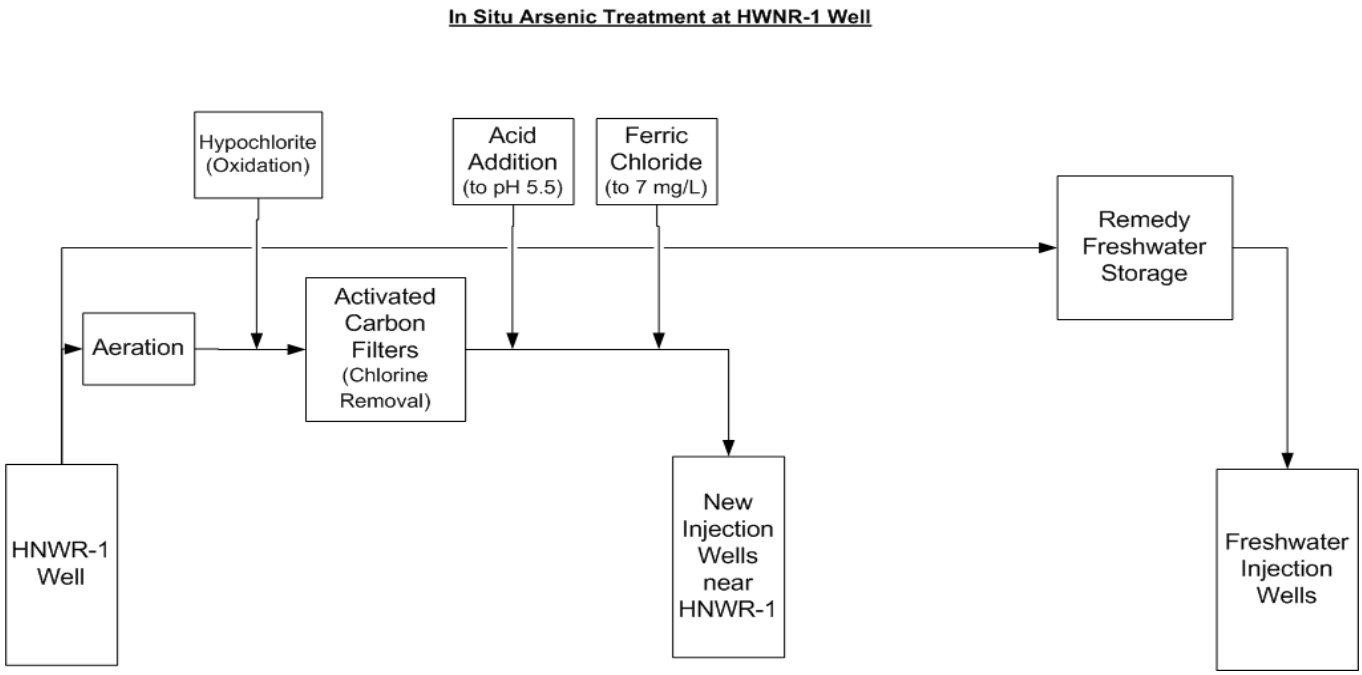


EXHIBIT 3-2
HNWR-1 Source with In Situ Arsenic Treatment at HNWR-1 Well
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

Rather than trying to treat the water being produced by HNWR-1, it might be possible to apply this technology by treating the water prior to injection in the freshwater wells. A process flow diagram for this application is provided in Exhibit 3-3. The disadvantage of treating injected water rather than maintaining an IRZ around HNWR-1 is that it would require treatment of the full 600 to 1,200 gpm of freshwater flow. The footprint for the above ground components of the *in situ* arsenic treatment plant would be similar to the footprint for conventional above-ground arsenic treatment. In addition, the *in situ* treatment scheme presents a risk to the injection wells. Well plugging could occur through air entrainment or iron precipitation in the well bore. If the pH adjustment system ever failed, the injection wells could be plugged in a matter of hours. Even if the system functioned perfectly, injecting 7 mg/L of iron would plug about 8 percent of the aquifer pore space within a 10 foot radius of the injection wells over the 30 year design life of the remediation system. This could have an adverse effect on injection rates over time. The low pH necessary to prevent iron precipitation in the injection wells might cause accelerated corrosion of pumps, valves, and other components or it might result in adverse geochemical reactions in the aquifer, such as dissolution of other metals. Further analysis would be needed to determine if this *in situ* approach of injecting low pH water containing iron would be feasible for the Topock freshwater injection wells.

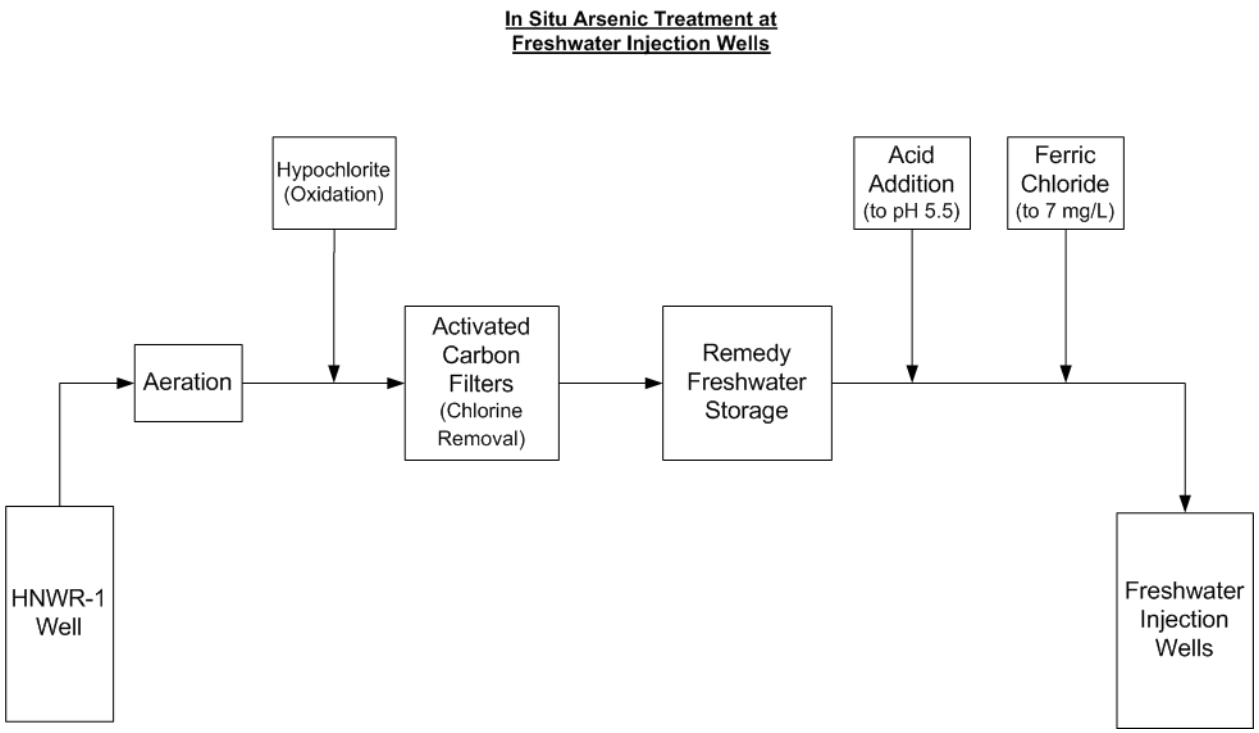


EXHIBIT 3-3
HNWR-1 Source with In Situ Arsenic Treatment at Freshwater Injection Well(s)
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

Overall, the experimental *in situ* approach described in the USGS report does not seem to have any significant advantage over conventional arsenic treatment technology for the Topock remediation project. In addition, because it is an experimental technology, pilot testing would likely be required to determine feasibility and develop design parameters prior to implementation.

Ex-situ arsenic treatment

The treatment process included is to use coagulation followed by media filtration. To optimize the process, hypochlorite will be added 30 to 60 seconds prior to the addition of ferric chloride. The process is shown schematically in Exhibit 3-4.

Filtered water would be pumped to the existing freshwater tanks and from there flow by gravity to the TCS for process and non-potable use and to the injection wells. The filters would be backwashed periodically and the backwash flow would be sent to a tank (“Decant Tank”) to decant the solids. Solids would be accumulated and then vacuumed out of the decant tank. These solids would be taken to the Produced Water Conditioning System liquid phase separators and disposed of offsite with the Produced Water solids. Water from the decant tank would overflow and be re-processed through the filtration system. More than 90 percent of the water can be recycled this way thereby reducing water use. Filter media is permanent and requires no regeneration or treatment.

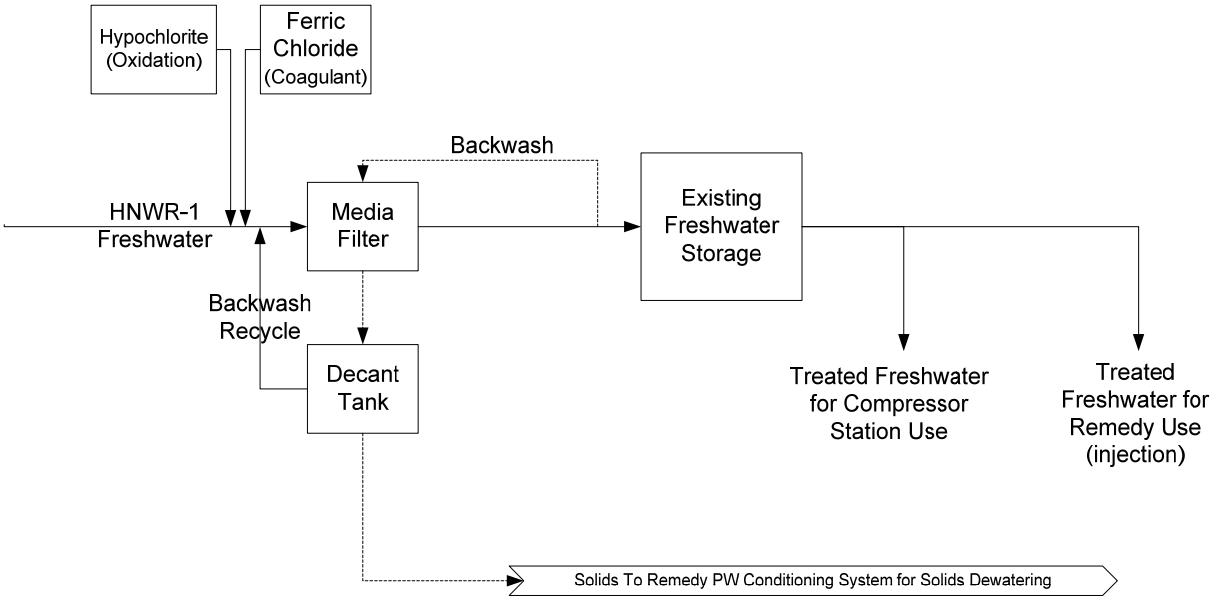


EXHIBIT 3-4
HNWR-1 Source with Ex-Situ Arsenic Treatment Process Schematic
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

Major equipment would include the following:

- Filters with manganese dioxide filter media in pressure rated housings complete with piping, automated valves for diverting flow from treatment to backwash modes.
- Process pumps for filter feed, backwash, decant water.
- Decant tank (cone-bottom tank) for backwash water storage and solids settling
- Chemical storage tanks and metering pumps for sodium hypochlorite (12.5 percent strength) and ferric chloride (35 to 45 percent strength)
- A pipe reactor would be built to allow sufficient hypochlorite mixing time before filtration.

The arsenic treatment system would be constructed at the TCS on a new concrete foundation with a building and partially sided roof structure (sunshade) for outdoor equipment like chemical storage. The footprint is estimated to be 2,000 square feet. For this assessment, it was assumed that the entire freshwater stream would receive arsenic treatment. In a more detailed design analysis, the option of treating a portion of the freshwater and blending with an untreated portion to meet arsenic concentration targets could be evaluated.

3.3.2 Well or Wells in California

This section discusses the water quality of wells water wells in and near Moabi Regional Park, and addresses the potential need for conditioning prior to injection. Table 3-1 provides a summary of available water quality information. Tables 3-3 thru 3-5 provide additional water quality data for wells PM-03 and PM-04, respectively (PG&E 2012).

Total Dissolved Solids

As shown in Table 3-1, one of the wells drilled at Moabi Regional Park (well PM-02) produced highly mineralized water and was never put into service. The other high-capacity well (PM-01) produced water with a TDS concentration around 3,000 mg/L (Crandall 1986b). The infiltration gallery that was installed near the river was equipped with a reverse osmosis system to remove minerals and make the water suitable for use by the park. The previous high capacity wells and infiltration gallery at Moabi Regional Park produced water with TDS that was considered undesirable by Moabi Regional Park.

Previous consultants have expressed concerns that higher pumping rates at Moabi Regional Park might pull in poor quality resulting in degradation of the water quality in existing wells (Crandall 1986c and Roberts 2006). LeRoy Crandall and Associates stated that for PM-03, "Pumping at rates greater than 60 gpm could also induce migration of poor quality water that is present in the vicinity of the trailer park and the old water well. Excessive pumping could also induce an upward flow of poor quality water that is present at depths below 200 feet" (LeRoy Crandall & Associates, 1986c). A similar concern was expressed by another consultant who designed and tested well PM-04 (Roberts 2006). Mr. Roberts recommended that PM-04 be pumped at rates not exceeding 40 gpm and used in conjunction with PM-03 to minimize stress on the aquifer.

Based on information presented in the Crandall Reports, there is significant variation in groundwater quality across relatively short distances and depths in the aquifer at Moabi Regional Park. The previous high capacity wells at Moabi Regional Park produced water with TDS greater than 1,500 mg/L. This relatively salty water appears to be more prevalent than the better water quality represented by wells PM-03 and PM-04. If a high capacity well were to be installed at Moabi Regional Park to supply the remedy, it would likely produce high TDS water. As mentioned above, previous consultants have expressed concerns that pumping from a high capacity well might draw high TDS water into the relatively low TDS zones tapped by current Park Moabi wells. This could occur by "upconing" of higher TDS water from depth, or lateral movement of higher TDS water from other portions of the aquifer. Upconing of high TDS water is more likely in a well that produces a lot of drawdown.

In the vicinity of Moabi Regional Park, the shallow alluvium is thin and does not produce sufficient water for the remedy. Even the deep wells that have been drilled previously at Moabi Regional Park have not produced sufficient water for the remedy. Although the TDS of the water from the high capacity wells at Moabi Regional Park might be suitable for injection at Topock, it was not considered acceptable for use by the Park. If a high capacity well were installed at Moabi Regional Park and the water used to for injection at Topock, there would be two concerns about water quality. As expressed by prior consultants, the pumping of a high capacity well could result in migration of nearby poor quality water into the existing Moabi Regional Park wells. In addition, the northward gradient induced by pumping fresh water at Moabi Regional Park would eventually draw some of the injected water back to Moabi Regional Park. If the quality of the injected water was objectionable to Moabi Regional Park, this could result in additional degradation of the water quality at the park.

Sulfide Odor

The Crandall report indicates that in addition to elevated salts, well PM-01 had a sulfide odor and an elevated temperature (LeRoy Crandall & Associates 1986a). The observation of sulfide odor suggests that the water from PM-01 may have been in a reduced or partly reduced geochemical state and could therefore have contained dissolved iron or manganese at concentrations that may require pre-treatment to prevent injection well plugging.

Chromium and Trace Metals

PG&E sampled wells PM-03 and PM-04 on annual basis and submitted the results to the Moabi Regional Park and DTSC. Data reported in the most recent letter report submitted on February 12, 2012 (PG&E 2012) indicate that the chromium concentrations continue to be below both the state and federal drinking water standards and are consistent with the range of concentrations found in other Topock area wells that contain naturally occurring ("background") chromium concentrations. No other compounds analyzed exceeded state and federal drinking water standards.

Well PM-03 (also called PMM-Supply) has the most extensive trace metal dataset in all available Park Moabi wells data (see Tables 3-4 and 3-5). Dissolved iron ranges from <100 to 931 μg/L, the most recent dissolved iron data was 50 μg/L (December 2011). Manganese ranges from <1 to 3.5 μg/L. Well PM-04 has dissolved iron ranges from <20 to 617 μg/L, the most recent dissolved iron data was 60 μg/L (December 2011). Manganese was below reporting limits of 10μg/L. PM-04 has one trace data set, zinc level of 605 μg/L exceeded the site background level of 77.7 μg/L.

No trace metals data are available for other older wells in the Moabi Regional Park. The potential for well clogging in the deeper water in this area due to iron and/or manganese concentrations remains unknown.

Conclusion for California Groundwater Option

The quality of water at a quantity adequate for the remedy use remains unknown. Exploratory drilling would be needed to find the desired water quality at a quantity adequate for the remedy. Again, the conceptual model expressed by Moabi Regional Park's consultants LeRoy Crandall and Associates and Mark Roberts is that "the best quality ground water in the vicinity of the Park occurs in the shallow alluvial deposits that traverse a large portion of the Park, and extend southwesterly toward the Chemehuevi Mountains" (Crandall 1986a). Existing wells (PM-03 and PM-04) completed in this zone apparently cannot sustain pumping rates of more than 70-80 gpm (Crandall 1986c, Roberts 2006).

Since water quality in the deeper water in this area is not known, it may be prudent to consider some water conditioning to remove iron and manganese for protection of injection wells from clogging. Below is a conceptual level discussion of a conditioning system that can be used to remove iron and manganese. There are many effective iron and manganese treatment methods such as oxidation (e.g., potassium permanganate) and filtration, adsorptive filtration, ion exchange, membrane filtration (e.g., reverse osmosis) and biological filtration. For the purpose of this discussion, adsorptive or greensand filtration is assumed.

As shown in Exhibit 3-5, hypochlorite is used to oxidize the iron and manganese into less soluble forms and then the water flows through a filter. The filter media consists of an adsorptive media or greensand, both of which increase iron and manganese removal by adsorbing the oxidized compounds. Excess chlorine is added to regenerate the media surface for sorption. The treatment process is illustrated schematically in Exhibit 3-5.

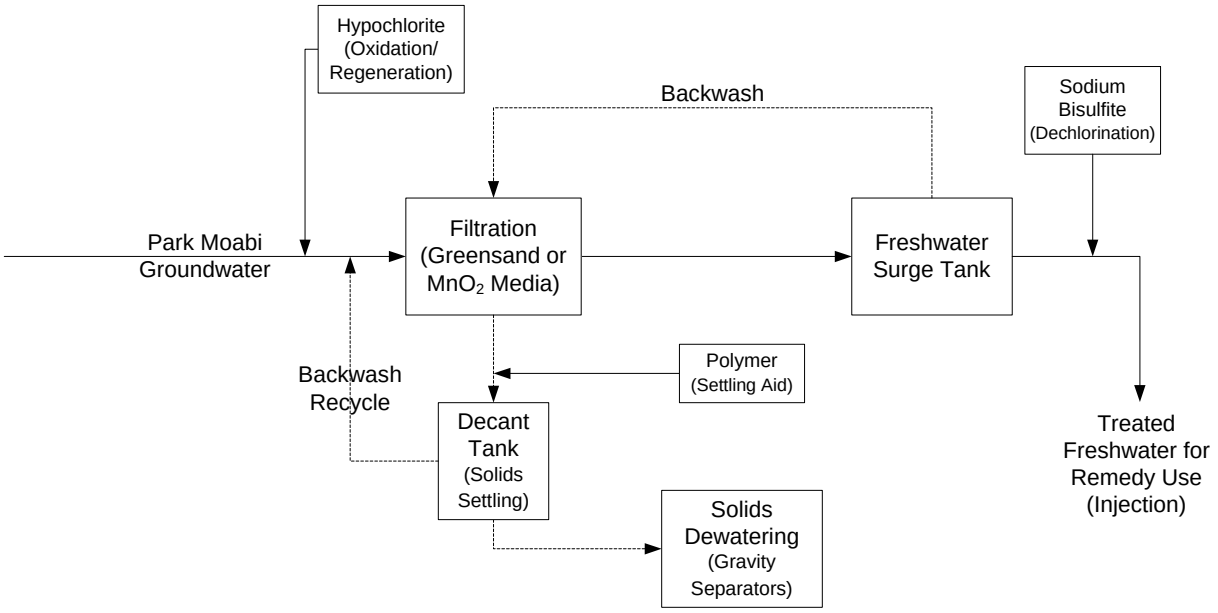


EXHIBIT 3-5
Park Moabi Source with Iron Conditioning Process Schematic
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

The filters would be backwashed periodically to remove accumulated and adsorbed solids and the backwash flow would be sent to a cone-bottom decant tank to settle the solids. A polymer would be injected into the stream to aid in settling. Settled solids would be vacuumed out of the decant tank when it reached a pre-designated level. These solids would be pumped to liquid phase separators located at the Remedy Produced Water Conditioning System and the dewatered solids would be disposed of offsite (see Section 3.4 for Implementability and Sustainability Considerations). Water from the decant tank would overflow and be re-processed through the filtration system. More than 90 percent of the water can be recycled this way thereby reducing consumptive water use. Filtered water would flow to a surge tank prior to flowing by gravity to the injection wells.

To prevent chlorinated water from affecting the IRZ, excess chlorine would be removed by the addition of a chemical such as sodium bisulfite.

Major equipment would include the following:

- Filters with filter media in pressure rated housings complete with piping and automated valves for diverting flow from treatment to backwash modes. Two banks of eight filters would be installed to treat the entire flow.
- Submersible pump for groundwater extraction located at Moabi Regional Park
- Process pumps for backwash, and decant water.
- Chemical storage tanks and metering pumps for sodium hypochlorite, polymer, and sodium bisulfite.
- Surge tank for filtered water.
- Decant tank (cone-bottom tank) for backwash water storage and solids settling.

The equipment would be mounted on a concrete foundation with a building or partially sided roof structure (sunshade). The footprint is estimated to be about 2,500 square feet.

3.3.3 Colorado River

This section evaluates the river water quality relative to the desired water quality for injection at the Topock site, and the potential need for conditioning prior to injection. Table 3-6 provides a summary statistics of surface water sample results collected by PG&E from July 1997 through June 2011 as part of its surface water sampling program. Tables 3-7 and 3-8 provides a summary statistics of the river data collected by MWD from 2008 through March 2012 for trace metals and other compounds with primary and secondary MCLs, as well as compounds in pharmaceuticals and personal care products (PPCP).

Total Dissolved Solids

The TDS averages around 680 mg/L in the river which is higher than the average in the HNWR-1 well (500 mg/L) but not considered to be a problem for injection at the Topock site (see Section 3.3.1).

Dissolved Organic Carbon Content

The average dissolved organic carbon content in the Colorado River near Topock is 9 mg/L. While this is considered low for a surface water source, it might be enough carbon to contribute to injection well fouling. It would likely depend on the bio-availability of the dissolved carbon present. If the carbon is relatively resistant to microbial uptake, the microbes would not be able to readily utilize it and well fouling potential would be less. If the carbon was in a form that the microbes could readily use, microbial growth would occur within or near the well and fouling would be more of a concern. If the river were selected as the freshwater source, laboratory tests would need to be conducted to determine the nature of the dissolved carbon present and whether or not it would be likely to cause problems with well fouling.

Turbidity

Turbidity in river water ranges from 2-2.6 NTU near Lake Havasu to 5 NTU at the Wildlife Refuge. There is no reliable way to relate the turbidity to total suspended solids, but it is anticipated that the river water would need filtration prevent plugging of the injection wells.

Coliform Bacteria

Based on data reported in MWD's 2011 Annual Water Quality Report, the Coliform Bacteria level in river water at Lake Havasu ranges from 3 to 1,700 cfu/100 ml (median is 330 cfu/100 mL). The Colorado River Sanitary Survey reported the following on the level of Coliform Bacteria in Lake Havasu at Whitsett Intake, 2005-2010:

	Total Coliforms	Fecal Coliform	E. coli
No. of Samples	72	59	72
Minimum	< 1	< 2	< 1
10th Percentile	9	< 2	< 1
Median	120	< 2	< 1
Average	370	3	< 1
90th Percentile	880	2	1
Maximum	7,700	130	3

Injection of water containing bacteria and microbes is likely result in biological growth on the well screens. The reason is the river water is oxygenated and pumping will add more oxygen. The injection areas are also oxygenated so the bacteria and microbes will have favorable conditions to multiply. Physical methods are somewhat effective in removing the biological growth from the well screens, but to stop the growth requires disinfection. The injection stream will be a continuous source of bacteria and microbes if disinfection is not used.

Trace Metals and Hexavalent Chromium

As shown in Tables 3-6 and 3-7, none of the compounds analyzed in river water exceeded the MCLs and Topock site background levels, where available.

Perchlorate and Nitrate

Low levels of perchlorate (3μg/L max) were detected in about 30 percent of the samples collected below Davis Dam and at the Lake Havasu Intake. At the Lake Mead Out Structure, perchlorate was detected in more than 75 percent of the samples analyzed with the maximum level detected was 4.6μg/L. These levels are below the California primary MCL of 6μg/L. Perchlorate was not analyzed in samples collected near the Topock site.

Nitrate was detected in most samples analyzed. In surface water samples collected by PG&E, average nitrate level is less than 1mg/L. In MWD samples, the maximum level of nitrate was found at 2.5mg/L in samples collected below Davis Dam and at the Wildlife Refuge. The maximum nitrate level is below the primary MCL of 10mg/L (as nitrogen) and 45mg/L (as NO3).

Contaminants with Secondary MCLs

Of the contaminants with secondary MCLs, aluminum was the only compound detected above the MCL of 200μg/L. The maximum level detected was 540μg/L above the railroad at the Topock site.

Compounds Associated with Pharmaceuticals and Personal Care Products (PPCP)/Emerging Contaminants

Due to the intensive use and re-use of the water in the Colorado River, it could contain many trace contaminants such as pharmaceuticals, personal care products, and possibly other contaminants that have not yet been identified. Table 3-7 shows a summary statistic of PPCP compounds in samples from the Colorado River. In general, the PPCP compounds are found in samples collected in more populated areas such as Lake Havasu than less populated areas such as the Wildlife Refuge or below Davis Dam. As areas become more or less populated over the next few decades, it is expected that the presence of PPCP compounds in river water to vary accordingly. In addition, as new and more advanced/exotic personal care products and pharmaceuticals are brought to the market as society advances over the next few decades, it is likely that new trace contaminants could be found in river water.

As analytical techniques improve, additional compounds may be detected that are present but below current detection limits. Because the river provides the primary source of water for the Mojave Valley, many of the compounds present in the river water will eventually be present in groundwater, but it may take many years for them to move from the river to a nearby well. Some of these emerging contaminant compounds are not mobile in the subsurface and may never move far from the river. If fresh water were obtained from a well rather than from

the river, this travel time from the river to a well provides a buffer that might allow for mitigation measures to be implemented prior to injecting an emerging contaminant and having it spread across the site.

Potential Need for Conditioning of River Water Prior to Injection

Based on available data, river water quality is generally good, with relatively low dissolved solids and trace compounds. Maintaining high injection well efficiency is an important consideration for the project regardless of the freshwater source. The common threats to injection efficiency are solids or particulate matter that could clog the well screens, and biological materials (bacteria or microorganisms) that could grow on the well screens reducing the open area. Therefore, solids and bacteria/microorganisms will need to be removed prior to injection.

To avoid the need for filtration and disinfection of water from a river intake, the 30% design discussed the option of drawing water from a shallow infiltration gallery beneath the river bottom. Under this option, the sand in the river bottom would provide filtration, removing suspended solids and microbes. However, the discussion also pointed out that the groundwater in the shallow zone beneath the river contains water that is geochemically reduced and contains elevated concentrations of iron and manganese which could clog the injection wells. It is therefore, likely that a conditioning system would be needed to remove iron and manganese before the water could be used for injection. There was a question as to whether a “river well” could be designed to preferentially filter oxygenated river water from the river and minimize extraction of the geochemically reduced water in the shallow groundwater (#134 DTSC-52). It should be noted that PG&E plans to selectively screen the river bank extraction wells in the lower, oxic portion of the aquifer specifically to avoid pumping the reduced water in the fluvial sediments. It is possible that reduced water may eventually be drawn down into the screened intervals of these wells, however experience with operation of PE-1 suggests that there is significant retardation of iron and manganese. Water in PE-1 has acquired the isotopic signature of river water but iron and manganese concentrations have not increased significantly. PGE-8 and 9 were designed to pump water from the river. They are screened over the entire thickness of the aquifer. After extended purging of these wells over a period of weeks, the water quality remained poor. The river water was not drawn in to any great extent. The Park Moabi infiltration trench was constructed at a shallow depth on the bank of the river and produced water with high TDS, which required RO treatment to be usable. Therefore, prior experience suggests it would be difficult to design a well that would preferentially pump river water.

Therefore, no matter whether the water is extracted directly from the river or beneath the river bed, some type of conditioning system would be needed to make river water suitable for injection. Multi-media filters could be used for solids removal and disinfection for removing bacteria and microorganisms. The process is illustrated schematically in Exhibit 3-6. It is assumed that no advanced treatment would be needed to remove trace / emerging contaminants.

Ferric chloride, a coagulant, would be added upstream of the filters to improve performance by removing more of the fine particles in the River water. Ferric chloride is commonly used in drinking water treatment plants. The filters would be backwashed periodically to remove accumulated solids and the backwash flow would be sent to a cone-bottom decant tank to settle the solids. A polymer would be injected into the stream to aid in settling. Settled solids would be vacuumed out of the decant tank when it reached a pre-designated level. These solids would be pumped to liquid phase separators and the dewatered solids would be disposed of offsite (see Section 3.4 for Implementation Considerations). Water from the decant tank would overflow and be re-processed through the filtration system. More than 90 percent of the water can be recycled this way thereby reducing consumptive water. Filtered water would flow to a surge tank prior to being pumped to the injection wells.

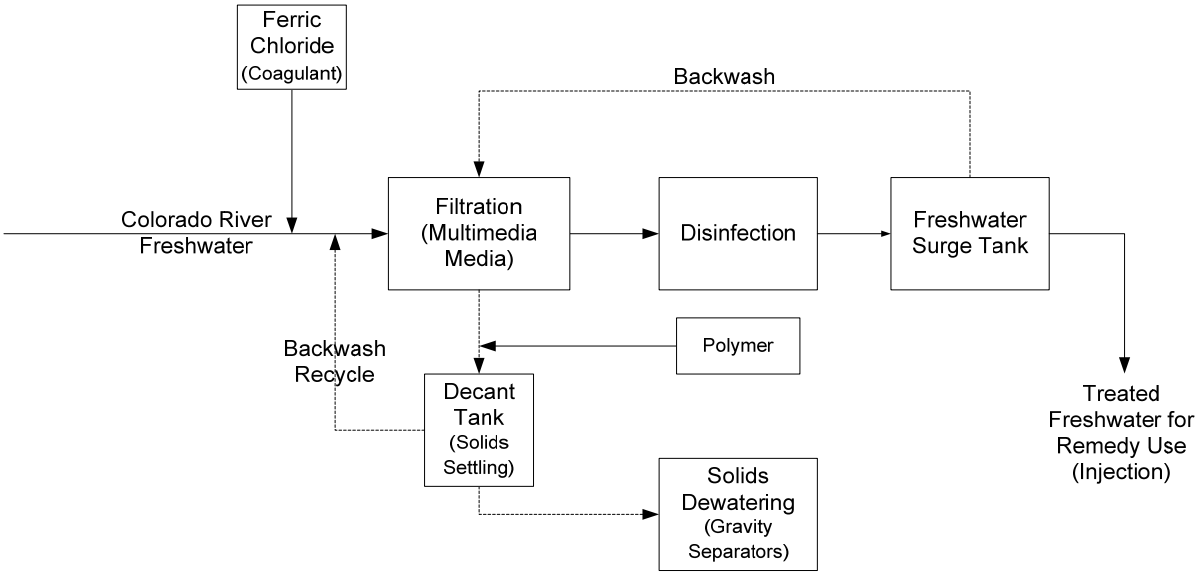


EXHIBIT 3-6
River Water Conditioning Process Schematic
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

Disinfection can be accomplished with chlorination, ultraviolet light, or ozone, and each approach has advantages and disadvantages. Chlorination uses hazardous chemicals such as gaseous chlorine or liquid sodium hypochlorite. It can result in unwanted byproducts such as trihalomethanes and requires dechlorination to remove excess chlorine prior to injection. UV disinfection is a physical disinfection process rather than a chemical disinfection process. It uses electromagnetic energy in the 200 to 300 nanometer wavelength ranges to inactivate microorganisms. UV light is generated by a flow of electrons from an electrical source through ionized mercury vapor within UV lamps. UV lamps are housed in quartz sleeves and arranged in a UV reactor. Ozone is generated electrically and is a very strong oxidizer that is effective for bacterial and microorganism control. The systems require cooling water, an ozone quench system (to remove residual ozone), instrumentation to monitor for ozone leaks since it affects health, and off-gas control to prevent ozone escape to the ambient air. Neither UV nor ozone have residuals which would need to be managed as a waste stream Injecting residual chlorine could potentially impinge on the IRZ and affect performance and introduce chloramines to the aquifer. UV uses no hazardous chemicals, is relatively safe, takes less space, and uses less power than ozone. Therefore, it was considered for this evaluation.

Major equipment would include the following:

- Filters with multiple filter media (e.g., garnet, anthracite, sand) in pressure rated housings complete with piping and automated valves for diverting flow from treatment to backwash modes. Two banks of 3 filters would be installed to treat the entire flow. In each bank (or train), two filters would be in service and one filter in standby or backwash mode to enable full time operation.
- Process pumps for backwash, decant water return, and injection.
- Surge tank for filtered water (20,000 gallons nominal capacity).
- Decant tank (cone-bottom tank) for backwash water storage and solids settling.
- Chemical storage tanks and metering pumps for ferric chloride and polymer.
- A pipe reactor would be built to allow sufficient ferric chloride mixing time before filtration.
- UV lamps would be installed in quartz sleeves fixed inside a stainless steel reactor vessel. Lamps would be replaced periodically.
- Two liquid phase separators (similar to those used at the IM No. 3 groundwater treatment plant)

A conditioning facility to house the equipment is estimated to be 5,400 square feet. It should be noted that the tanks (chemical storage, surge, and decant tanks) and filtration equipment occupies more than 85 percent of the plant footprint. The footprint for UV disinfection is relatively small compared to filtration.

3.3.4 Conclusion

For criterion #3 (Water Quality/Potential Need for Conditioning Prior to Injection), all three candidate water sources have pros and cons. Groundwater from Arizona is the only source that is not expected to require conditioning and the associated construction and operational footprint. River water currently has good quality, but the presence of TSS and organic carbon would likely be detrimental to well performance unless conditioned (filtration/disinfection) prior to injection. From a water quality perspective, the primary risk of using river water as a freshwater source is that it is susceptible to future contamination and the possibility that the water could contain compounds that may become emerging contaminants in the future and require cleanup.

Amongst the two groundwater well options, the California option has significant unknowns. Exploratory drilling is required to find the best well location from a water quantity and quality perspective. If a Park Moabi well is considered, it would be prudent to condition the water since there were reports of sulfide odor in some of the early analyses. There were no iron, manganese, sulfide, or other redox indicators (Dissolved Oxygen, Oxidation Reduction Potential, Nitrate, Total Organic Carbon, etc.) analyzed for the early samples to verify this, so it remains a possibility that the deeper water at Park Moabi could pose well clogging potential.

The Arizona well option (HNWR-1) has an arsenic level above the MCL. Transport modeling predicts that the arsenic will not be mobile in the environment surrounding the proposed injection wells and will attenuate under site conditions and return to pre-remedy baseline levels after the end of active remediation. Therefore, based on the modeling, treatment for arsenic in HNWR-1 water is not needed. Monitoring will be implemented during remedy implementation to verify the modeling results and adjustments will be made as needed. Potential contingency actions include adding ex-situ arsenic treatment or switching to another source (see Section 3.4).

To complete the evaluation/comparison of these options, Section 3.4 considers factors related to implementability and sustainability.

3.4 Evaluation Criterion #4 – Implementability and Sustainability

This section evaluates and compares the three freshwater sources against the fourth criterion – Implementability considerations. This criterion includes the following factors:

- Significance and type of disturbance
  - Volume of soil disturbed, construction duration, new facilities
  - Number and size of components such as wells, pipes, access roads, treatment and support facilities
  - Infrastructure footprint
  - Ability to make use of existing facilities
- Administrative requirements
  - Substantive permitting requirements/approvals, easements/access, compliance with ARARs and EIR mitigation measures
- Maintenance requirements of facilities
- Ease of replacement or redundancy, or implementation of potential contingencies
- Flexibility of design
  - Ability to handle changes in flow and quality

For this evaluation, the Arizona groundwater source will be the HNWR-1 well and the California groundwater source will be one or more hypothetical wells in Moabi Regional Park. River water will be extracted directed from the Colorado River via an intake structure and a fish screen. Multiple locations for an intake structure exist with the Project Area, therefore, surveys were performed to evaluate potential locations from an engineering and fish protection perspective. Below is a summary of the surveys.

3.4.1 Summary of Preliminary Engineering Survey/Evaluation of River Intake Structure and Fish Screen and Fish Habitat Survey

Potential locations for a river intake structure and fish screen within the EIR Project Area were reviewed and field surveyed on March 9, 2012. Locations that are considered not desirable for construction, installation, and operation of an intake structure are areas of known habitats for special-status fish and avian species, other sensitive habitats such as jurisdictional wetlands, areas with shallow waters, and areas with high likelihood for high turbidity water (e.g., along the Arizona shore south of the Topock Marsh). Exhibit 3-6 shows five potential locations evaluated. Attachment B contains the technical memorandum with details on the engineering evaluation.



EXHIBIT 3-6
Potential Locations of River Intake Structure and Fish Screen
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

Initial Design

The initial design criteria for the river intake and fish screen are:

- Design flowrate is 1,200 gpm (the potential maximum flow for freshwater injection)
- A 12-inch intake pipe with a submersible pump and a 30-inch end-of-pipe type fish screen (Exhibit 3-7 presents pictures of a similar design). The fish screen will comply with the California Department of Fish and Game (CDFG) and National Marine Fisheries Service (NMFS) fish screen design criteria for maximum approach velocity and size of screen openings.



EXHIBIT 3-7
Example of End-of-Pipe Type Fish Screen Design
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

The intake structure/fish screen design and the location of the intake structure is subject to Agencies approval. The substantive permitting requirements and requirements for compliance with ARARs/EIR mitigation measures associated with river intake and fish screen are extensive, and so is the potential number of Federal and State Agencies that are likely to be involved. The Federal Agencies will include US Fish and Wildlife Services, the US Army Corps of Engineers, the US Coast Guard, and the Bureau of Reclamation. The State Agencies will include CDFG and State Lands Commission, and could include the Regional Water Quality Control Board and San Bernardino County. Therefore, additional time would be required which may impact the project schedule for consultation with the Agencies throughout the design phase and for obtaining the necessary approvals prior to construction.

For the purpose of this TM, the criteria used to evaluate potential locations for the intake and fish screen are as follows:

- **Long-term Siting** --- Water Depth, Debris Protection, Site Space Constraints, Access for Operations and Maintenance, and Water Quality
- **Construction** --- Constructability, Temporary Construction Impacts, and Relative Costs
- **Approvals/Compliance with ARARs and EIR** --- Right of ways, Fisheries Impact, and Compliance with ARARs/EIR

Implementability issues also arise due to special status fish species that occur in the Topock area, specifically the razorback sucker and the bonytail chub. Both are federally-listed and state-listed as endangered and are covered under the Lower Colorado River Multi-Species Conservation Program. Of special concern is the razorback sucker which is also a California Fully Protected Species. The Colorado River is also designated critical habitat for bonytail chub ~~both fish species~~ under federal law. The Lower Colorado River supports the largest remaining populations of razorback sucker (AECOM 2011). Dam construction and subsequent habitat degradation have led to the decline of these fish species. The ARARs and EIR Mitigation and Monitoring Program for the groundwater remedy contain requirements to protect endangered fish species and to mitigate potential negative impacts from the construction and operation of a river intake structure and fish screen.

Specifically, the DOI Record of Decision (ROD) (DOI 2010) states that "[t]he Selected Remedy will be designed and implemented to attain action-specific ARARs, including, for example, the following. . . . Installation of wells, piping, and reagent storage equipment will be performed in a manner that does not result in a "take" of threatened or endangered species, [or] damage their critical habitat (50 CFR part 402) . . . ." (ROD at 39-40). See also ROD at 57-58 (ARAR Table: "Any remedial action selected for the Topock site will not result in the take of, or adverse impacts to, threatened and endangered species or their habitats, as determined based on consultation with the Fish and Wildlife Service under section 7 of the ESA."). California state law also prohibits the take of state-listed "Fully Protected Species", such as the razorback sucker, except where a conservation plan has been approved and is being implemented to ensure protection of those species pursuant to the California Natural Community

Conservation Planning Act. Preliminary discussion with CDFG indicated that approval of a fish screen and intake structure that would avoid incidental take of the razorback sucker may be difficult to obtain. This issue will need to be explored further, may not be feasible, and would likely add more time to the project.

To assess fisheries impact at the potential intake structure locations, a fish habitat survey was conducted on April 4, 2012 in compliance with the EIR mitigation measure BIO-3b. The purpose of the fish habitat survey is to determine the preferred locations for spawning and rearing of the razorback sucker and bonytail chub. Field methodology included documentation of bottom topography and depth using sonar and GPS, photo documentation of bank area, and visual inspection of substrate using view box from boat and Ponar dredge. A fish habitat assessment report is forthcoming.

General observations from the fish habitat survey are as follows:

- **Sites 1 and 2** - Ranged from 6 to 20 feet water depth in areas 10 to 50 feet from shoreline. Fast currents, bedrock on shoreline grading to boulder, cobble, gravel, and sand.
- **Site 3** - Ranged from 6 to 24 feet water depth in areas 10 to 50 feet from shoreline. Fast currents with calm back eddies; bedrock shoreline grading to boulder, cobble, gravel, and sand. Largemouth bass and their nests seen at this site in shallow, unscoured depositional areas (see Exhibit 3-8).
- **Site 4** - Ranged from 3 to 13 feet water depth in areas 10 to 50 feet from shoreline. Fast currents, bedrock or sand on shoreline grading to boulder, cobble, gravel, and sand. Mostly as bedrock to scoured sand (see Exhibit 3-8).

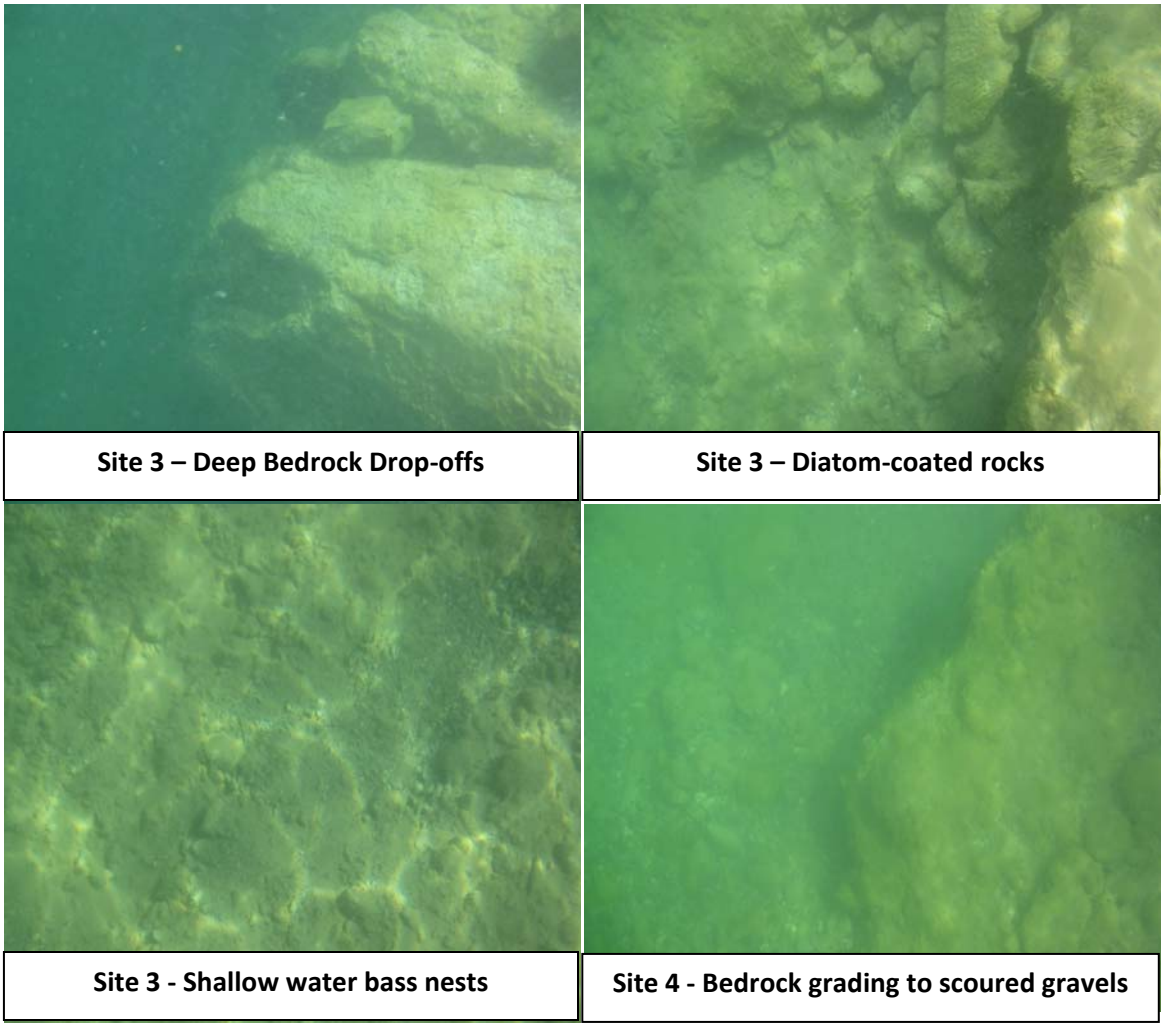


EXHIBIT 3-8
Underwater Views – Sites 3 and 4
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

Based on the preliminary engineering evaluation and fish habitat surveys, Site 4 appears to be the most feasible location for a river intake structure and fish screen (see Exhibit 3-6 above and Exhibit 3-9 below). This location is north of Bat Cave Wash and south of the Moabi Regional Park Slough. The surface of the site is previously disturbed. Consultation and approvals from the agencies will be required prior to the final determination of a suitable location. However, for the purpose of comparing the three freshwater source options, it is assumed that Site 4 is the selected location.



EXHIBIT 3-9
Views of Site 4 from Top of Bank and from the Colorado River
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needle s, California

3.4.2 Summary of Evaluation of Implementability and Sustainability Considerations

Exhibit 3-10 summarizes the evaluation and comparison for the three freshwater sources (the 30% design is also included in the exhibit for reference). The basic assumptions for this evaluation are as follows:

- Infrastructure such as the sunshade, equipment pads, power supply, communications and controls, surge tanks, and conveyance piping will be built to service the maximum flowrate of 1,200 gpm. Information on soil disturbance is based on the infrastructure for the 1,200 gpm flowrate.
- The conditioning components to be housed within the sunshade will be built to service half the maximum flowrate or 600 gpm. Information on energy use, waste generation, and maintenance requirements are based on the 600 gpm flowrate and the assumption that new treatment/conditioning facilities are located at TCS.

Exhibit 3-11 presents a contingency matrix for some of the more serious types of problems that might be associated with the freshwater sources or with the injection of fresh water at the Topock site. This matrix addresses issues associated with river water separate from issues associated with well.

3.4.3 Conclusion

For this criterion #4 (Implementability and Sustainability Considerations), the River water option carries many unknowns compared to the groundwater options. Consultation with Agencies on suitable locations and intake/fish screen design, as well as substantive permitting requirements will be needed, and additional time will be required to comply with these requirements. Additionally, the DOI ROD states that remedial design will be performed in a manner that does not result in a “take” of threatened or endangered species, or damage their critical habitat. California state law also prohibits the take of state-listed “Fully Protected Species”, such as the razorback sucker, except where a conservation plan has been approved and is being implemented to ensure

protection of those species pursuant to the California Natural Community Conservation Planning Act. Preliminary discussion with CDFG indicated that approval of a fish screen and intake structure that would avoid incidental take of the razorback sucker may be difficult to obtain. This issue will need to be explored further, may not be feasible, and would likely add more time to the project.

From a disturbance perspective, disturbance of soil/habitat in the river and on the river bank will occur from construction of the intake structure. Construction would require a coffer dam at the base of the river bank to allow for dewatering of the work area. Further up the bank, construction would require trenching and/or a shoring system within the area excavated for the river intake structure. The coffer dam would be approximately 10 feet by 10 feet if constructed using sheet piles and the trenched area further up the bank could be as wide as 50 feet. The exact footprint of these construction areas would depend on the contractor's means and methods.

Operation of the river intake/fish screen will require routine inspections, more inspections are needed for areas with high debris exposure. Replacement or modification of intake structure can be challenging and time consuming, depending on the nature and extent of repairs needed. With advanced planning and approvals, replacement of a well can be less challenging and less time consuming.

The river supply and CA groundwater supply are assumed to require conditioning prior to use. All new conditioning facilities or arsenic treatment facility will require electricity and strong chemicals for operations and will also generate wastes (e.g., sludge) that will need to be managed. Trained and qualified personnel will be required to operate these facilities. It is anticipated that waste sludge will be disposed offsite at appropriate permitted landfills. The electricity needed to operate these new facilities will add to the electrical loads for the remedy in California. The existing HNWR-1 well will continue to use existing power supplied by Mojave Electric in Arizona.

Using the existing HNWR-1 well is consistent with the mitigation directives in the EIR to give priority to re-use of existing physical improvements. PG&E is working with the Refuge to confirm that this well has sufficient capacity to meet the Refuge's use and that of the remedy. Topock-2/3 wells can be used as backup for HNWR-1 well.

EXHIBIT 3-10
Comparison of Implementability and Sustainability Considerations
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

Factors Considered	Arizona Groundwater		California Groundwater Hypothetical Well(s) in Moabi Regional Park with a Conditioning Facility at TCS	River Water River Intake Structure/Fish Screen at Site 4 and a Conditioning Facility at TCS	Summary
	HNWR-1 with no treatment (30% Design)	**HNWR-1 with Ex-Situ Arsenic Treatment Facility at TCS**			
New Infrastructure Footprint	• Approx. 7,100 feet of new freshwater pipe from HNWR-1 well to the TCS water storage tanks.	• Approx. 7,100 feet of new freshwater pipe from HNWR-1 well to the TCS water storage tanks. • New arsenic treatment plant at TCS (2,000 sq. ft.)	• One or multiple new test wells and extraction well(s) and new access roads. • A new conditioning facility (2,500 sq. ft.) at TCS. Alternate locations include the MW-20 bench and Site 4. • Approx. 7,400 feet of new underground trench from Moabi Regional Park to the northern end of the existing utility corridor at NTH. • The freshwater system would be separate from the TCS freshwater system.	• A new river intake structure and fish screen (with associated electrical/controls equipment) at Site 4. • A new conditioning facility (5,400 sq. ft.) at TCS. Alternate locations include MW-20 Bench and Site 4. • The freshwater system would be separate from the TCS freshwater system.	• In general, the River water option requires a larger footprint than the groundwater options (e.g., a larger conditioning footprint, additional footprint for the river intake structure). • The proposed 30% design (HNWR-1 well) has the least amount of footprint and allows for the use of the existing well and co-use of the TCS freshwater storage tanks. If the arsenic treatment were to be added, the Arizona and California groundwater options will have similar footprint. However, if exploratory drilling north of Moabi Regional Park is needed to find the appropriate quantity and quality of water for the remedy, additional footprint is likely required for new access roads, well vaults/houses, and control/electrical/ communication equipment.
Use of existing facilities	• Existing HNWR-1 well [a] • Existing TCS freshwater storage tanks • Minor surface improvements to HNWR-1 wellhead • Improvements to existing roads	• Existing HNWR-1 well • Existing TCS freshwater storage tanks • Minor surface improvements to HNWR-1 wellhead • Improvements to existing roads	• Use of the existing utility corridor along NTH to transport water to TCS.	• Use of the existing utility corridor along NTH to transport water to TCS.	
Soil disturbance	• The underground trench for the pipeline connecting to the HNWR-1 well is assumed to be 3 feet wide by 3 feet deep and the total length is about 4,000 feet resulting in approximately 1,320 cubic yards of soil disturbed. The trenchless crossing under I-40 in Arizona is 236 feet long (43 cubic yards for a 30 inch diameter casing) and there would be a bore pit and receiving pit (320 cubic yards). An approximate disturbed volume of 1,700 cubic yards of soil would be required.	• The underground trench for the pipeline connecting to the HNWR-1 well is assumed to be 3 feet wide by 3 feet deep and the total length is about 4,000 feet resulting in approximately 1,320 cubic yards of soil disturbed. The trenchless crossing under I-40 in Arizona is 236 feet long (43 cubic yards for a 30 inch diameter casing) and there would be a bore pit and receiving pit (320 cubic yards). An approximate disturbed volume of 1,700 cubic yards of soil would be required. • Soil disturbance related to construction of the new arsenic treatment facility (2,000 sq. ft.). Soil borings needed for foundation design of the new treatment facility.	• An estimated 7,400-foot long section of new underground trench (3’ wide by 3’ deep) with a total disturbed volume of 2,460 cubic yards of soil would be required. All other pipe is assumed to follow the existing utility corridor. • Soil disturbance related to construction of the new conditioning facility (2,500 sq. ft.). Soil borings needed for foundation design of the new conditioning facility.	• To pipe water from the intake structure at Site 4, a 100-foot long section of new underground trench (3’ wide by 3’ deep) with a total disturbed volume of 33 cubic yards would be required. The remaining pipe run to the TCS will follow the existing utility corridor. • Disturbance related to construction of the new conditioning facility (5,400 sq.ft.). Soil borings needed for foundation design of the new conditioning facility. • Construction of the river intake structure would require a coffer dam at the base of the river bank to allow for dewatering of the work area. Further up the bank, construction would require trenching and/or a shoring system within the area excavated for the river intake structure. The coffer dam would be approximately 10 feet by 10 feet if constructed using sheet piles and the trenched area further up the bank could be as wide as 50 feet; the exact footprint of these construction areas would depend on the contractor’s means and methods. • Geotechnical borings needed for engineering design.	• The volume of soil disturbed is smaller for the Arizona groundwater option (HNWR-1 well) than the California option because of the trenchless crossing under I-40 in Arizona. • With regards to construction of conditioning facilities, the River water option has the largest soil disturbance associated with the largest facility footprint. • Construction of the river intake structure will disturb soil on the bank of the river as well as soil in the river. The exact amount of soil disturbance and associated impacts will depend on further consultation with the Agencies on the intake/fish screen design, suitable locations, and further details on the mitigation measures that would be required for the construction and operation of such structure on the bank of the Colorado River. The coffer dam would be approximately 10 feet by 10 feet if constructed using sheet piles and the trenched area further up the bank could be as wide as 50 feet; the exact footprint of these construction areas would depend on the contractor’s means and methods.

EXHIBIT 3-10
Comparison of Implementability and Sustainability Considerations
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

Factors Considered	Arizona Groundwater		California Groundwater Hypothetical Well(s) in Moabi Regional Park with a Conditioning Facility at TCS	River Water River Intake Structure/Fish Screen at Site 4 and a Conditioning Facility at TCS	Summary
	HNWR-1 with no treatment (30% Design)	**HNWR-1 with Ex-Situ Arsenic Treatment Facility at TCS**			
Energy Use [b]	• 1,400,000 kw-hr/year for the HNWR-1 well pump **(source of electricity is Mohave Electric Cooperative in Arizona)**	• 1,400,000 kw-hr/year for the HNWR-1 well pump **(source of electricity is Mohave Electric Cooperative in Arizona)** • **New electric loads in California**: o 4,000 kw-hr/year for process pumps o 175,000 kw-hr/year for additional facilities (an allowance for items like heating & cooling, lights, chemical metering pumps, instruments, power panels and transformers)	• **New electric loads in California**: o 6,000 kw-hr/year for process pumps o 1,100,000 kw-hr/year for the Moabi Regional Park well pump o 175,000 kw-hr/year for additional facilities (an allowance for items like heating & cooling, lights, chemical metering pumps, instruments, power panels and transformers)	• **New electric loads in California**: o 17,000 kw-hr/year for process pumps o 11,000 kw-hr/year for UV disinfection o 1,100,000 kw-hr/year for the river intake pump o 175,000 kw-hr/year for additional facilities (an allowance for items like heating & cooling, lights, chemical metering pumps, instruments, power panels and transformers)	• The existing HNWR-1 well is powered by Mohave Electric Cooperative in Arizona, and is designed as such in the 30%. • The new conditioning facilities at TCS, the new hypothetical wells in Moabi Regional Park, and the new river intake structure/fish screen will all require electricity to operate and will add to the current electrical loads for the remedy in California.
Waste Generation		• The arsenic treatment system will generate between 40 and 195 cubic yards of dewatered sludge per year. The sludge is assumed to be non-hazardous and hauled offsite to an appropriate landfill in 4 to 20 phase separators bins.	• The conditioning system will generate 150 to 310 cubic yards of dewatered sludge per year. This will result in 15 to 31 phase separator bins being hauled offsite to an appropriate Class III landfill.	• The conditioning system will generate 100 to 670 cubic yards of dewatered sludge per year. This will result in 10 to 67 phase separator bins being hauled offsite to an appropriate Class III landfill.	• Sludge will be generated from conditioning/ treatment facilities. In general, the River water option will generate more sludge than the groundwater options as the ground acts as a natural filter for the extracted groundwater.
Maintenance Requirements		• This type of equipment is commonly used in water treatment facilities across the country and should be operated by trained personnel. • It is estimated that 10 to 30 chemical deliveries (ferric chloride, sodium hypochlorite and polymer) would be required per year. • Safety procedures need to be followed during chemical loading transfers and to make sure safe chemical injection occurs to prevent worker exposures or releases to the environment. Both chemicals (hypochlorite and ferric chloride) although widely used are strong chemicals.	• This type of conditioning equipment is commonly used in water treatment facilities across the country and should be operated by trained personnel. • It is estimated that 20 to 27 chemical deliveries (sodium bisulfite, sodium hypochlorite, and polymer) would be required per year. • Safety procedures need to be followed during chemical loading transfers and to make sure safe chemical injection occurs to prevent worker exposures or releases to the environment. These chemicals (sodium hypochlorite and bisulfite), although widely used are strong chemicals.	• This type of conditioning equipment is commonly used in water treatment facilities across the country and should be operated by trained personnel. • Maintenance of river intake and fish screen requires routine inspection similar to typical pumping facilities. Annual maintenance would include changing the oil filter on the power unit and miscellaneous maintenance. The screen itself will be visually inspected when the river is low; more frequent visual inspections would be required in areas where the debris exposure is high. • It is estimated that 10 to 22 chemical deliveries (ferric chloride and polymer) would be required per year. • Safety procedures need to be followed during chemical loading transfers and to make sure safe chemical injection occurs to prevent worker exposures or releases to the environment. Although widely used, ferric chloride is a strong chemical.	• For all three options, the aboveground conditioning/treatment facilities will require trained and qualified personnel to maintain and operate the system. Strong chemicals will be used in all processes. The amount of chemical use and frequency of chemical deliveries will depend on actual water quality. • The River water option will require additional O&M of the river intake and fish screen. Routine inspection is necessary. Frequent visual inspections of the fish screen is recommended, especially in areas with high debris exposure; therefore, higher likelihood the structure being damaged by debris.

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Comparison of Implementability and Sustainability Considerations
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PG&E Topock Compressor Station, Needles, California

Factors Considered	Arizona Groundwater		California Groundwater Hypothetical Well(s) in Moabi Regional Park with a Conditioning Facility at TCS	River Water River Intake Structure/Fish Screen at Site 4 and a Conditioning Facility at TCS	Summary
	HNWR-1 with no treatment (30% Design)	HNWR-1 with Ex-Situ Arsenic Treatment Facility at TCS			
Administrative requirements	• Easements and access agreements would be needed for the operation of HNWR-1, road improvements, and construction under I-40. • Modification to lease with State Lands Commission for adding pipe to bridge would be required. • Use of HNWR-1 (on the Refuge) will require agreement with the USFWS.	• Easements and access agreements would be needed for the operation of HNWR-1, road improvements, and construction under I-40. • Modification to lease with State Lands Commission for adding pipe to bridge would be required. • Use of HNWR-1 (on the Refuge) will require agreement with the USFWS.	• Easements and access agreements would be needed for exploration drilling to locate, as well as installation of new well(s), new facility at Site 4, road improvements and construction under I-40.	• Easements and access agreements would be needed for construction of new river water conditioning facility, road improvements, and construction under I-40 on non-federal lands. • The river intake structure location/design, and the fish screen design requires approvals from Agencies. Compliance with the substantive requirements of the identified ARARs and the EIR mitigation measures for the construction and operation of the intake structure/fish screen is extensive. The DOI ROD states that remedial design will be performed in a manner that does not result in a "take" of threatened or endangered species, or damage their critical habitat. California state law also prohibits the take of state-listed "Fully Protected Species", such as the razorback sucker, except where a conservation plan has been approved and is being implemented to ensure protection of those species pursuant to the California Natural Community Conservation Planning Act. Preliminary discussion with CDFG indicated that approval of a fish screen and intake structure that would avoid incidental take of the razorback sucker may be difficult to obtain. This issue will need to be explored further, may not be feasible, and would likely add more time to the project. • Federal -- Compliance with substantive permitting requirements includes Section 404 of the Clean Water Act, Endangered Species Act (ESA) Section 7, and Section 10 River and Harbors Act. • State -- Compliance with substantive permitting requirements includes Section 1601 under the California Department of Fish and Game Code, California Endangered Species Act, Section 401 of the Clean Water Act, Clean Water Act Section 402 Construction SWPP, leases under State Lands Commission, etc. Additional consultation would be required if the project design included a log screen or upstream diversion structure to protect the intake from surface and submerged debris.	• Additional time will need to be budgeted in the project schedule to fulfill the administrative requirements anticipated for both the California groundwater and the River water options. • At this time, the implementability/feasibility of the River water option cannot be determined without consultation with the Agencies on suitable locations, the intake/fish screen design, associated mitigation measures and anticipated impacts to endangered species and designated critical habitat. Multiple agencies will need to be consulted. • If exploratory drilling is required to site a suitable well location in California, research on property ownership and any required easements access agreements will need to be secured. • Use of the HNWR-1 well will require an agreement with the USFWS.

EXHIBIT 3-10
Comparison of Implementability and Sustainability Considerations
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

Factors Considered	Arizona Groundwater		California Groundwater	River Water	Summary
	HNWR-1 with no treatment (30% Design)	HNWR-1 with Ex-Situ Arsenic Treatment Facility at TCS	Hypothetical Well(s) in Moabi Regional Park with a Conditioning Facility at TCS	River Intake Structure/Fish Screen at Site 4 and a Conditioning Facility at TCS	
Flexibility of design	• Can accommodate moderate changes in flow (up to maximum 1200 gpm) as remedy needs dictate. • Changes in water quality or quantity at the HNWR-1 well would require rehab or installation of new wells, with backup from Topock 2 and 3, if needed.	• Can accommodate moderate changes in flow (up to maximum 1,200 gpm) as remedy needs dictate. • Changes in water quality or quantity at the HNWR-1 well would require rehab or installation of new wells, with backup from Topock-2/3 wells, if needed.	• Can accommodate moderate changes in flow (up to maximum 1,200 gpm) as remedy needs dictate. • Changes in water quality or quantity at the well would require rehab or new wells, with backup from Topock-2/3, if needed.	• Can accommodate moderate changes in flow (up to maximum 1,200 gpm) as remedy needs dictate. • Source vulnerable to changes in water quality as a result of upstream discharges or spills. • Short term changes in water quality at the intake would require shut down and reliance on stored water. Permanent changes in water quality would require alternative source.	• The aboveground infrastructure needed for the options will be designed with flexibility to accommodate the quantity needed by the remedy (up to the maximum flow of 1,200 gpm). • For the HNWR-1 well, PG&E is working with the Refuge to confirm that this well has sufficient capacity to meet the Refuge's use and that of the remedy. Topock-2/3 wells can be used as backup for HNWR-1 well. • With advanced planning and approvals in the design, installation of new wells (in the vicinity of HNWR-1) can be executed with fewer challenges and require less time than installation of a new river intake structure.
Ease of replacement or redundancy	• New wells would require exploration and drilling new wells, rerouting of piping will be required. • With proper planning, pumps and associated parts can be replaced with ease.	• New wells would require exploration and drilling new wells, rerouting of piping will be required. • With proper planning, pumps and associated parts can be replaced with ease.	• New wells would require exploration and drilling new wells, rerouting of piping of pipe will be required. • With proper planning, pumps and associated parts can be replaced with ease.	• Replacement or modification to river intake structure can be made, the degree of ease or difficulty depends on the nature and extent of the modifications required. • With proper planning, pumps and associated parts can be replaced.	• With advanced planning and approvals in the design, installation of new wells (in the vicinity of HNWR-1) can be executed with fewer challenges and require less time than installation of a new river intake structure. • Replacement or modification to river intake structure can be made, the degree of ease or difficulty depends on the nature and extent of the modifications required.

Notes - Additional design and optimization, siting considerations (including alternate locations for conditioning facilities), testing, and analysis may result in altered configurations and different equipment being selected and changing the estimated values described in this TM. Alternate locations for conditioning facilities include Site 4 and MW-20 Bench.

[a] HNWR-1 well has sufficient capacity for the remedy. Please note that PG&E is coordinating with the Refuge to confirm this assumption.

[b] Energy usage for pumps based on calculated motor nameplate power.

EXHIBIT 3-11
Contingency Matrix
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

	Failure Mode	Likely Causes for Failure	Effects of Failure	Possible Contingency Measures
Failure Modes Associated with Groundwater Source	Well yield declines below the minimum required for optimal remedy operation	• Extraction well fouling • Excessive drawdown due to competing water users	• Delay in reaching RAOs • Potential westerly spread of water from "inner loop" injection wells	• Rehab or replace fouled well • Seek other location for well(s) • Seek alternative freshwater water supply to augment primary supply • Enforce institutional control to prevent excessive drawdown from competing water users
	Quality of water in freshwater well declines over time	• Pumping draws in saline water from below or geochemically reduced water from river / marsh	• Could result in shutting down remedial action if water quality is not suitable for injection	• Install treatment to remove harmful constituents • Seek other sources of fresh water or other locations for well(s)
	Freshwater pumping causes adverse effects on water quality or capacity in nearby wells	• Over pumping of aquifer in areas with marginal groundwater quality / transimssivity	• Could result in shutting down remedial action if affected water users cannot be made whole	• Seek other sources of fresh water or other locations for well(s) • Provide alternate water supply for affected water users
	Arsenic is more mobile or persistent than expected after injection	• Heterogeneity of geochemical and/or hydraulic conditions in the aquifer near freshwater injection wells	• Could result in shutting down remedial action if there is a risk that harmful concentrations of arsenic could reach receptors	• Implement arsenic treatment on all or part of freshwater stream • Seek other source of fresh water
Failure Modes Associated with River Source	Short term or localized decline in water quality	• Spill or release of harmful substance into river between Topock and Davis Dam	• Could result in shutting down remedial action if water quality is not suitable for injection	• Shut down freshwater injection until harmful substance flushes out (likely a few days to a week) • Implement interim treatment to remove harmful substance prior to injection

EXHIBIT 3-11
Contingency Matrix
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

	Failure Mode	Likely Causes for Failure	Effects of Failure	Possible Contingency Measures
	Long term or regional decline in river water quality	• Major spill or release of harmful substance to river basin, such as collapse of uranium tailings dam in Utah • Identification of a new emerging contaminant in the river system, such as with perchlorate in the 1990's	• Could result in shutting down remedial action if water quality is not suitable for injection • In worst case, could result in the need to clean up a plume of an emerging contaminant that had been injected prior to being identified.	• Seek other source of fresh water • Implement treatment to remove harmful substance prior to injection

4.0 Selection of Preferred Freshwater Source

All of the freshwater options evaluated have some advantages and some drawbacks. The following section summarizes the relative strengths and weaknesses of each option and proposes a preferred option.

The HNWR-1 well is a proven water source, and initial testing shows that the capacity of nearby wells would not be affected if fresh water for the remedy was obtained from HNWR-1. The fact that it is an existing well with power already connected means that there would be less disturbance associated with use of HNWR-1 than with construction of a new well or river intake. The TDS of the HNWR-1 water is well within the requirements for the remedy. Piping can be routed over existing corridors between HNWR-1 and the compressor station. The primary drawback to the use of HNWR-1 is the elevated concentration of arsenic in the well. Geochemical modeling indicates that this arsenic will not migrate far from the injection points and will dissipate within a reasonable period of time after the completion of the remedy. If arsenic does not behave as predicted, a treatment plant could be constructed at the compressor station to remove arsenic from the water prior to injection. Another possible drawback is that HNWR-1 is located outside the existing APE, but this is offset because by using an existing well, the disturbance that would be associated with installation of new well can be avoided, and the APE can be amended under the Programmatic Agreement should use of HNWR-1 be selected as desirable.

Water obtained from a well or wells near Moabi Regional Park in California would likely not have arsenic elevated above the MCL. Electric power is available nearby and there is a pipeline route along National Trials Highway to deliver the water to the compressor station. The primary drawback is that the aquifer at Moabi Regional Park does not appear to be capable of delivering a sufficient quantity of water for the remedial action without adversely affecting the quality and quantity of water available from the existing wells that supply water to Moabi Regional Park. It is also likely that the TDS of the water from a high capacity well would be greater than 3,000 mg/L, making it undesirable for injection into the less saline, upper portions of the aquifer at the Topock site. It might also contain iron and manganese at concentrations that would require conditioning prior to injection.

It is possible that a well or wells drilled some distance to the north of Moabi Regional Park might provide an adequate supply of freshwater, but these wells would be far outside the existing APE in a relatively undisturbed area with no power or improved roads. Exploratory drilling would be required to determine if the aquifer in this area north of the Park could provide a sufficient quantity and quality of water. Piping and power would need to be extended over relatively large distances through a relatively undisturbed area. There would likely be significant delays to the project associated with development of a water supply from wells north of Moabi Regional Park.

A river intake structure could offer a secure source of water for the duration of the remedy. Availability of water from the river would not be affected by development in the local area. The river water has low TDS, As, and Cr(VI). One of the key drawbacks to a river intake is the process and the time needed for getting approvals (which may ultimately be infeasible) and authorizations necessary prior to construction. Multiple agencies will be involved in the consultation and approvals. Specifically, the DOI ROD states that remedial design will be performed in a manner that does not result in a “take” of threatened or endangered species, or damage their critical habitat. California state law also prohibits the take of state-listed “Fully Protected Species”, such as the razorback sucker, except where a conservation plan has been approved and is being implemented to ensure protection of those species pursuant to the California Natural Community Conservation Planning Act. Preliminary discussion with CDFG indicated that approval of a fish screen and intake structure that would avoid incidental take of the razorback sucker may be difficult to obtain. This issue will need to be explored further, may not be feasible, and would likely add more time to the project.

In addition, river water needs to be conditioned to remove suspended solids and bacteria. Presuming that a river intake structure could be allowed to be built within the Project Area, there would be disturbance associated with the construction of the structure and a cofferdam and the associated conditioning facility. Lastly, the river water contains some trace contaminant compounds such as perchlorate, pharmaceuticals, and personal care products, these might in the future become contaminants of concern, requiring treatment or possible remediation of the area affected by the freshwater injection.

After reviewing the available options for a freshwater supply, the use of the HNWR-1 well presents less uncertainty, less risk to project schedule, and less disturbance of the site. Arsenic treatment is not necessary and the arsenic will be monitored during the progress of the remedy. Because the contingency of arsenic treatment could be implemented within the compressor station property, the downtime due to approvals and consultation could be minimized with pre-planning. HNWR-1 is therefore considered the preferred freshwater supply option for the remedial action.

5.0 References

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Figures

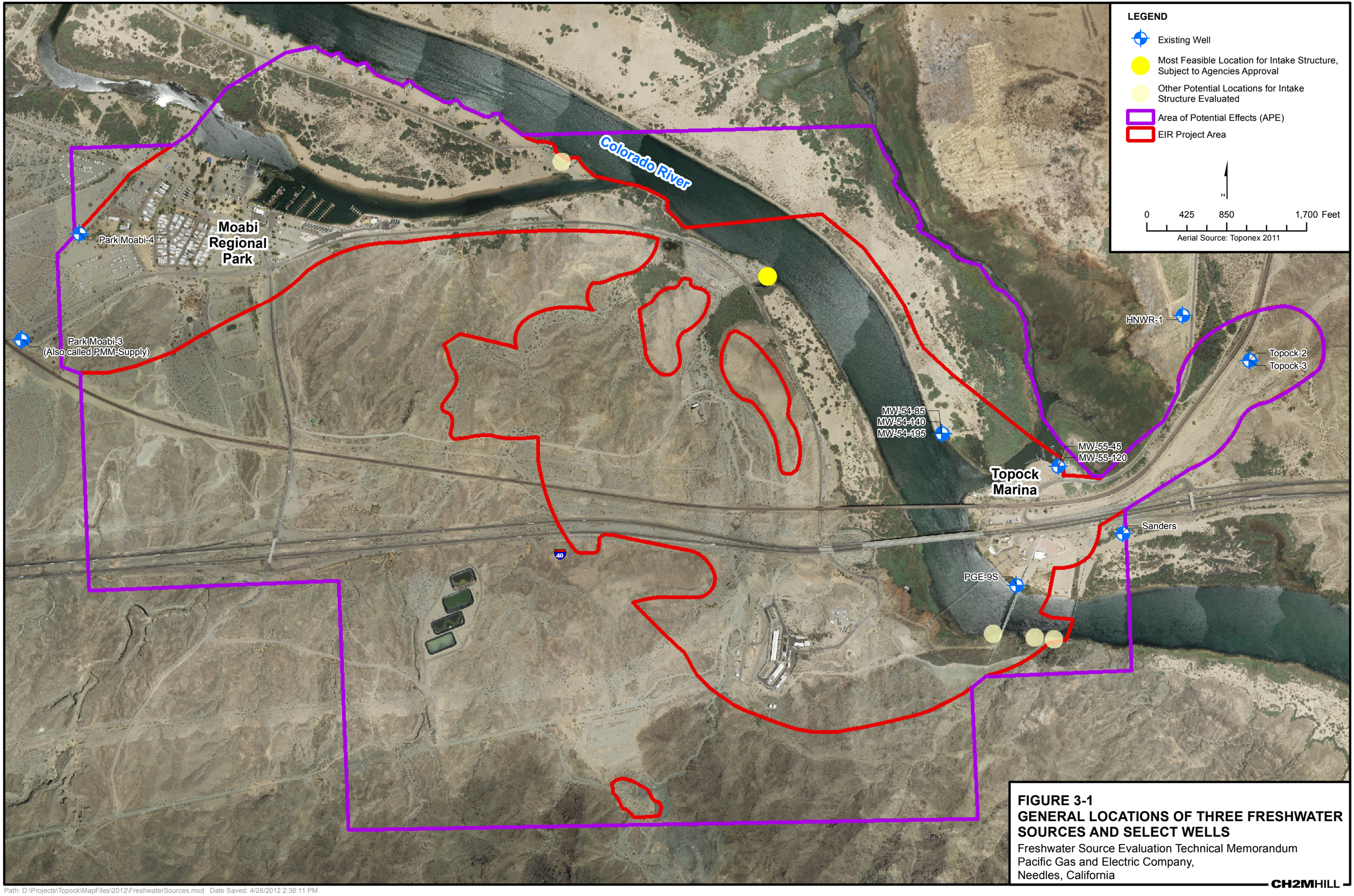
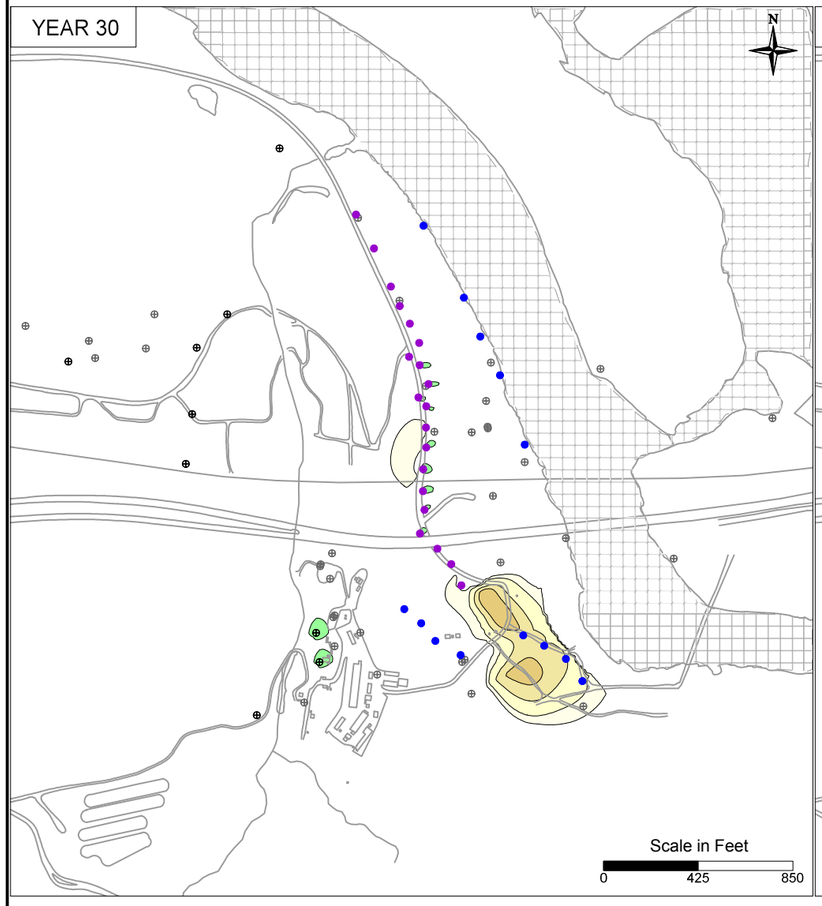


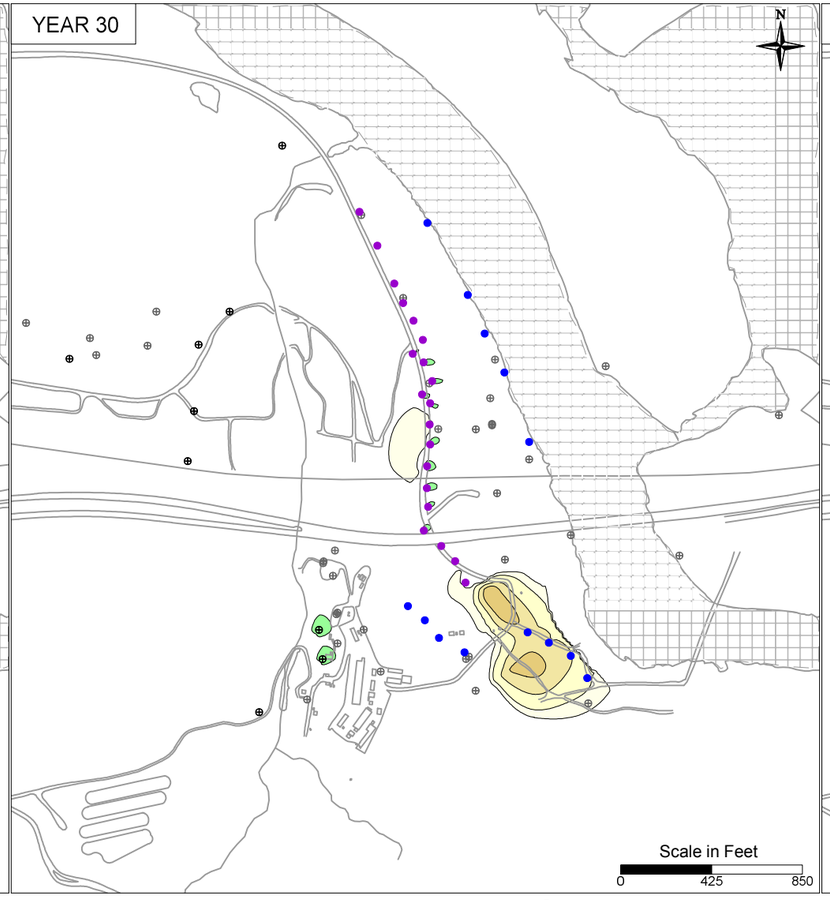
FIGURE 3-1
GENERAL LOCATIONS OF THREE FRESHWATER SOURCES AND SELECT WELLS
Freshwater Source Evaluation Technical Memorandum
Pacific Gas and Electric Company,
Needles, California

CH2MHILL

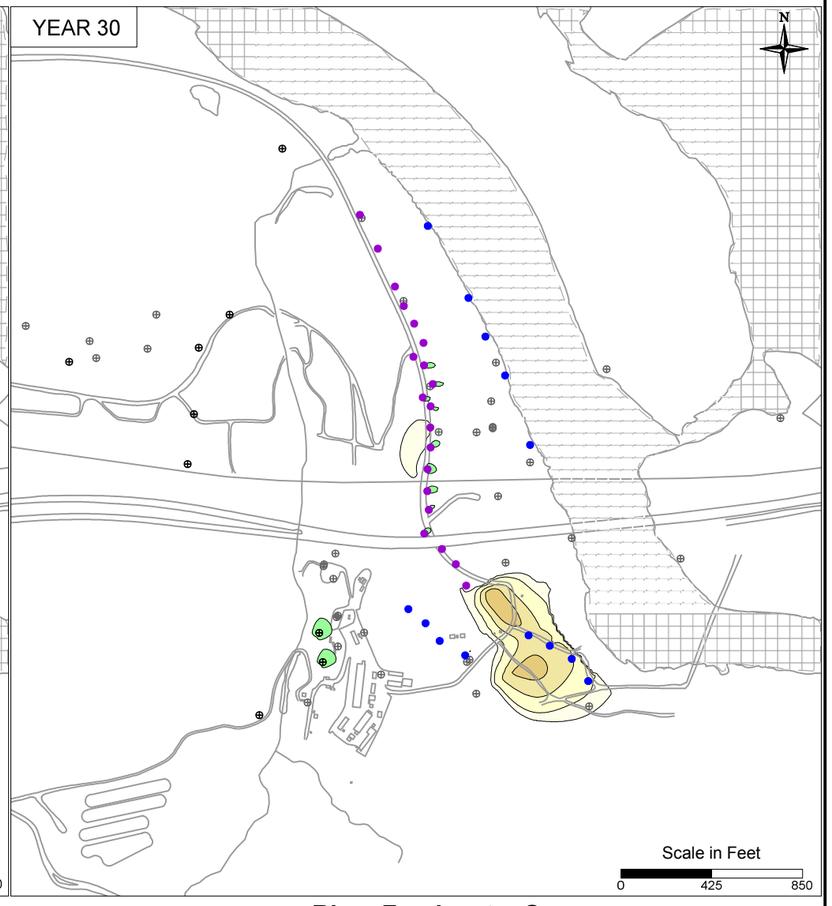
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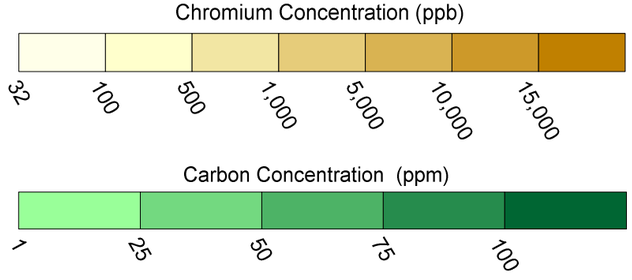
HNWR-1 Freshwater Source



Park Moabi Freshwater Source



River Freshwater Source



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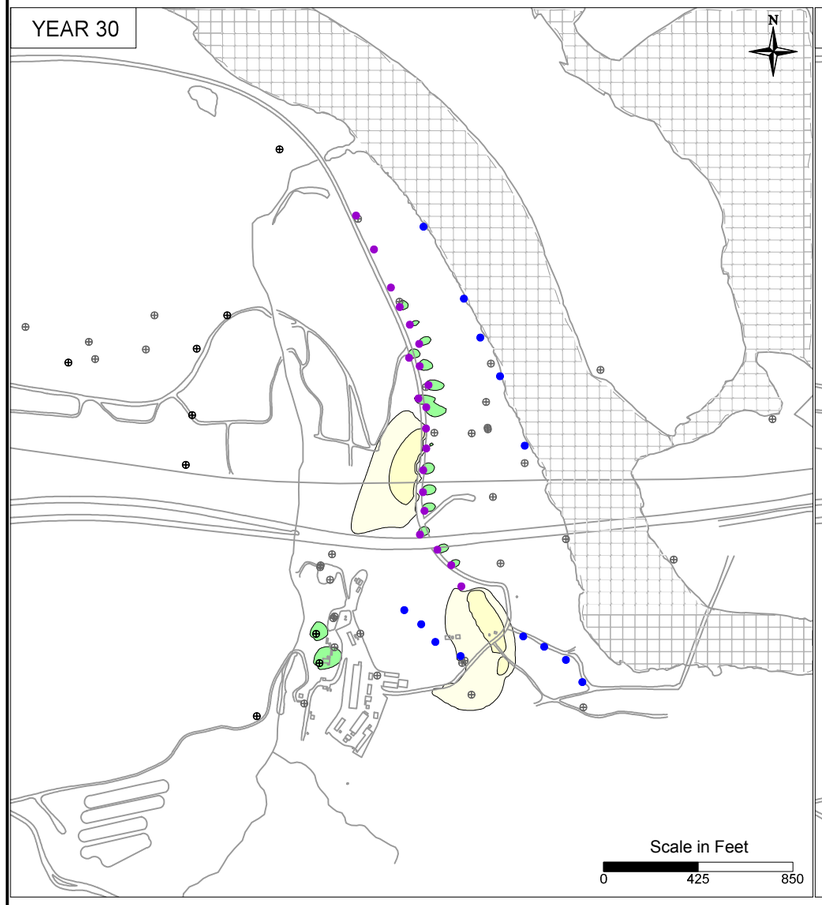
- IRZ WELLS
- UPGRADIENT INJECTION WELLS
- EXTRACTION WELLS
- MONITORING WELLS

PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
MODELING APPENDIX

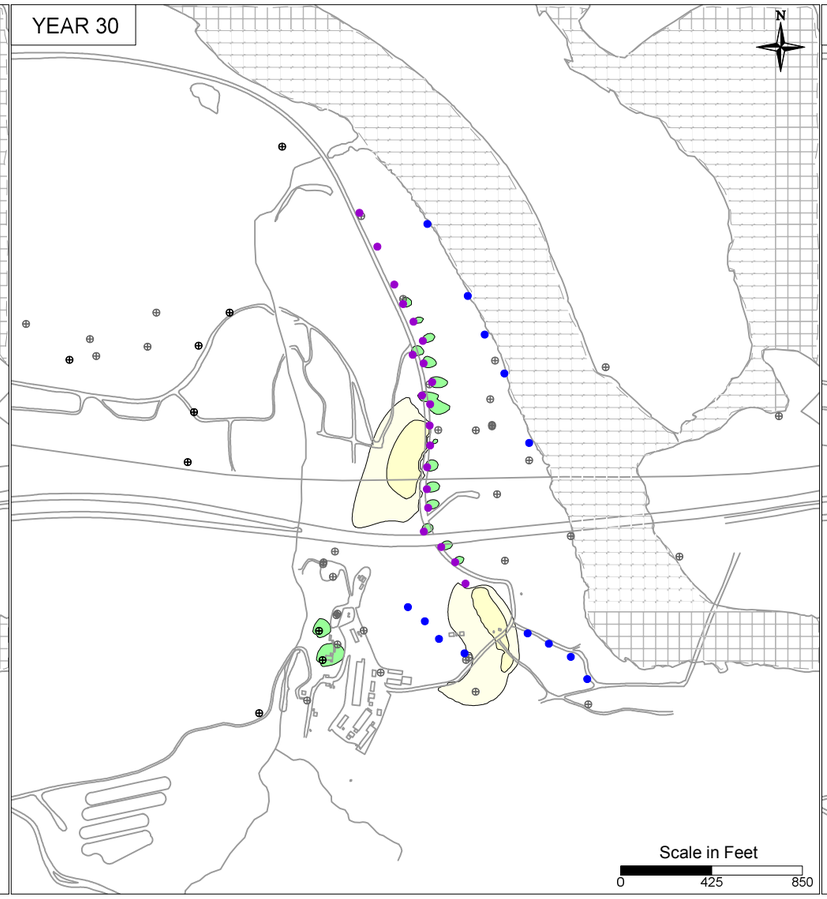
FRESHWATER SOURCE EVALUATION:
30 YEAR SIMULATED HEXAVALENT CHROMIUM TRANSPORT RESULTS IN MODEL LAYER 1

ARCADIS

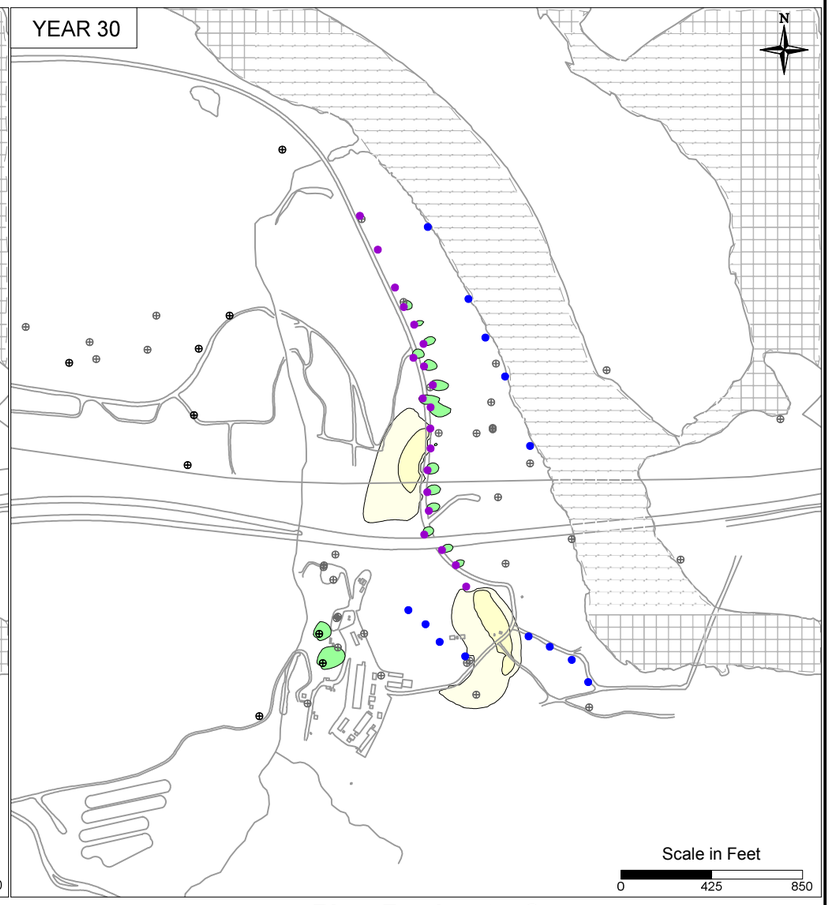
FIGURE
3-2



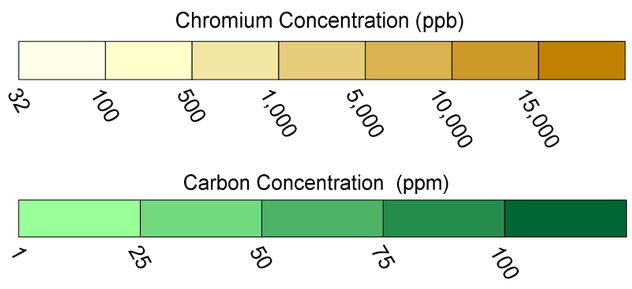
HNWR-1 Freshwater Source



Park Moabi Freshwater Source



River Freshwater Source



LEGEND

- IRZ WELLS
- UPGRADIENT INJECTION WELLS
- EXTRACTION WELLS
- MONITORING WELLS

PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
MODELING APPENDIX

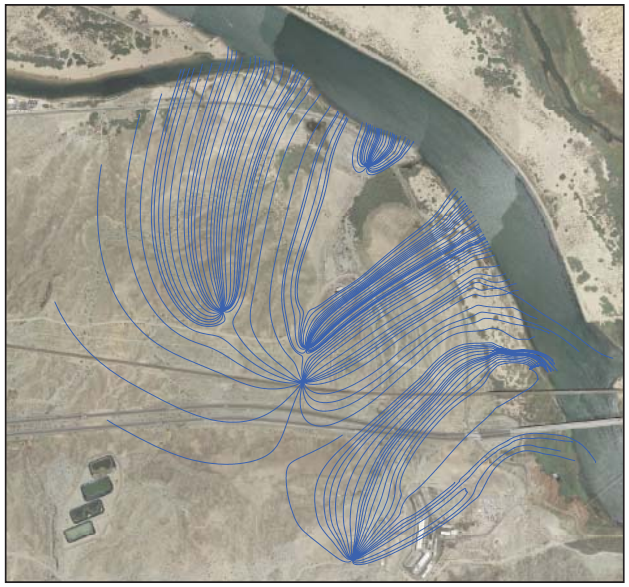
FRESHWATER SOURCE EVALUATION:
30 YEAR SIMULATED HEXAVALENT CHROMIUM TRANSPORT RESULTS IN MODEL LAYER 3

ARCADIS

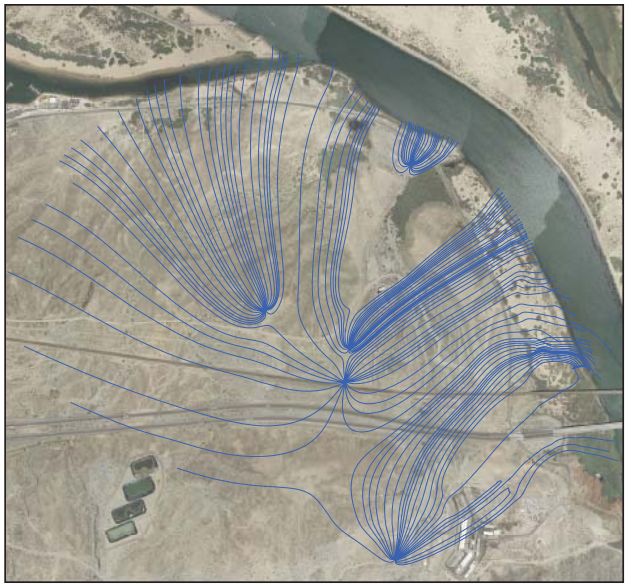
FIGURE
3-3

Sub-surface particle tracks from Freshwater Injection Points (Layer 1)

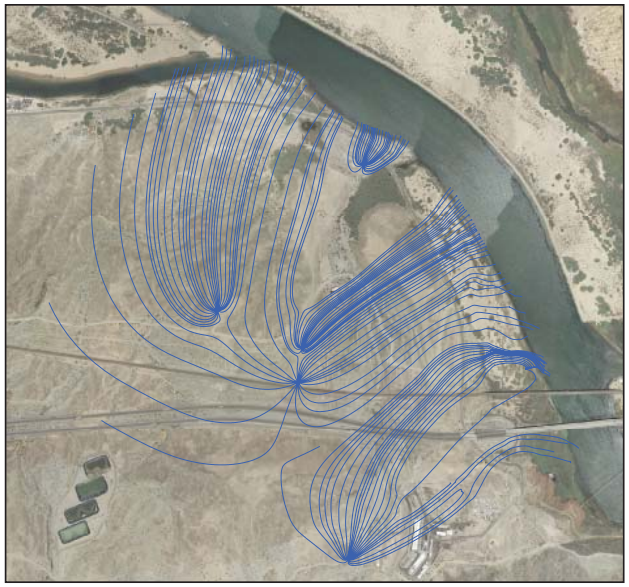
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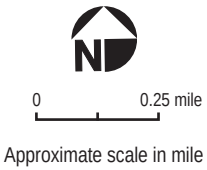
HNWR-1



Park Moabi



River

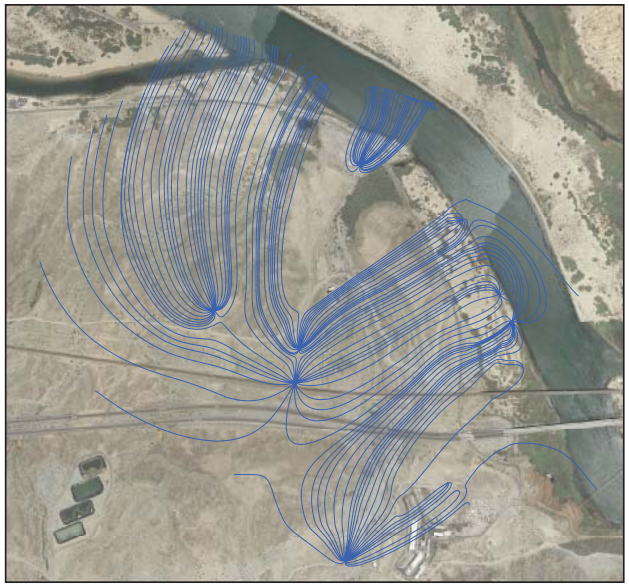


Approximate scale in mile

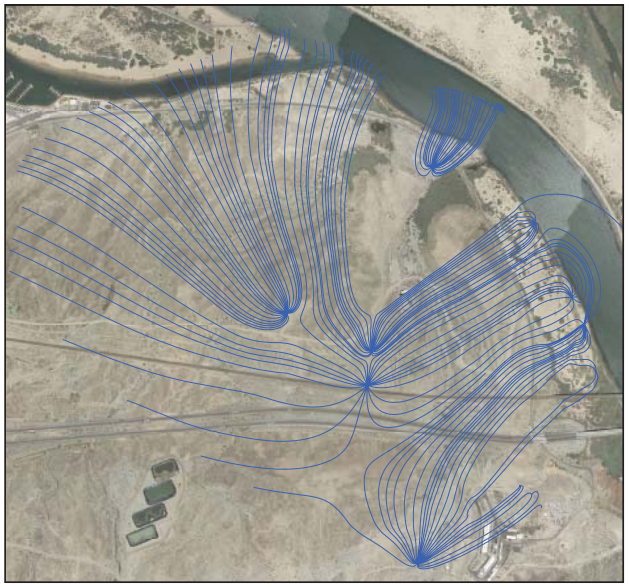
FIGURE 3-4
Freshwater Source Evaluation Technical Memorandum
PG&E Topock Compressor Station
Needles, California

Sub-surface particle tracks from Freshwater Injection Points (Layer 3)

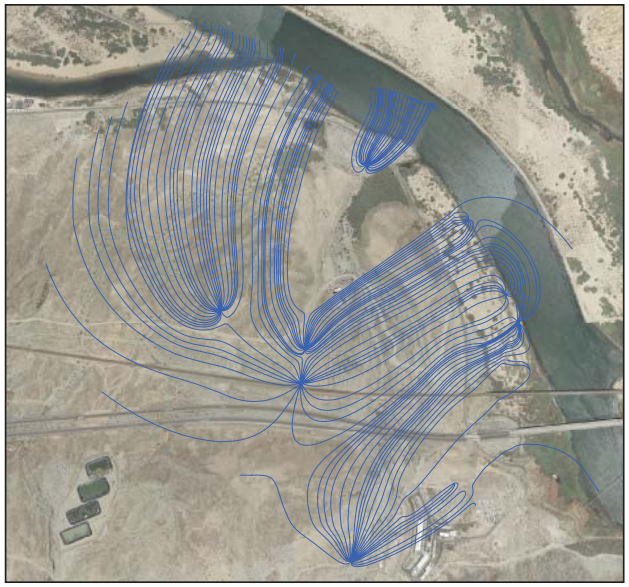
Simulation Time = 30 yr



HNWR-1



Park Moabi



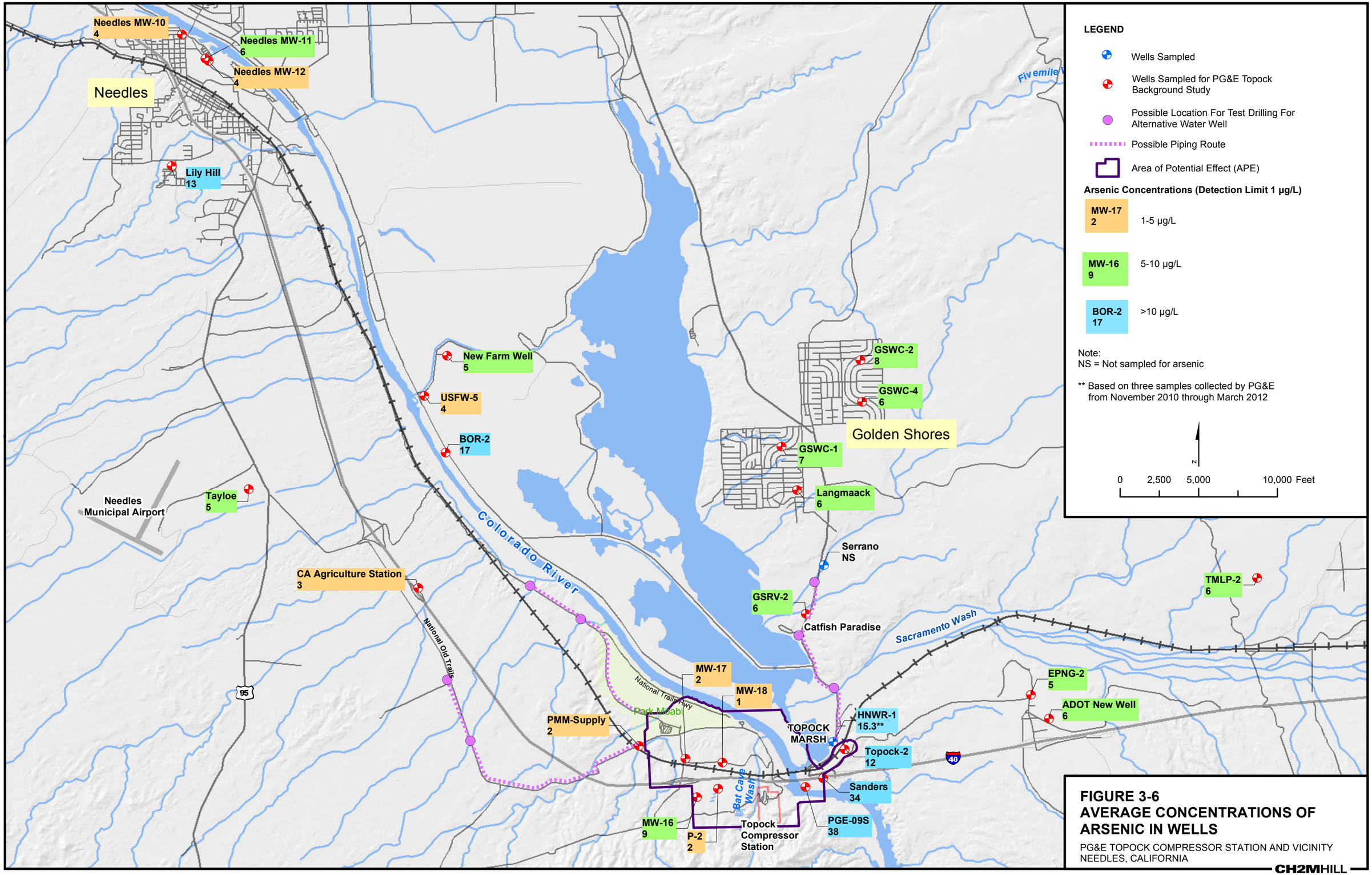
River



Approximate scale in mile

FIGURE 3-5
Freshwater Source Evaluation Technical Memorandum
PG&E Topock Compressor Station
Needles, California

CH2MHILL



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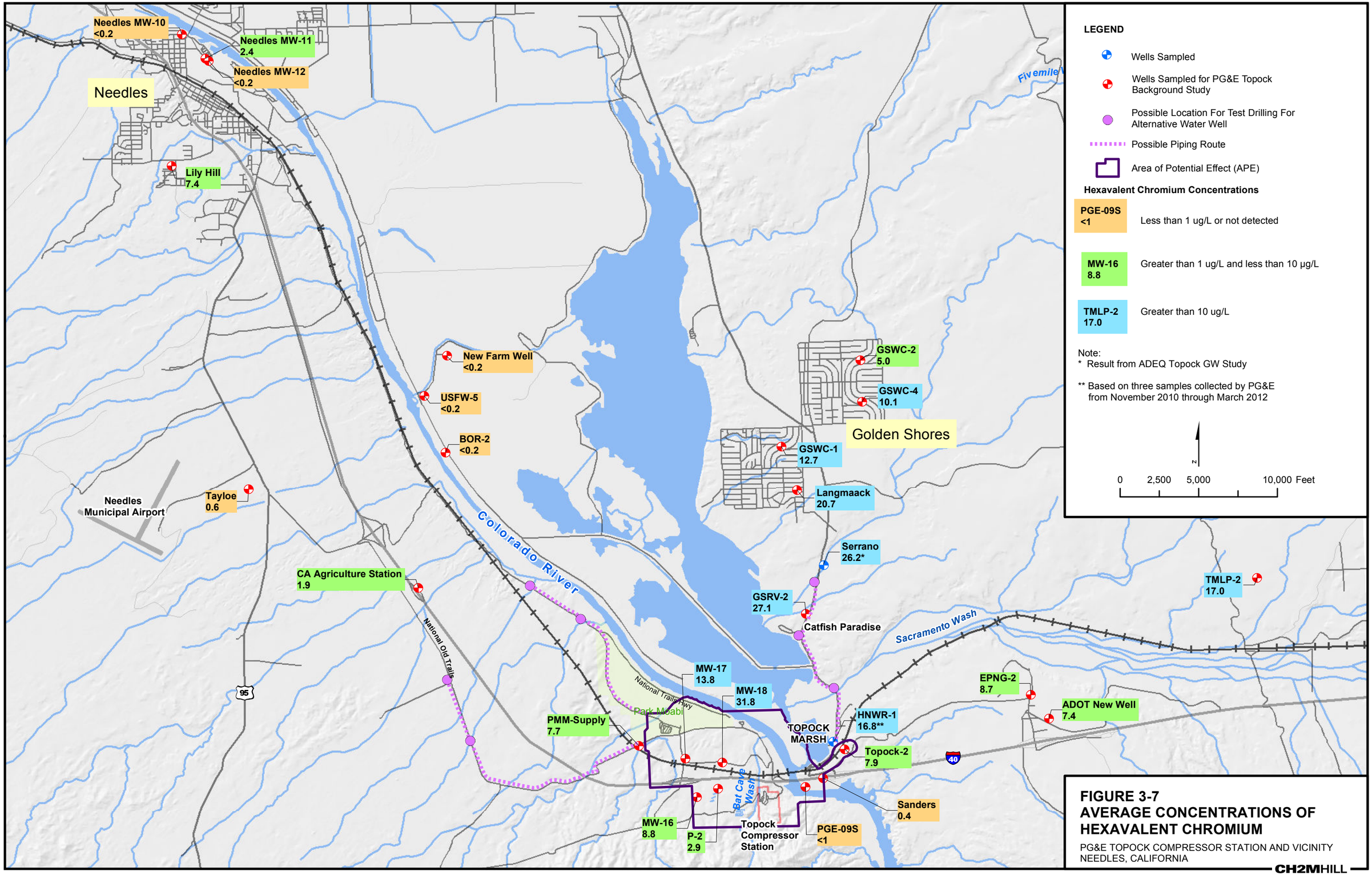
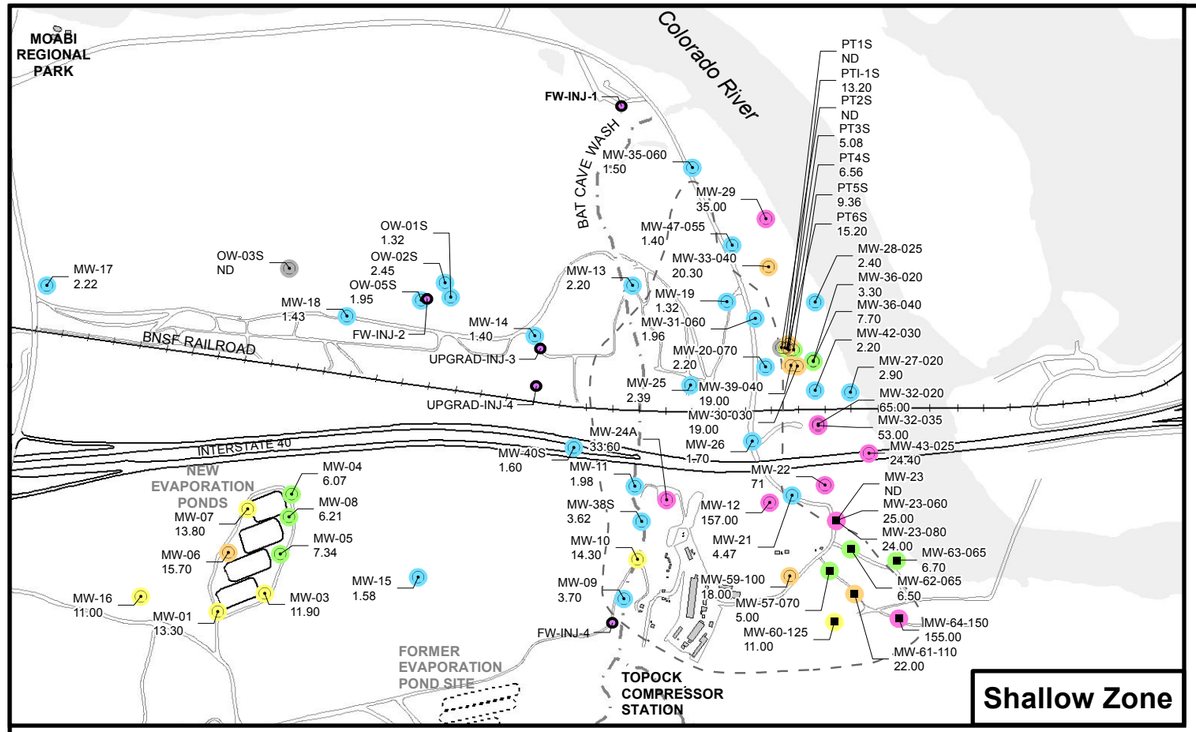
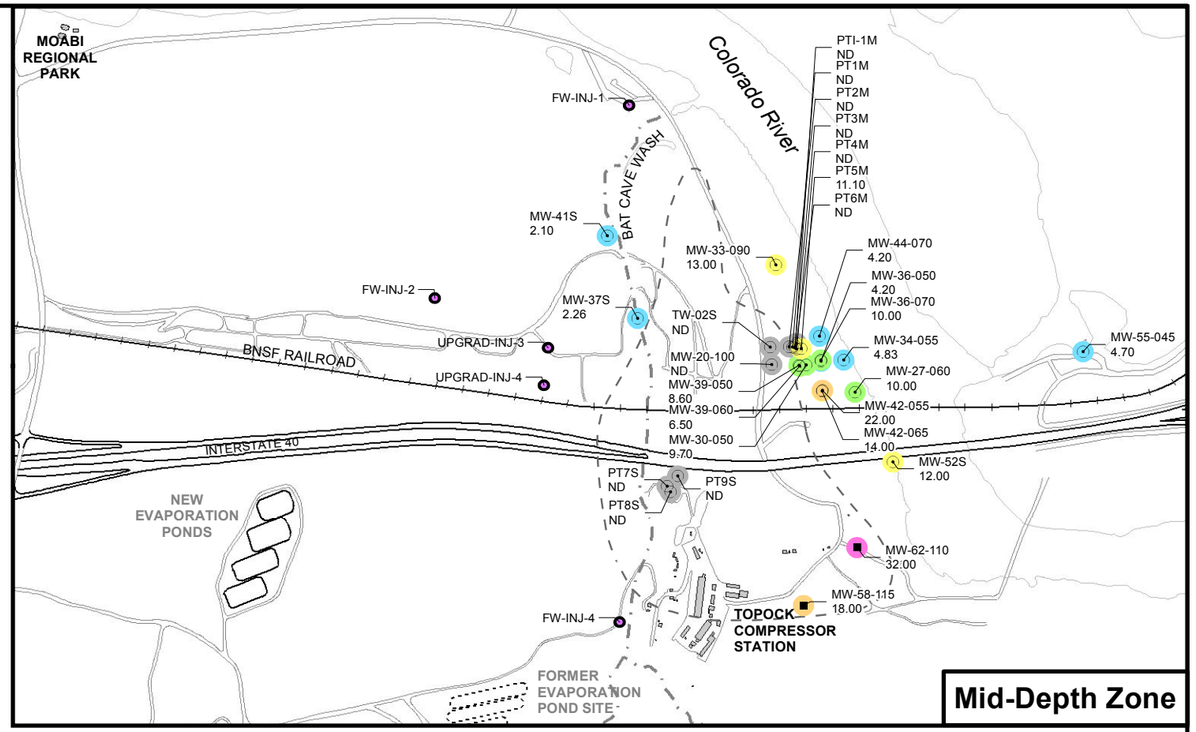


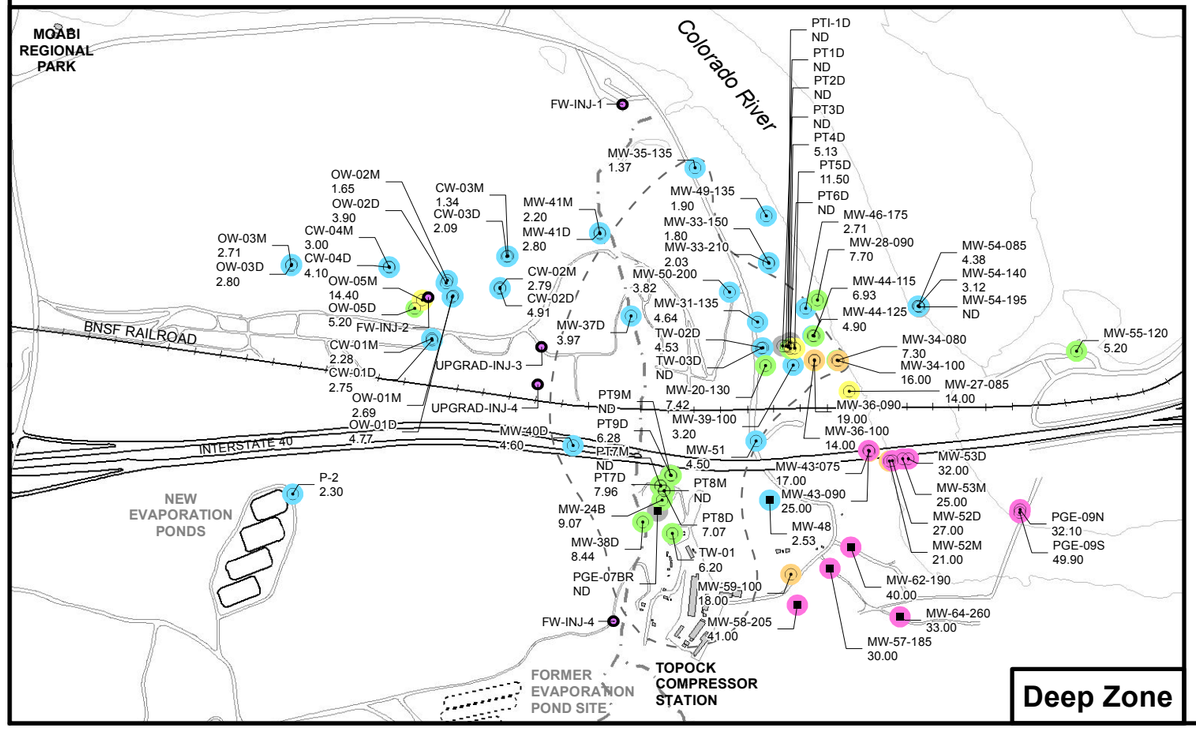
FIGURE 3-7
AVERAGE CONCENTRATIONS OF HEXAVALENT CHROMIUM
PG&E TOPOCK COMPRESSOR STATION AND VICINITY
NEEDLES, CALIFORNIA

CH2MHILL

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LEGEND

- Bedrock Well
- Groundwater Well completed in Alluvial Aquifer (Shallow, Mid-depth or Deep Zones)
- Freshwater Injection Well

Dissolved Arsenic Concentrations

MW-10 ← Well ID

5.8 ← Maximum concentration, micrograms per liter (µg/L) 1997-2011 groundwater sampling

- ND
- < 5 µg/L
- 5 - 10 µg/L
- 10.1 - 15 µg/L
- 15.1 - 24.3 µg/L
- > 24.3 µg/L

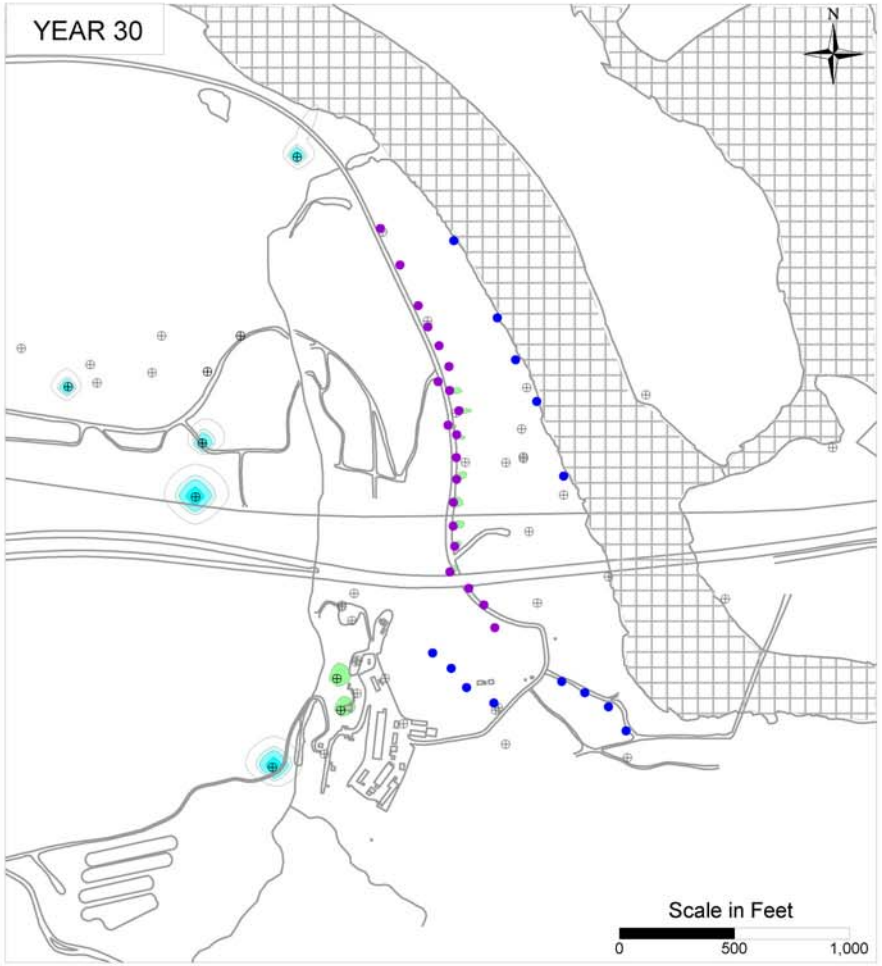
Approximate outline of Cr(VI) in Aluvial Aquifer depth zone ≥ 32 µg/L, Fourth Quarter 2011.

Notes:
Arsenic Background Study Upper Tolerance Limit (UTL) = 24.3 µg/L
Arsenic Applicable or Relevant and Appropriate Requirement (ARAR) = 10 µg/L

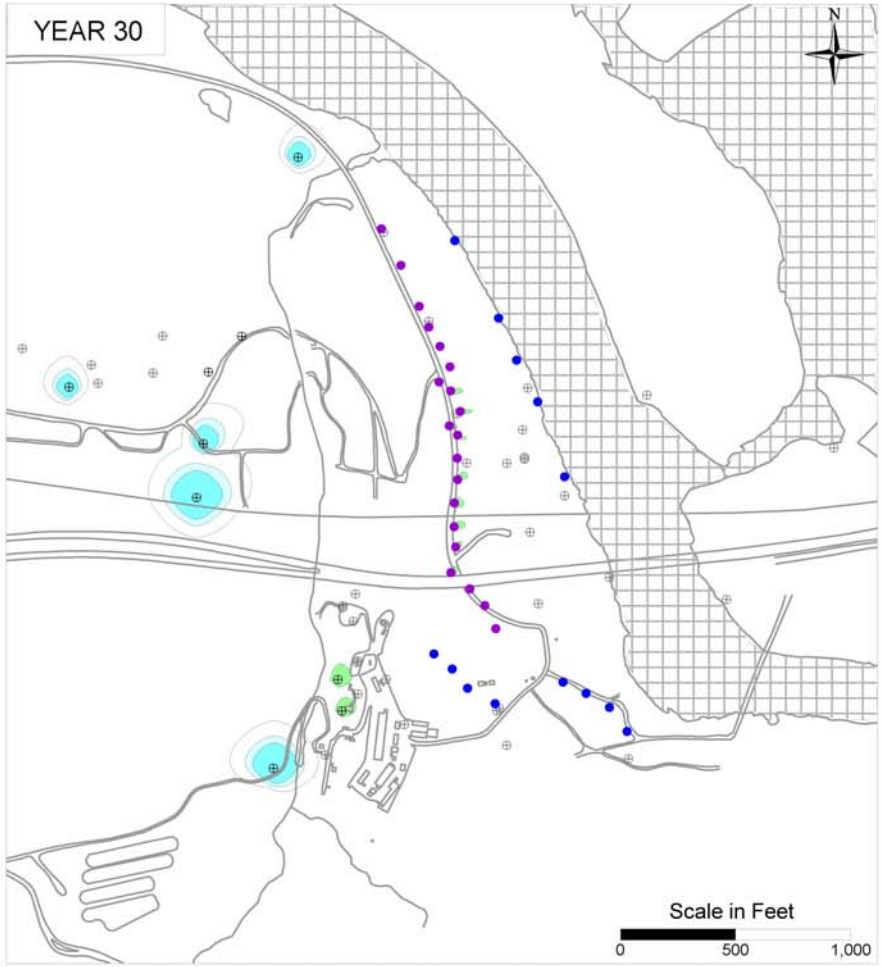
FIGURE 3-8
MAXIMUM ARSENIC CONCENTRATIONS IN GROUNDWATER, 1997 THROUGH 2011

RCRA FACILITY INVESTIGATION/REMEDIAL INVESTIGATION REPORT (VOLUME 2 ADDENDUM)
PG&E TOPOCK COMPRESSOR STATION,
NEEDLES, CALIFORNIA

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30% Design: Arsenic Precipitation Only



Update: Uplands Arsenic Sorption Only

Arsenic Concentration (ppm)

0.005 0.01 0.012 0.015

Carbon Concentration (ppm)

1 25 50 75 100

LEGEND

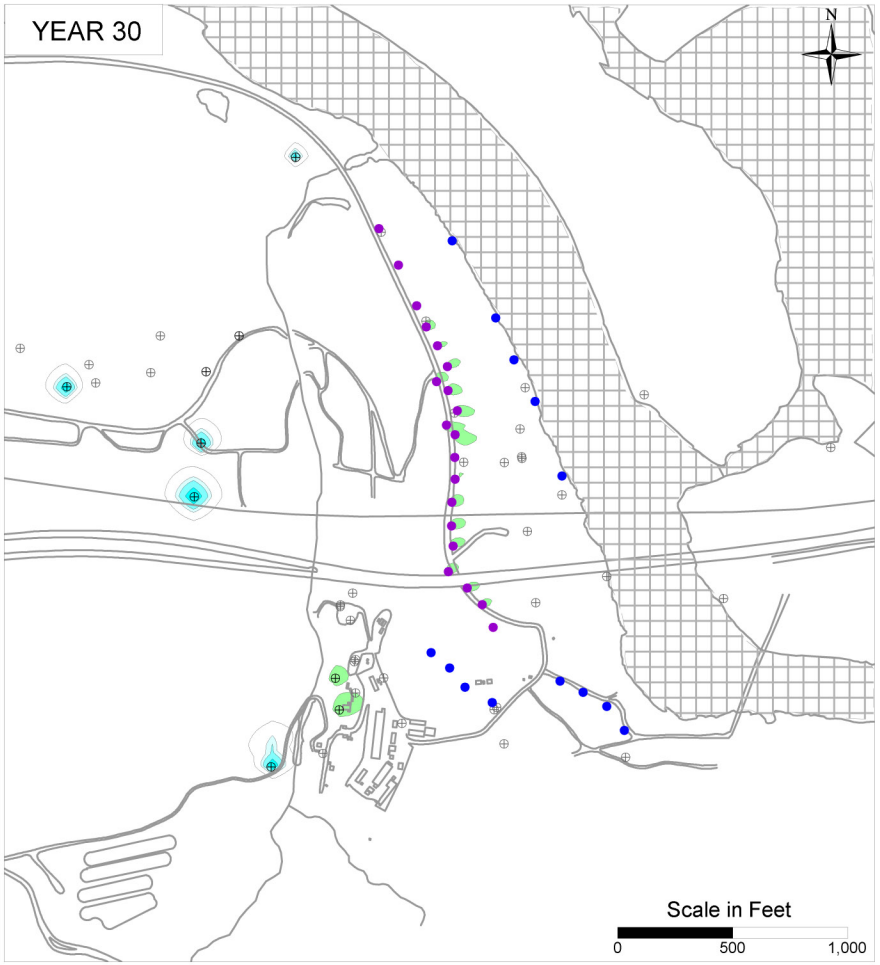
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- EXTRACTION WELLS
- MONITORING WELLS

PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

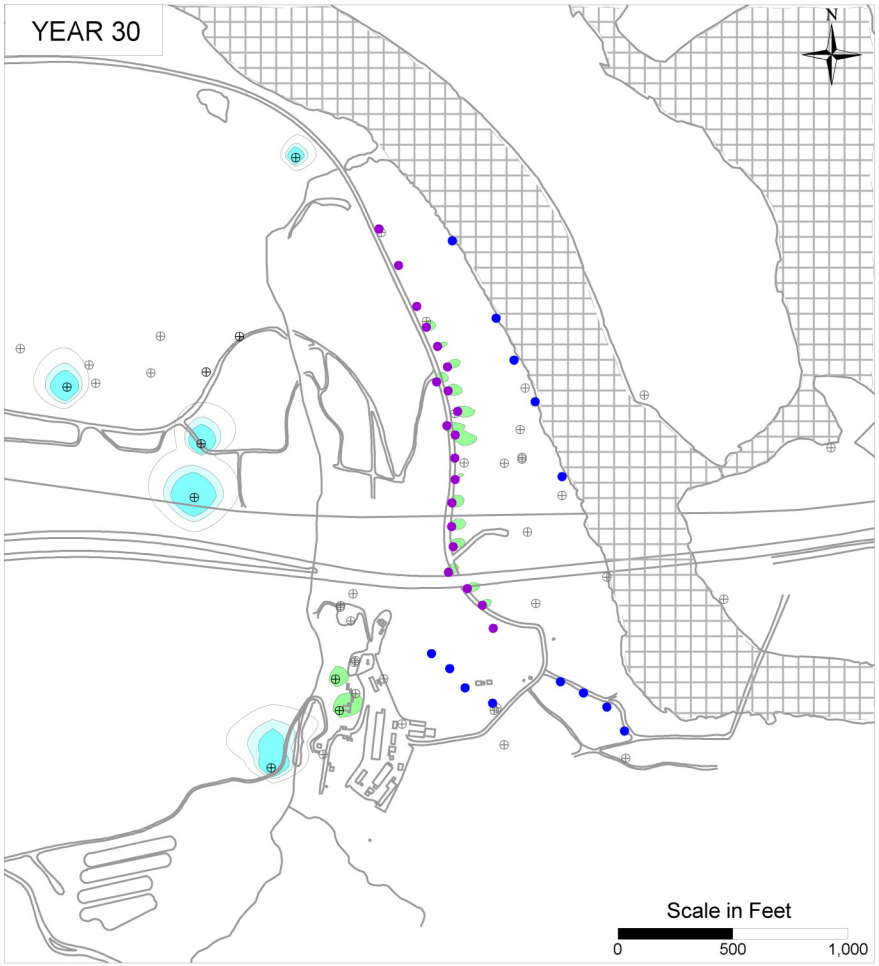
ARSENIC PARAMETER REFINEMENT:
30 YEAR SIMULATED ARSENIC TRANSPORT
RESULTS IN MODEL LAYER 1

ARCADIS

FIGURE
3-9



30% Design: Arsenic Precipitation Only



Update: Uplands Arsenic Sorption Only

Arsenic Concentration (ppm)

0.005 0.01 0.012 0.015

Carbon Concentration (ppm)

1 25 50 75 100

LEGEND

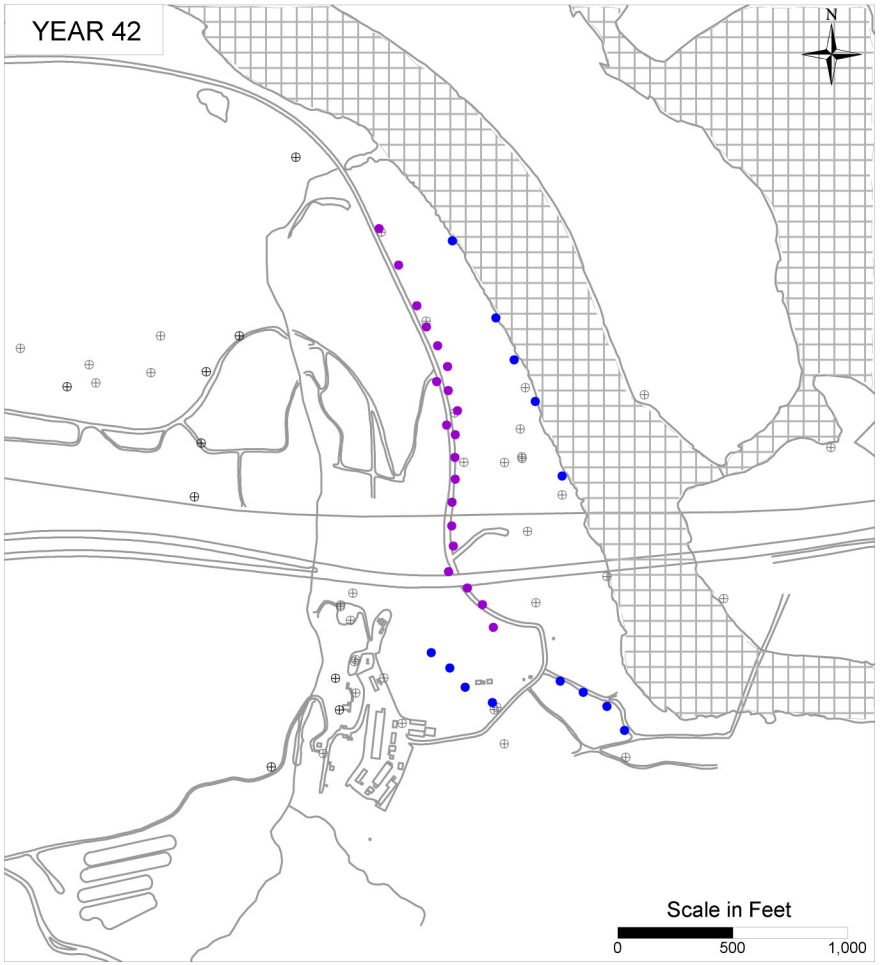
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- UPGRADIENT INJECTION WELLS
- EXTRACTION WELLS
- MONITORING WELLS

PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

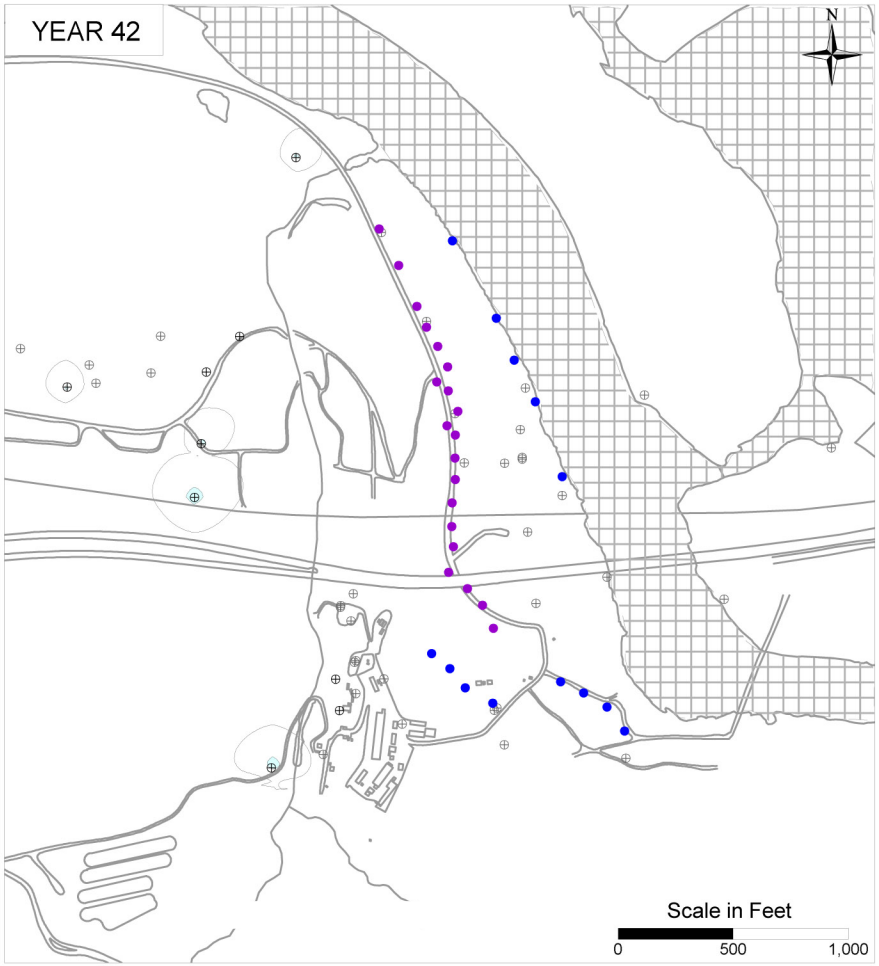
ARSENIC PARAMETER REFINEMENT:
30 YEAR SIMULATED ARSENIC TRANSPORT
RESULTS IN MODEL LAYER 3

ARCADIS

FIGURE
3-10



30% Design: Arsenic Precipitation Only



Update: Uplands Arsenic Sorption Only

Arsenic Concentration (ppm)

0.005 0.01 0.012 0.015

Carbon Concentration (ppm)

1 25 50 75 100

LEGEND

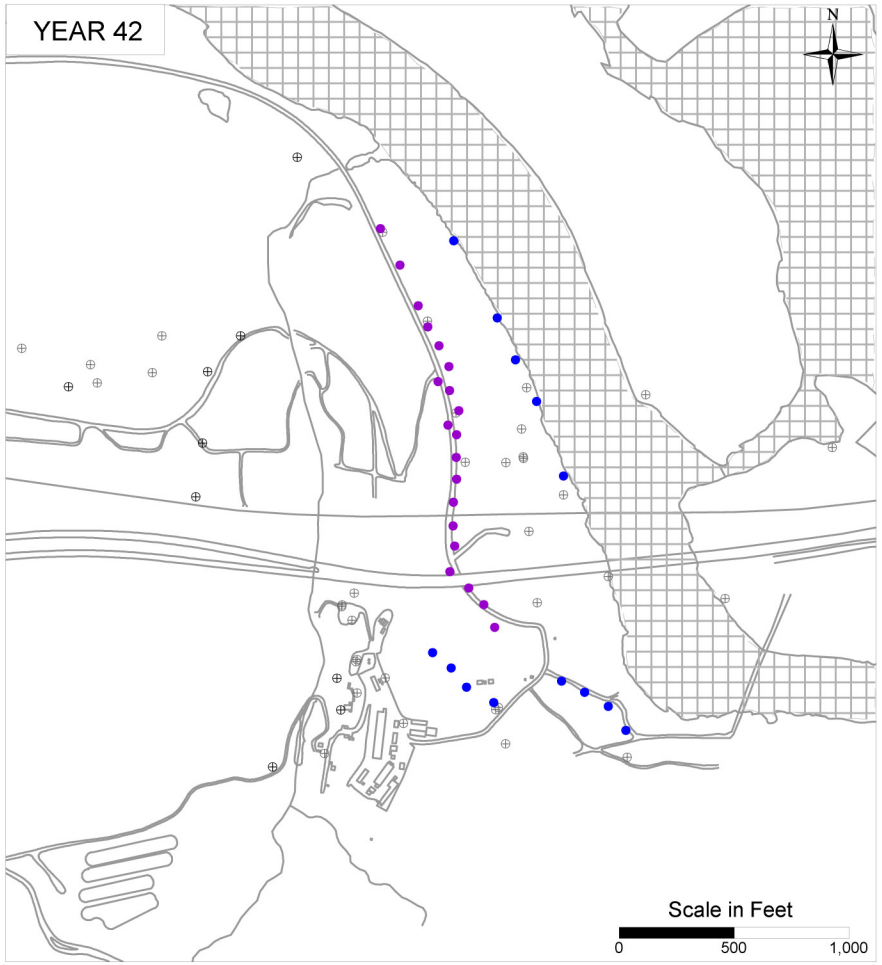
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- UPGRADIENT INJECTION WELLS
- EXTRACTION WELLS
- MONITORING WELLS

PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

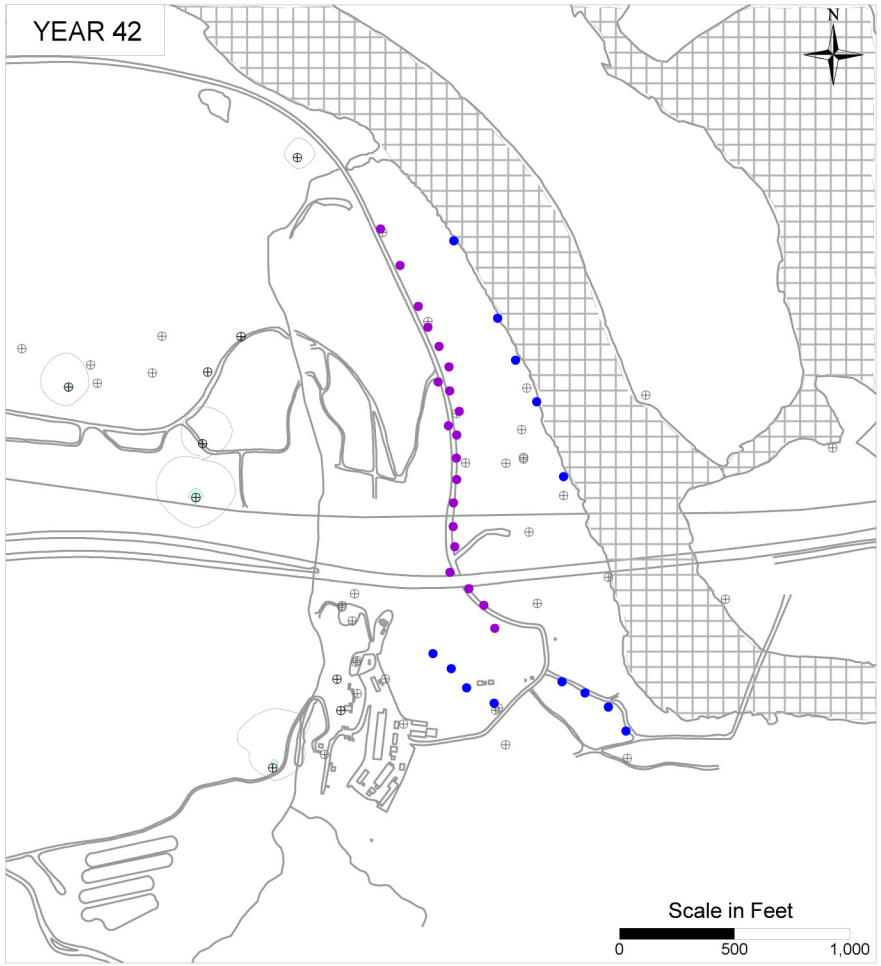
ARSENIC PARAMETER REFINEMENT:
42 YEAR SIMULATED ARSENIC RECOVERY
TRANSPORT RESULTS IN MODEL LAYER 1

ARCADIS

FIGURE
3-11



30% Design: Arsenic Precipitation Only



Update: Uplands Arsenic Sorption Only

Arsenic Concentration (ppm)

0.005 0.01 0.012 0.015

Carbon Concentration (ppm)

1 25 50 75 100

LEGEND

- IRZ WELLS
- UPGRADIENT INJECTION WELLS
- EXTRACTION WELLS
- MONITORING WELLS

PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

ARSENIC PARAMETER REFINEMENT:
42 YEAR SIMULATED ARSENIC RECOVERY
TRANSPORT RESULTS IN MODEL LAYER 3

ARCADIS

FIGURE
3-12

Tables

TABLE 3-1
Summary of Available Data from Wells near Park Moabi, California and near Topock Marina, Arizona
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

	Well No. / Name	Description	Casing Depth	Casing Diameter	Perforated Interval	Pumping Rate (gpm)	Specific Capacity	Available Water Quality Information	Current Status
Wells Near Moabi Regional Park, California	**PM-01**	Original well drilled in 1961	190'	10"	28' to 180'	350 gpm	16 gpm/ft	TDS = 1,500 to 3,000 mg/L* (Cr(VI) and As not available)	Unknown. Well was sounded in 1986.
	PM-02	Unused PM supply well. Exact location unknown	114'	10"	86' to 106'	430 gpm	Unknown	Well reportedly produced highly saline water and was considered unusable	Unknown
	PM-03 (also called PMM-Supply)	Well installed in 1986 near where Natl. Trails Highway crosses RR tracks	210'	8"	80' to 200'	60 gpm	0.8 gpm/ft	TDS = 500 mg/L Cr(VI) <= 9.6 µg/L Arsenic = 1.7 µg/L Manganese <10 µg/L Dissolved Iron = 50 µg/L Nitrate = 3.1 mg/L Avg. Selenium = 1.6 µg/L Avg. Molybdenum = 5.4 µg/L	Active
	PM-04	Well installed in 2006 near bathrooms	145'	8"	93' to 140'	40 gpm	0.8 gpm/ft	TDS = 900 mg/L Cr(VI) <=21.4 µg/L Arsenic <=1.0 µg/L Manganese <10 µg/L Dissolved Iron = 60 µg/L Nitrate = 2.2 mg/L Selenium = 1.47 µg/L Molybdenum = 6.02 µg/L	Active
	Park Moabi Infiltration Gallery	Consisted of 300' of perforated pipe laid near river draining a 26' deep sump	26' deep sump	4' diameter sump	300' of horizontal pipe	Estimated to be 40 to 70 gpm	Unknown	TDS = 2,000 mg/L (Cr(VI) and As not available) Reverse osmosis was needed to make water usable. R.O. system produced 18 gpm	Unknown
	Park Moabi Test Boring	Test boring installed near existing Park Moabi water tanks	512' borehole depth	No casing installed	NA	NA	Unknown	Not sampled	Abandoned Borehole produced very little water so no well was installed.
	Unnamed Well Used for Highway Construction	Located about 1/2 mile west of Park Moabi	86'	12"	Unknown	< 5 gpm	Unknown	Unknown	Unknown. Well was sounded in 1986.

TABLE 3-1
Summary of Available Data from Wells near Park Moabi, California and near Topock Marina, Arizona
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

	Well No. / Name	Description	Casing Depth	Casing Diameter	Perforated Interval	Pumping Rate (gpm)	Specific Capacity	Available Water Quality Information	Current Status
Wells near Topock Marina, Arizona**	**Topock - 2**	Water Supply Well Installed 1980	140'	12"	100' to 140'	Est. 200 gpm with current pump	11 gpm/ ft***	TDS = 900 mg/L Cr(VI) = 7 µg/L Arsenic = 12 µg/L Avg Mn = 3.1 µg/L	Active
	Topock - 3	Water Supply Well Installed 1974	130'	12"	85' to 130'	Est. 200 gpm with current pump	30 gpm/ ft***	TDS = 800 mg/L Cr(VI) = 11 µg/L Arsenic = 14 µg/L	Active
	HNWR -1	Irrigation Well for Pilot Revegetation Project	157'	10"	92' to 157'	900 gpm	12 gpm/ft	TDS = 480-500 mg/L Cr(T) = 16 µg/L Cr(VI) = 15-16 µg/L Arsenic = 14-15 µg/L Manganese = 0.64-1.9 µg/L Dissolved Iron = <20-37 µg/L Nitrate = 2.5-2.6 mg/L Selenium = 0.73-0.87 µg/L Molybdenum = 9.4-11 µg/L	Active
	MW-54 Cluster	Monitoring Well, Nested	85', 140', 195'	2" each	10-foot screen	NA	NA	TDS>= 6,000 mg/L (MW-54-85) TDS> 12,000 mg/L (MW-54-195) Avg TDS = 8,800 mg/L (all 3 wells) Cr(VI)<reporting limit (all 3 wells) Mn = 199 to 1090 µg/L As < 4.4 µg/L	Active
	MW-55 Cluster	Monitoring Well, Nested	45', 120'	2" each	10-foot screen	NA	NA	As = 4.7-5.2 ug/L Cr(VI)<=6.91 ug/L (MW-55-120) Mn = <100 to 1,230 µg/L	Active
	PGE-9S	Water Supply Well	100'	12"	70-foot screen	NA	NA	Cr(VI)<1 µg/L Avg As = 38.5 µg/L Avg Mn = 1,320 µg/L	No
	Sanders	Water Supply Well	230'	12"	Unknown	NA	NA	Cr(VI)<1 µg/L Avg As = 33.7µg/L Avg Mn = 99.8 µg/L	Unknown

Notes:
* In its comments #142 DTSC-55 and #143DTSC-56, DTSC noted that the 3,000 mg/L value cited in the report appears to be an error as PG&E data indicates TDS ranged from 800 to 1,000 mg/L circa 2005 to 2006 in well PM-1 and that unlike what was presented in Exhibit 3-1, well PM-01 data for chromium and arsenic are available. Cr(VI) measures about 9µg/L while arsenic is around 2µg/L. In response to these comments, PG&E reviewed its database and did not locate any PM-01 well data. The TDS value of 3000 mg/L cited came from the Crandall report (Crandall 1986b). The values cited in DTSC comments are data for well PMM-Supply, also known as well PM-03.

TABLE 3-1
Summary of Available Data from Wells near Park Moabi, California and near Topock Marina, Arizona
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

Well No. / Name	Description	Casing Depth	Casing Diameter	Perforated Interval	Pumping Rate (gpm)	Specific Capacity	Available Water Quality Information	Current Status

** - In response to comments DTSC-55 through DTSC-57 and DTSC-66, PG&E performed a well search in the Arizona Department of Water Resources (ADWR) Imaged Records Database but was unable to identify any new wells in the area. Using the Earth Point Townships layer in Google Earth, the cadastral location of the Topock Marina area was determined. This included only Quadrant B, Township 15 North, Range 21 West, Section 3, as all other surrounding property on the Arizona side were determined to belong to the Havasu National Wildlife Refuge. This cadastral location was used to conduct the well search in the ADWR database records. The ADWR database is current as of December 13, 2011, as stated on the ADWR website. Available information regarding wells and their corresponding files in the section that includes the Topock Marina were downloaded from the database and reviewed. These wells were then compared to PG&E's current database of wells in that location. It was determined that no new wells existed in the ADWR database near the Topock Marina.

PG&E recently learned from the Topock Marina Resort that no onsite well is currently planned and that water will be purchased from an existing water purveyor. PG&E will continue to inquire about the Resort's planned water use. New information, if any, obtained will be provided.

*** From pump test conducted by PG&E in 2012.

TABLE 3-2

SUMMARY OF HNWR-1 WELL SAMPLE RESULTS

Freshwater Sources Evaluation Technical Memorandum

PG&E Topock Compressor Station, Needles, California

	Location:	HNWR-01	HNWR-01	HNWR-01	HNWR-01
	Sample Date:	**11/10/2010**	**2/23/2012**	**3/14/2012**	**4/4/2012**
Parameter	**Units**				
Field					
Dissolved oxygen	mg/L	**5.33**	**3.52**	**3.29**	**3.72**
Oxidation reduction potential	mV	**159**	**172**	**200**	**112**
pH	pH units	**7.84**	**7.68**	**7.61**	**8.07**
Salinity	%	**0.42**	**0.0662**	**0.0537**	**0.0509**
Specific conductance	µS/cm	**870**	**1,024**	**830**	**787**
Temperature	°C	**35.9**	**38.3**	**38.1**	**38.0**
Turbidity	NTU	**5.10**	**5.10**	**2.50**	**---**
Anions					
Chloride	mg/L	**---**	**130**	**130**	**130**
Fluoride	mg/L	**3.80**	**---**	**---**	**---**
Nitrate (as nitrogen)	mg/L	**2.50**	**2.60**	**2.50**	**2.50**
Sulfate	mg/L	**47.0**	**45.0**	**44.0**	**45.0**
General Chemistry					
Alkalinity, bicarb as CaCO3	mg/L	**---**	**110**	**110**	**110**
Alkalinity, carb as CaCO3	mg/L	**---**	ND (5.0)	ND (5.0)	ND (5.0)
Alkalinity, hydroxide	mg/L	**---**	ND (5.0)	ND (5.0)	ND (5.0)
Alkalinity, total as CaCO3	mg/L	**100**	**110**	**110**	**110**
Ammonia as nitrogen	mg/L	ND (0.1)	**0.13**	**0.12**	**0.15**
Cyanide	mg/L	**---**	**---**	ND (0.01)	**---**
Deuterium	0/00	**-75.3**	**-73.8**	**---**	**---**
Oxygen 18	0/00	**-10.3**	**-10.2**	**---**	**---**
Soluble silica	mg/L	**28.6**	**---**	**---**	**---**
Specific conductance	µS/cm	**740**	**---**	**---**	**---**
Total dissolved solids	mg/L	**490 J**	**480**	**510**	**430**
Total Kjeldahl Nitrogen	mg/L	ND (0.4)	**---**	**---**	**---**
Total organic carbon	mg/L	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)
Total Suspended Solids (TSS)	mg/L	**---**	**---**	ND (10)	**---**
Herbicides					
2,4,5-T	µg/L	**---**	**---**	ND (2.7)	**---**
2,4,5-TP (Silvex)	µg/L	**---**	**---**	ND (2.7)	**---**
2,4-D	µg/L	**---**	**---**	ND (2.7)	**---**
2,4-DB	µg/L	**---**	**---**	ND (2.7)	**---**
4-Nitrophenol	µg/L	**---**	**---**	ND (2.7)	**---**
Dalapon	µg/L	**---**	**---**	ND (4.4)	**---**
Dicamba	µg/L	**---**	**---**	ND (2.7)	**---**
Dichlorprop	µg/L	**---**	**---**	ND (2.7)	**---**

TABLE 3-2
SUMMARY OF HNWR-1 WELL SAMPLE RESULTS
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

	Location:	HNWR-01	HNWR-01	HNWR-01	HNWR-01
	Sample Date:	11/10/2010	2/23/2012	3/14/2012	4/4/2012
Parameter	**Units**				
Herbicides					
Dinoseb	µg/L	---	---	ND (2.7)	---
MCPA	µg/L	---	---	ND (2.7)	---
MCPP	µg/L	---	---	ND (2.7)	---
Pentachloro phenol	µg/L	---	---	ND (2.7)	---
Metals					
Aluminum, dissolved	µg/L	ND (50)	---	ND (50)	ND (50)
Antimony, dissolved	µg/L	ND (10)	ND (10)	ND (10)	ND (10)
Arsenic, dissolved	µg/L	**15.0**	**15.0**	**16.0**	**15.0**
Barium, dissolved	µg/L	**130**	**110**	**110**	**110**
Beryllium, dissolved	µg/L	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)
Boron, dissolved	µg/L	**380**	---	---	---
Cadmium, dissolved	µg/L	ND (3.0)	ND (3.0)	ND (3.0)	ND (3.0)
Calcium, dissolved	µg/L	**23,000**	**19,000 J**	**19,000**	**20,000**
Chromium, Hexavalent	µg/L	**17.5**	**15.0**	**18.0**	**14.0**
Chromium, total dissolved	µg/L	**19.2**	**16.0**	**18.0**	**17.0**
Cobalt, dissolved	µg/L	ND (3.0)	ND (3.0)	ND (3.0)	ND (3.0)
Copper, dissolved	µg/L	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)
Iron, dissolved	µg/L	ND (20)	**37.0**	ND (20)	**25.0**
Lead, dissolved	µg/L	ND (10)	ND (10)	ND (10)	ND (10)
Magnesium, dissolved	µg/L	**4,000**	**3,100**	**3,200 J**	**3,100 J**
Manganese, dissolved	µg/L	ND (10)	**1.90**	**0.64**	**1.70**
Mercury, dissolved	µg/L	ND (0.2)	ND (0.2)	ND (0.2)	ND (0.2)
Molybdenum, dissolved	µg/L	**11.0**	**9.40**	**10.0**	**9.00**
Nickel, dissolved	µg/L	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)
Potassium, dissolved	µg/L	**5,100**	**4,400**	**4,000**	**3,700**
Selenium, dissolved	µg/L	**0.73**	**0.87**	**0.75**	**0.75**
Silver, dissolved	µg/L	ND (3.0)	ND (3.0)	ND (3.0)	ND (3.0)
Sodium, dissolved	µg/L	**130,000**	**130,000**	**130,000**	**130,000**
Thallium, dissolved	µg/L	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)
Vanadium, dissolved	µg/L	**20.0**	**21.0**	**22.0 J**	**20.0**
Zinc, dissolved	µg/L	ND (10)	ND (10)	**16.0**	ND (10)
Perchlorate					
Perchlorate	µg/L	---	---	ND (2.0)	ND (2.0)
Pesticides					
4,4-DDD	µg/L	---	---	ND (0.053)	ND (0.052)
4,4-DDE	µg/L	---	---	ND (0.053)	ND (0.052)

TABLE 3-2
SUMMARY OF HNWR-1 WELL SAMPLE RESULTS
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

	Location:	HNWR-01	HNWR-01	HNWR-01	HNWR-01
	Sample Date:	11/10/2010	2/23/2012	3/14/2012	4/4/2012
Parameter	**Units**				
Pesticides					
4,4-DDT	µg/L	---	---	ND (0.053)	ND (0.052)
Aldrin	µg/L	---	---	ND (0.027)	ND (0.026)
alpha-BHC	µg/L	---	---	ND (0.027)	ND (0.026)
alpha-Chlordane	µg/L	---	---	ND (0.027)	ND (0.026)
beta-BHC	µg/L	---	---	ND (0.027)	ND (0.026)
delta-BHC	µg/L	---	---	ND (0.027)	ND (0.026)
Dieldrin	µg/L	---	---	ND (0.053)	ND (0.052)
Endo sulfan I	µg/L	---	---	ND (0.027)	ND (0.026)
Endo sulfan II	µg/L	---	---	ND (0.053)	ND (0.052)
Endosulfan sulfate	µg/L	---	---	ND (0.053)	ND (0.052)
Endrin	µg/L	---	---	ND (0.053)	ND (0.052)
Endrin aldehyde	µg/L	---	---	ND (0.053)	ND (0.052)
gamma-BHC	µg/L	---	---	ND (0.027)	ND (0.026)
gamma-Chlordane	µg/L	---	---	ND (0.027)	ND (0.026)
Heptachlor	µg/L	---	---	ND (0.027)	ND (0.026)
Heptachlor Epoxide	µg/L	---	---	ND (0.027)	ND (0.026)
Methoxy chlor	µg/L	---	---	ND (0.27)	ND (0.26)
Toxaphene	µg/L	---	---	ND (2.7) J	ND (2.6) J
Polyaromatic Hydrocarbons					
1-Methyl naphthalene	µg/L	---	---	ND (0.22)	ND (0.2)
2-Methyl naphthalene	µg/L	---	---	ND (0.22)	ND (0.2)
Acenaphthene	µg/L	---	---	ND (0.22)	ND (0.2)
Acenaphthylene	µg/L	---	---	ND (0.22)	ND (0.2)
Anthracene	µg/L	---	---	ND (0.22)	ND (0.2)
Benzo (a) anthracene	µg/L	---	---	ND (0.22)	ND (0.2)
Benzo (a) pyrene	µg/L	---	---	ND (0.22)	ND (0.2)
Benzo (b) fluoranthene	µg/L	---	---	ND (0.22)	ND (0.2)
Benzo (ghi) perylene	µg/L	---	---	ND (0.22)	ND (0.2)
Benzo (k) fluoranthene	µg/L	---	---	ND (0.22)	ND (0.2)
Chrysene	µg/L	---	---	ND (0.22)	ND (0.2)
Dibenzo (a,h) anthracene	µg/L	---	---	ND (0.22)	ND (0.2)
Fluoranthene	µg/L	---	---	ND (0.22)	ND (0.2)
Fluorene	µg/L	---	---	ND (0.22)	ND (0.2)
Indeno (1,2,3-cd) pyrene	µg/L	---	---	ND (0.22)	ND (0.2)
Naphthalene	µg/L	---	---	ND (0.22)	ND (0.2)
Phenanthrene	µg/L	---	---	ND (0.22)	ND (0.2)
Pyrene	µg/L	---	---	ND (0.22)	ND (0.2)

TABLE 3-2
SUMMARY OF HNWR-1 WELL SAMPLE RESULTS
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

Location:		HNWR-01	HNWR-01	HNWR-01	HNWR-01
Sample Date:		**11/10/2010**	**2/23/2012**	**3/14/2012**	**4/4/2012**
Parameter	**Units**				
Polychlorinated Biphenyls					
Aroclor 1016	µg/L	---	---	ND (0.53)	ND (0.52)
Aroclor 1221	µg/L	---	---	ND (1.1)	ND (1.0)
Aroclor 1232	µg/L	---	---	ND (0.53)	ND (0.52)
Aroclor 1242	µg/L	---	---	ND (0.53)	ND (0.52)
Aroclor 1248	µg/L	---	---	ND (0.53)	ND (0.52)
Aroclor 1254	µg/L	---	---	ND (0.53)	ND (0.52)
Aroclor 1260	µg/L	---	---	ND (0.53)	ND (0.52)
Total Petroleum Hydrocarbons					
TPH as diesel	µg/L	---	---	**190**	ND (51) J
TPH as gasoline	µg/L	---	---	ND (100)	ND (100)
TPH as motor oil	µg/L	---	---	ND (53)	ND (51)
Volatile Organic Compounds					
1,1,1,2-Tetrachloroethane	µg/L	---	---	ND (1.0)	ND (1.0)
1,1,1-Trichloroethane	µg/L	---	---	ND (1.0)	ND (1.0)
1,1,2,2-Tetrachloroethane	µg/L	---	---	ND (1.0)	ND (1.0)
1,1,2-Trichloroethane	µg/L	---	---	ND (1.0)	ND (1.0)
1,1,2-Trichlorotrifluoroethane (Freon 113)	µg/L	---	---	ND (1.0)	ND (1.0)
1,1-Dichloroethane	µg/L	---	---	ND (1.0)	ND (1.0)
1,1-Dichloroethene	µg/L	---	---	ND (1.0)	ND (1.0)
1,1-Dichloropropene	µg/L	---	---	ND (1.0)	ND (1.0)
1,2,3-Trichlorobenzene	µg/L	---	---	ND (1.0)	ND (1.0)
1,2,3-Trichloropropane	µg/L	---	---	ND (1.0)	ND (1.0)
1,2,4-Trichlorobenzene	µg/L	---	---	ND (1.0)	ND (1.0)
1,2,4-Trimethylbenzene	µg/L	---	---	ND (1.0)	ND (1.0) J
1,2-Dibromo-3-chloropropane	µg/L	---	---	ND (2.0)	ND (2.0)
1,2-Dibromoethane	µg/L	---	---	ND (1.0)	ND (1.0)
1,2-Dichlorobenzene	µg/L	---	---	ND (1.0)	ND (1.0)
1,2-Dichloroethane	µg/L	---	---	ND (1.0)	ND (1.0)
1,2-Dichloropropane	µg/L	---	---	ND (1.0)	ND (1.0)
1,3,5-Trimethylbenzene	µg/L	---	---	ND (1.0)	ND (1.0) J
1,3-Dichlorobenzene	µg/L	---	---	ND (1.0)	ND (1.0)
1,3-Dichloropropane	µg/L	---	---	ND (1.0)	ND (1.0)
1,4-Dichlorobenzene	µg/L	---	---	ND (1.0)	ND (1.0)
2,2-Dichloropropane	µg/L	---	---	ND (1.0)	ND (1.0)
2-Chlorotoluene	µg/L	---	---	ND (1.0)	ND (1.0)
4-Isopropyltoluene	µg/L	---	---	ND (1.0)	ND (1.0)

TABLE 3-2
SUMMARY OF HNWR-1 WELL SAMPLE RESULTS
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

	Location:	HNWR-01	HNWR-01	HNWR-01	HNWR-01
	Sample Date:	**11/10/2010**	**2/23/2012**	**3/14/2012**	**4/4/2012**
Parameter	**Units**				
Volatile Organic Compounds					
Acetone	µg/L	---	---	ND (10)	ND (10)
Acrolein	µg/L	---	---	ND (20)	ND (20)
Acrylonitrile	µg/L	---	---	ND (20)	ND (20)
Benzene	µg/L	---	---	ND (1.0)	ND (1.0)
Bromobenzene	µg/L	---	---	ND (1.0)	ND (1.0)
Bromochloromethane	µg/L	---	---	ND (1.0)	ND (1.0)
Bromodichloromethane	µg/L	---	---	ND (1.0)	ND (1.0)
Bromoform	µg/L	---	---	ND (1.0)	ND (1.0)
Bromomethane	µg/L	---	---	ND (1.0)	ND (1.0)
Carbon disulfide	µg/L	---	---	ND (1.0)	ND (1.0)
Carbon tetrachloride	µg/L	---	---	ND (1.0)	ND (1.0)
Chloro methane	µg/L	---	---	ND (1.0)	ND (1.0)
Chlorobenzene	µg/L	---	---	ND (1.0)	ND (1.0)
Chloroethane	µg/L	---	---	ND (1.0)	ND (1.0)
Chloroform	µg/L	---	---	ND (1.0)	ND (1.0)
cis-1,2-Dichloroethene	µg/L	---	---	ND (1.0)	ND (1.0)
cis-1,3-Dichloropropene	µg/L	---	---	ND (1.0)	ND (1.0)
Dibromochloromethane	µg/L	---	---	ND (1.0)	ND (1.0)
Dibromomethane	µg/L	---	---	ND (1.0)	ND (1.0)
Dichlorodifluoromethane	µg/L	---	---	ND (1.0)	ND (1.0)
Ethylbenzene	µg/L	---	---	ND (1.0)	ND (1.0)
Hexachlorobutadiene	µg/L	---	---	ND (1.0)	ND (1.0)
Isopropylbenzene	µg/L	---	---	ND (1.0)	ND (1.0)
m,p-Xylenes	µg/L	---	---	ND (1.0)	ND (1.0)
Methyl ethyl ketone	µg/L	---	---	ND (10)	ND (10)
Methyl isobutyl ketone	µg/L	---	---	ND (10)	ND (10)
Methyl tert-butyl ether (MTBE)	µg/L	---	---	ND (1.0)	ND (1.0) J
Methylene chloride	µg/L	---	---	ND (5.0)	ND (5.0)
N-Butylbenzene	µg/L	---	---	ND (1.0)	ND (1.0)
N-Propylbenzene	µg/L	---	---	ND (1.0)	ND (1.0)
o-Xylene	µg/L	---	---	ND (1.0)	ND (1.0)
p-Chlorotoluene	µg/L	---	---	ND (1.0)	ND (1.0)
sec-Butylbenzene	µg/L	---	---	ND (1.0)	ND (1.0)
Styrene	µg/L	---	---	ND (1.0)	ND (1.0) J
tert-Butylbenzene	µg/L	---	---	ND (1.0)	ND (1.0)
Tetrachloroethene	µg/L	---	---	ND (1.0)	ND (1.0)
Toluene	µg/L	---	---	ND (2.5)	ND (2.5)

TABLE 3-2

SUMMARY OF HNWR-1 WELL SAMPLE RESULTS

Freshwater Sources Evaluation Technical Memorandum

PG&E Topock Compressor Station, Needles, California

	Location:	HNWR-01	HNWR-01	HNWR-01	HNWR-01
	Sample Date:	**11/10/2010**	**2/23/2012**	**3/14/2012**	**4/4/2012**
Parameter	**Units**				
Volatile Organic Compounds					
trans-1,2-Dichloroethene	µg/L	---	---	ND (1.0)	ND (1.0)
trans-1,3-Dichloropropene	µg/L	---	---	ND (1.0)	ND (1.0)
Trichloroethene	µg/L	---	---	ND (1.0)	ND (1.0)
Trichlorofluoromethane (Freon 11)	µg/L	---	---	ND (1.0)	ND (1.0)
Vinyl chloride	µg/L	---	---	ND (1.0)	ND (1.0)
Xylenes, total	µg/L	---	---	ND (2.0)	ND (2.0)

Notes:

---	not collected or not available.
%	percent
0/00	differences from global standards in ppt.
°C	degrees Celcius.
J	analyte was present, but reported value was estimated.
mg/L	milligrams per liter.
mV	millivolts.
ND	parameter not detected at the listed reporting limit.
NTU	nephelometric turbidity units.
µg/L	micrograms per liter.
µS/cm	microSiemens per centimeter.

TABLE 3-3
Moabi Regional Park, San Bernardino County, CA; Analytical Results - Historical Chemicals of Potential Concern
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

Location ID	Sample Date	Hexavalent Chromium (µg/L)	Dissolved ^ Chromium (µg/L)	Total Chromium (µg/L)	pH (phunits)	Specific Conductance (µS/cm)	Oxygen Reduction Potential (mV)	Dissolved Copper (µg/L)	Dissolved Nickel (µg/L)	Dissolved Zinc (µg/L)
PM-03	07/01/1997	ND (10)	18.0 J	---	7.88	1040	96.4	3.80 J	ND (25)	6.10
PM-03	09/01/1997	ND (10)	13.0 J	---	7.96	1140	---	ND (10)	ND (25)	12.0
PM-03	02/18/1998	ND (10)	ND (20)	---	7.94	1070	263	ND (10)	ND (25)	10.0
PM-03	06/15/1998	ND (10)	11.0 J	---	7.72	1120	189	3.70 J	ND (25)	11.0 J
PM-03	06/15/1999	ND (10)	ND (20)	---	7.89	1700	---	ND (10)	ND (25)	8.20
PM-03	09/14/1999	ND (10)	12.0 J	---	7.84	1330	249	18.0	ND (25)	15.0
PM-03	12/03/1999	ND (10)J	ND (20)	---	7.88 J	1210	113	ND (10)	5.00	21.0
PM-03	03/23/2000	ND (10)	12.0 J	---	7.44	877	198	4.10 J	ND (25)	47.0
PM-03	06/13/2000	ND (10)	13.0 J	---	7.86	1210	136	12.0	0.99 J	13.0
PM-03	09/01/2000	ND (10)	10.0 J	---	7.58	1570	250	3.60 J	1.70 J	4.80 J
PM-03	12/01/2000	ND (10)	ND (20)	---	7.79	1150	---	3.70 J	5.00	16.0
PM-03	03/28/2001	ND (10)	11.0 J	---	7.66	1650	263	ND (10)	1.30 J	6.40 J
PM-03	06/06/2001	ND (10)	ND (20)	---	7.72	1480	230	3.50 J	ND (25)	3.90 J
PM-03	08/25/2001	ND (10)	16.0 J	---	7.41	1040	301	3.40 J	1.10 J	57.0
PM-03	09/12/2001	ND (10)	ND (20)	---	7.89	1050	310	5.00 J	ND (25)	27.0
PM-03	11/29/2001	ND (10)	17.0 J	---	7.93	1680	183	5.80 J	ND (400)	24.0
PM-03	03/05/2002	ND (10)	---	22.3	7.70	2200	15.0 (a)	9.20 *	8.70 *	54.6 *
PM-03	03/18/2003	ND (10)	11.4	---	8.54 (a)	---	---	ND (11)	ND (28)	303
PM-03	11/04/2003	0.28	1.20	---	8.20 (a)	---	51.0 (a)	---	---	---
PM-03	12/11/2003	6.70	7.00	---	7.91	1250	-88 (a)	ND (10)	ND (20)	54.4

Notes:

(a) field measurements.
µg/L micrograms per liter (parts per billion).
µS/cm microSiemens per centimeter.
mV millivolts.
ND parameter not detected at the listed reporting limit.
J analyte was present, but reported value was estimated.
--- not collected or not available.
FD field duplicate.
* not filtered.
^ From May 2, 2007 onward, samples were collected for total (unfiltered) chromium rather than dissolved chromium.

TABLE 3-3
Moabi Regional Park, San Bernardino County, CA; Analytical Results - Historical Chemicals of Potential Concern
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

Location ID	Sample Date	Hexavalent Chromium (µg/L)	Dissolved ^ Chromium (µg/L)	Total Chromium (µg/L)	pH (phunits)	Specific Conductance (µS/cm)	Oxygen Reduction Potential (mV)	Dissolved Copper (µg/L)	Dissolved Nickel (µg/L)	Dissolved Zinc (µg/L)
PM-03	03/16/2004	2.60	2.10	7.60	7.87	1260	204 (a)	ND (10)	ND (20)	74.8 J
PM-03	06/09/2004	ND (0.2)	ND (1.0)	6.40	7.70	1140	-81 (a)	ND (10)	ND (20)	ND (120)
PM-03	09/22/2004	9.40	7.70	---	7.88	1260	118 (a)	---	---	---
PM-03	12/15/2004	ND (0.2)	ND (1.0)	---	8.08	1300	-235 (a)	---	---	---
PM-03	03/11/2005	0.35	ND (1.0)	---	8.03	1260	-59 (a)	---	---	---
PM-03 (FD)	05/18/2005	10.0	10.9	11.0	7.77	1260	---	4.75	ND (1.0)J	25.6
PM-03	05/18/2005	10.2	11.5	10.9	7.74	1220	93.0 (a)	4.64	2.71 J	37.5
PM-03	06/15/2005	9.90	8.60	---	8.16	1200	158 (a)	---	---	---
PM-03	07/21/2005	9.70	10.2	---	7.82 (a)	---	37.0 (a)	2.41	ND (1.0)	14.5
PM-03 (FD)	07/21/2005	9.60	10.8	---	---	---	---	1.52	ND (1.0)	24.7
PM-03	10/05/2005	9.20	7.60	---	7.69	1280	93.0 (a)	---	---	---
PM-03	11/02/2005	0.50	5.47	---	7.56 (a)	---	-131 (a)	1.98	ND (1.0)	51.6
PM-03	12/16/2005	ND (0.2)	ND (1.0)	---	7.38	2100	-26 (a)	---	---	---
PM-03	12/19/2005	7.90	9.89	---	7.72 (a)	---	27.0 (a)	ND (1.0)	ND (1.0)	22.2
PM-03	02/22/2006	8.40	9.46	---	7.16 (a)	---	214 (a)	1.02	ND (1.0)	29.0
PM-03	03/06/2006	9.50	7.80	---	7.69	1260	275 (a)	---	---	---
PM-03	05/01/2006	9.50	10.6	---	7.31 (a)	---	18.0 (a)	ND (1.0)	ND (1.0)	17.4
PM-03	05/03/2006	9.60	---	11.8	7.92	1300	112 (a)	---	---	---
PM-03	10/04/2006	2.00	6.30	---	7.25	1150	69.0 (a)	---	---	---
PM-03	05/02/2007	0.90	---	1.30	7.82 J	1890	14.0 (a)	---	---	---

Notes:

(a) field measurements.
µg/L micrograms per liter (parts per billion).
µS/cm microSiemens per centimeter.
mV millivolts.
ND parameter not detected at the listed reporting limit.
J analyte was present, but reported value was estimated.
--- not collected or not available.
FD field duplicate.
* not filtered.
^ From May 2, 2007 onward, samples were collected for total (unfiltered) chromium rather than dissolved chromium.

TABLE 3-3
Moabi Regional Park, San Bernardino County, CA; Analytical Results - Historical Chemicals of Potential Concern
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

Location ID	Sample Date	Hexavalent Chromium (µg/L)	Dissolved ^ Chromium (µg/L)	Total Chromium (µg/L)	pH (phunits)	Specific Conductance (µS/cm)	Oxygen Reduction Potential (mV)	Dissolved Copper (µg/L)	Dissolved Nickel (µg/L)	Dissolved Zinc (µg/L)
PM-03	10/04/2007	ND (1.0)	---	ND (1.0)	7.93 J	1920	-92.4 (a)	---	---	---
PM-03	10/02/2008	8.74	---	8.35	7.42 (a)	1400	-30 (a)	---	---	---
PM-03	10/01/2009	9.90	---	9.50	7.72 (a)	1400	345 (a)	---	---	---
PM-03	12/10/2010	11.9	---	10.5	7.57 (a)	1200	47.8 (a)	---	---	---
PM-03	12/12/2011	6.60	---	7.00	7.50 (a)	1400	13.4 (a)	---	---	---
PM-04	05/02/2007	ND (0.2)	---	ND (1.0)	7.99 J	1530	---	1.96	6.30	605 J
PM-04	10/04/2007	21.4	---	23.5	8.14 J	1720	-62.2 (a)	---	---	---
PM-04	11/13/2007	13.4	---	21.9	8.01 J	1470	-120 (a)	---	---	---
PM-04	10/02/2008	20.6	---	18.5	7.44 (a)	1700	-7.0 (a)	---	---	---
PM-04	10/01/2009	21.0	---	18.0	7.91 (a)	1800	726 R (a)	---	---	---
PM-04	12/10/2010	21.0	---	20.6	7.44 (a)	1700	39.5 (a)	---	---	---
PM-04	12/12/2011	18.9	---	18.2	7.70 (a)	1800	---	---	---	---

Notes:

(a)	field measurements.
µg/L	micrograms per liter (parts per billion).
µS/cm	microSiemens per centimeter.
mV	millivolts.
ND	parameter not detected at the listed reporting limit.
J	analyte was present, but reported value was estimated.
---	not collected or not available.
FD	field duplicate.
*	not filtered.
^	From May 2, 2007 onward, samples were collected for total (unfiltered) chromium rather than dissolved chromium.

TABLE 3-4
Moabi Regional Park, San Bernardino County, CA; Analytical Results, PM-03 - Sampling Events with Expanded Analyte Suite
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

Group	Analyte	Units	PM-03 1997 Qtr 2 7/1/1997	PM-03 2000 Qtr 3 9/1/2000	PM-03 2001 Qtr 4 11/29/2001	PM-03 2004 Qtr 2 6/9/2004 (a)	PM-03 BKG Study 01 5/18/2005	PM-03 (FD) BKG Study 01 5/18/2005	PM-03 BKG Study 02 7/21/2005	PM-03 (FD) BKG Study 02 7/21/2005	PM-03 BKG Study 03 11/2/2005	PM-03 BKG Study 04 12/19/2005	PM-03 BKG Study 05 2/22/2006	PM-03 BKG Study 06 5/1/2006	PM-03 2007 Qtr 3 10/4/2007	PM-03 2008 Qtr 3 10/2/2008	PM-03 2009 Qtr 3 10/1/2009	PM-03 2010 Qtr 4 12/10/2010	PM-03 2011 Qtr 4 12/12/2011
Anion																			
	Bromide	mg/L	---	---	---	---	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	---	---	---	---	---	---	---	---	---
	Chloride	mg/L	197	241	411	290	297	290	314	310	402	307	323	321	---	320	320	270	340
	Fluoride	mg/L	0.72	2.69	2.50	2.30	2.32	2.27	2.18	2.16	2.28	2.31	2.26	2.11	---	---	---	---	---
	Nitrate (as nitrogen)	mg/L	3.90	2.80	3.00	3.40	3.03	3.04	3.14 J	3.15 J	2.86	3.02	3.15	3.07	---	3.50	3.20	3.30	3.10
	Nitrite	mg/L	ND (0.02)	0.004 J	ND (0.02)	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Sulfate	mg/L	44.6	47.0	75.4	59.0	62.4	61.0	58.3	58.2	64.0	61.0	63.2	74.1	---	61.0	58.0	54.0	59.0
General																			
	Alkalinity, hydroxide	mg/L	---	---	---	ND (5.0)	---	---	---	---	---	---	---	---	---	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)
	Alkalinity, bicarb as CaCO3	mg/L	90.4	93.0	78.8	85.0	90.1	85.0	81.1	83.6	67.4	82.7	68.2	90.6	---	88.0	83.0	89.0	89.0
	Alkalinity, carb as CaCO3	mg/L	ND (2.0)	ND (2.0)	ND (2.0)	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)	---	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)
	Alkalinity, total as CaCO3	mg/L	---	---	---	85.0	90.1	85.0	81.1	83.6	67.4	82.7	68.2	90.6	65.0 J	88.0	83.0	89.0	89.0
	Ammonia	mg/L	ND (0.2)	0.20 J	ND (0.2)	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Ammonia as nitrogen	mg/L	---	---	---	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	---	---	---	ND (0.1)	ND (0.1)
	Bicarbonate	mg/L	---	---	---	---	---	---	---	---	---	---	---	---	79.3 J	---	---	---	---
	Carbonate	mg/L	---	---	---	---	---	---	---	---	---	---	---	---	ND (5.0)J	---	---	---	---
	Deuterium	0/00	---	---	---	-65	-88	-70	-66	-65	-65	-64	-68	-62.7	---	---	---	---	---
	Dissolved organic carbon	mg/L	---	---	---	---	1.30	ND (1.0)	1.08	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	---	---	---	---	---
	Iodide	µg/L	---	---	---	---	ND (500)J	ND (500)J	ND (500)J	ND (500)J	---	---	---	---	---	---	---	---	---
	Orthophosphate	mg/L	---	---	---	ND (0.5)	---	---	ND (0.1)	ND (0.1)	---	---	---	---	---	---	---	---	---
	Oxidation reduction potential	mV	96.4	250	183	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Oxygen 18	0/00	---	---	---	-8.4	-8.9	-8.9	-9.0	-8.8	-9.1	-9.0	-9.8	-9.6	---	---	---	---	---
	Perchlorate	µg/L	---	---	---	---	ND (2.0)	ND (2.0)	ND (2.0)	ND (2.0)	---	---	---	---	---	---	---	---	---
	pH	pH units	7.88	7.58	7.93	7.70	7.74	7.77	---	---	---	---	---	---	7.93 J	7.42 **(b)**	7.72**(b)**	7.57 **(b)**	7.50 **(b)**
	Phosphate	mg/L	0.098	0.03 J	0.019 J	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Soluble silica	mg/L	---	---	---	---	22.0	22.4	18.0	18.7	21.2	21.3	23.2	21.1	---	---	---	---	---
	Specific conductance	µS/cm	1040	1570	1680	1140	1220	1260	---	---	---	---	---	---	1920	1400	1400	1200	1400
	Sulfide	mg/L	ND (0.2)	ND (0.2)J	ND (0.2)	ND (0.4)	ND (2.0)	ND (2.0)	ND (2.0)	ND (2.0)	---	---	---	---	---	---	---	---	---
	Total dissolved solids	mg/L	581	694	1080	820	905	875	870	850	1070	885	915	790	---	---	---	---	---
	Total Kjeldahl Nitrogen	mg/L	---	---	---	---	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	0.511	ND (0.5)	ND (0.5)	ND (0.5)	---	---	---	---	---
	Total organic carbon	mg/L	1.00	2.40	ND (1.0)	ND (0.5)	1.01	ND (1.0)	ND (1.0)	ND (1.0)	1.13	ND (1.0)	ND (1.0)	ND (1.0)	---	---	---	---	---
	Total suspended solids	mg/L	---	---	---	---	ND (10)	ND (10)	ND (10)	ND (10)	ND (10)	ND (10)	ND (10)	ND (10)	---	---	---	---	---
	Tritium	pCi/L	---	---	---	---	ND (350)	ND (350)	ND (14)	ND (-8.2)	---	---	---	---	---	---	---	---	---
	Turbidity	NTU	---	---	---	---	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	2.29	ND (1.0)	ND (1.0)	---	---	---	---	---
Metals (Dissolved)																			
	Aluminum, dissolved	µg/L	---	---	---	---	ND (50)	57.8	60.0	ND (50)	ND (50)	ND (50)	ND (50)	ND (50)	---	---	---	---	---
	Antimony, dissolved	µg/L	---	---	---	---	ND (2.0)	ND (2.0)	ND (2.0)	ND (2.0)	ND (2.0)	ND (2.0)	ND (2.0)	ND (2.0)	---	---	---	---	---
	Arsenic, dissolved	µg/L	---	---	---	---	1.58	1.64	2.06	1.89	1.52	1.63	1.69	1.56	---	---	---	---	---
	Barium, dissolved	µg/L	109	130	170	140	143	141	155	158	188	149	148	153	---	---	---	---	---

Notes:
(a) PM-03 for event 2004 Q2 was sampled on 6/9/2004, 7/30/2004 and 8/4/2004, each for different analytes.
(b) pH results from October 2008 onwards are field measurements.
^ From May 2, 2007 onward, samples were collected for total (unfiltered) chromium rather than dissolved chromium.

µg/L micrograms per liter (parts per billion).
mg/L milligrams per liter (parts per million).
0/00 differences from global standards in parts per thousand.
NTU nephelometric turbidity units.
µS/cm microSiemens per centimeter.
mV millivolts.
pci/L pico curies per liter.

FD field duplicate.
ND parameter not detected at the listed reporting limit (listed in the adjacent parenthesis).
J analyte was present, but reported value was estimated.
--- not collected or not available.

TABLE 3-4
Moabi Regional Park, San Bernardino County, CA; Analytical Results, PM-03 - Sampling Events with Expanded Analyte Suite
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

Group	Analyte	Units	PM-03 1997 Qtr 2 7/1/1997	PM-03 2000 Qtr 3 9/1/2000	PM-03 2001 Qtr 4 11/29/2001	PM-03 2004 Qtr 2 6/9/2004 (a)	PM-03 BKG Study 01 5/18/2005	PM-03 (FD) BKG Study 01 5/18/2005	PM-03 BKG Study 02 7/21/2005	PM-03 (FD) BKG Study 02 7/21/2005	PM-03 BKG Study 03 11/2/2005	PM-03 BKG Study 04 12/19/2005	PM-03 BKG Study 05 2/22/2006	PM-03 BKG Study 06 5/1/2006	PM-03 2007 Qtr 3 10/4/2007	PM-03 2008 Qtr 3 10/2/2008	PM-03 2009 Qtr 3 10/1/2009	PM-03 2010 Qtr 4 12/10/2010	PM-03 2011 Qtr 4 12/12/2011
Metals (Dissolved)																			
	Beryllium, dissolved	µg/L	---	---	---	---	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	---	---	---	---	---
	Boron, dissolved	µg/L	---	---	---	---	201	200	205	206	211	192	199	188	---	---	---	---	---
	Cadmium, dissolved	µg/L	---	---	---	---	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	---	---	---	---	---
	Calcium, dissolved	µg/L	49900	64400	98100	91000	82000	80400	86100	89300	106000	87500	93900	80400	144000	75600	87000	78000	90000
	Chromium, Hexavalent	µg/L	ND (10)	ND (10)	ND (10)	ND (0.2)	10.2	10.0	9.70	9.60	0.50	7.90	8.40	9.50	ND (1.0)	8.74	9.90	11.9	6.60
	Chromium, total dissolved	µg/L	18.0 J	10.0 J	17.0 J	ND (1.0)	11.5	10.9	10.2	10.8	5.47	9.89	9.46	10.6	---	---	---	---	---
	Cobalt, dissolved	µg/L	---	---	---	---	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	---	---	---	---	---
	Copper, dissolved	µg/L	3.80 J	3.60 J	5.80 J	ND (10)	4.64	4.75	2.41	1.52	1.98	ND (1.0)	1.02	ND (1.0)	---	---	---	---	---
	Iron (+2)	µg/L	17.0	50.0	ND (10)	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	Iron, dissolved	µg/L	12.0 J	---	---	880	ND (100)	ND (100)	ND (100)	ND (100)	144	ND (100)	ND (100)	ND (100)	931	ND (20)	ND (20)	ND (20)	50.0
	Lead, dissolved	µg/L	1.20 J	ND (5.0)	1.80 J	---	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	1.62	ND (1.0)	ND (1.0)	ND (1.0)	---	---	---	---	---
	Magnesium, dissolved	µg/L	9890	12800	19200	14200	16300	15900	16900	18000	21500	17400	17500	17400	30900	14900	15000	14000	17000
	Manganese, dissolved	µg/L	ND (5.0)	1.80 J	4.20 J	ND (10)	1.14	ND (1.0)	ND (1.0)	ND (1.0)	3.46	1.13	1.93	ND (1.0)	ND (20)	ND (10)	ND (10)	ND (10)	ND (10)
	Mercury, dissolved	µg/L	---	---	---	---	ND (0.2)	ND (0.2)	ND (0.2)	ND (0.2)	ND (0.2)	ND (0.2)	ND (0.2)	ND (0.2)	---	---	---	---	---
	Molybdenum, dissolved	µg/L	5.00	5.60	3.70 J	---	5.31	5.44	5.41	5.35	4.77	5.36	5.76	5.63	---	---	---	---	---
	Nickel, dissolved	µg/L	ND (25)	1.70 J	ND (400)	ND (20)	2.71 J	ND (1.0)J	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	---	---	---	---	---
	Potassium, dissolved	µg/L	5220	6600	8900	9670	6520	6360	6810	6900	7230	6590	6410	6280	---	---	---	---	---
	Selenium, dissolved	µg/L	---	---	---	---	1.36	1.84	1.51	1.41	1.60	1.68	2.09	1.58	---	---	---	---	---
	Silver, dissolved	µg/L	---	---	---	---	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	1.25	ND (1.0)	ND (1.0)	ND (1.0)	---	---	---	---	---
	Sodium, dissolved	µg/L	115000	130000	177000	133000	149000	148000	155000	163000	181000	162000	173000	148000	245000	155000	130000	130000	160000
	Thallium, dissolved	µg/L	---	---	---	---	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	---	---	---	---	---
	Vanadium, dissolved	µg/L	7.00 J	8.20 J	7.90 J	---	9.65	9.96	9.31	9.16	10.0	9.55	8.54	9.10	---	---	---	---	---
	Zinc, dissolved	µg/L	6.10	4.80 J	24.0	ND (120)	37.5	25.6	14.5	24.7	51.6	22.2	29.0	17.4	---	---	---	---	---
Metals (Total)																			
	Aluminum	µg/L	---	---	---	---	ND (50)	74.0	---	---	---	---	---	---	---	---	---	---	---
	Antimony	µg/L	---	---	---	---	ND (2.0)	ND (2.0)	---	---	---	---	---	---	---	---	---	---	---
	Arsenic	µg/L	---	---	---	---	1.62	1.71	---	---	---	---	---	---	---	---	---	---	---
	Barium	µg/L	---	---	---	---	145	144	---	---	---	---	---	---	---	---	---	---	---
	Beryllium	µg/L	---	---	---	---	ND (1.0)	ND (1.0)	---	---	---	---	---	---	---	---	---	---	---
	Boron	µg/L	---	---	---	---	205	198	---	---	---	---	---	---	---	---	---	---	---
	Cadmium	µg/L	---	---	---	---	ND (1.0)	ND (1.0)	---	---	---	---	---	---	---	---	---	---	---
	Calcium	µg/L	---	---	---	---	82400	81100	---	---	---	---	---	---	---	---	---	---	---
	Chromium, total	µg/L	---	---	---	6.40	10.9	11.0	---	---	---	---	---	---	ND (1.0)	8.35	9.50	10.5	7.00
	Cobalt	µg/L	---	---	---	---	ND (1.0)	ND (1.0)	---	---	---	---	---	---	---	---	---	---	---
	Copper	µg/L	---	---	---	---	4.92 J	5.00 J	---	---	---	---	---	---	---	---	---	---	---
	Iron	µg/L	---	35.0	260	---	ND (100)	ND (100)	---	---	---	---	---	---	---	---	---	---	---
	Lead	µg/L	---	---	---	---	ND (1.0)	ND (1.0)	---	---	---	---	---	---	---	---	---	---	---
	Magnesium	µg/L	---	---	---	---	16500	16200	---	---	---	---	---	---	---	---	---	---	---

Notes:
(a) PM-03 for event 2004 Q2 was sampled on 6/9/2004, 7/30/2004 and 8/4/2004, each for different analytes.
(b) pH results from October 2008 onwards are field measurements.
^ From May 2, 2007 onward, samples were collected for total (unfiltered) chromium rather than dissolved chromium.

µg/L micrograms per liter (parts per billion).
mg/L milligrams per liter (parts per million).
0/00 differences from global standards in parts per thousand.
NTU nephelometric turbidity units.
µS/cm microSiemens per centimeter.
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FD field duplicate.
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--- not collected or not available.

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Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

Group	Analyte	Units	PM-03 1997 Qtr 2 7/1/1997	PM-03 2000 Qtr 3 9/1/2000	PM-03 2001 Qtr 4 11/29/2001	PM-03 2004 Qtr 2 6/9/2004 (a)	PM-03 BKG Study 01 5/18/2005	PM-03 (FD) BKG Study 01 5/18/2005	PM-03 BKG Study 02 7/21/2005	PM-03 (FD) BKG Study 02 7/21/2005	PM-03 BKG Study 03 11/2/2005	PM-03 BKG Study 04 12/19/2005	PM-03 BKG Study 05 2/22/2006	PM-03 BKG Study 06 5/1/2006	PM-03 2007 Qtr 3 10/4/2007	PM-03 2008 Qtr 3 10/2/2008	PM-03 2009 Qtr 3 10/1/2009	PM-03 2010 Qtr 4 12/10/2010	PM-03 2011 Qtr 4 12/12/2011
Metals (Total)																			
	Manganese	µg/L	---	---	---	---	ND (1.0)	1.20	---	---	---	---	---	---	---	---	---	---	---
	Mercury	µg/L	---	---	---	---	ND (0.2)	ND (0.2)	---	---	---	---	---	---	---	---	---	---	---
	Molybdenum	µg/L	---	---	---	---	5.39	5.61	---	---	---	---	---	---	---	---	---	---	---
	Nickel	µg/L	---	---	---	---	ND (1.0)	ND (1.0)	---	---	---	---	---	---	---	---	---	---	---
	Potassium	µg/L	---	---	---	---	6490	6460	---	---	---	---	---	---	---	---	---	---	---
	Selenium	µg/L	---	---	---	---	1.45	2.09	---	---	---	---	---	---	---	---	---	---	---
	Silver	µg/L	---	---	---	---	ND (1.0)	ND (1.0)	---	---	---	---	---	---	---	---	---	---	---
	Sodium	µg/L	---	---	---	---	151000	149000	---	---	---	---	---	---	---	---	---	---	---
	Thallium	µg/L	---	---	---	---	ND (1.0)	ND (1.0)	---	---	---	---	---	---	---	---	---	---	---
	Vanadium	µg/L	---	---	---	---	9.72	9.47	---	---	---	---	---	---	---	---	---	---	---
	Zinc	µg/L	---	---	---	---	17.9	28.5	---	---	---	---	---	---	---	---	---	---	---

Notes:

(a) PM-03 for event 2004 Q2 was sampled on 6/9/2004, 7/30/2004 and 8/4/2004, each for different analytes.
(b) pH results from October 2008 onwards are field measurements.
^ From May 2, 2007 onward, samples were collected for total (unfiltered) chromium rather than dissolved chromium.

µg/L micrograms per liter (parts per billion).
mg/L milligrams per liter (parts per million).
0/00 differences from global standards in parts per thousand.
NTU nephelometric turbidity units.
µS/cm microSiemens per centimeter.
mV millivolts.
pci/L pico curies per liter.

FD field duplicate.
ND parameter not detected at the listed reporting limit (listed in the adjacent parenthesis).
J analyte was present, but reported value was estimated.
--- not collected or not available.

TABLE 3-5
Moabi Regional Park, San Bernardino County, CA; Analytical Results, PM-04 - Sampling Events with Expanded Analyte Suite
Freshwater Sources Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

Group	Analyte	Units	PM-04 2007 Qtr 2 5/2/2007	PM-04 2007 Qtr 3 10/4/2007	PM-04 2008 Qtr 3 10/2/2008	PM-04 2009 Qtr 3 10/1/2009	PM-04 2010 Qtr 4 12/10/2010	PM-04 2011 Qtr 4 12/12/2011
Anion								
	Bromide	mg/L	ND (0.2)	---	---	---	---	---
	Chloride	mg/L	330	---	440	470	480	490
	Fluoride	mg/L	---	---	---	---	---	---
	Nitrate (as nitrogen)	mg/L	2.80 **(a)**	---	2.50	2.20	2.20	2.20
	Nitrite	mg/L	---	---	---	---	---	---
	Sulfate	mg/L	73.9	---	85.0	82.0	92.0	91.0
General								
	Alkalinity, hydroxide	mg/L	---	---	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)
	Alkalinity, bicarb as CaCO3	mg/L	67.5	---	64.0	68.0	61.0	58.0
	Alkalinity, carb as CaCO3	mg/L	ND (5.0)	---	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)
	Alkalinity, total as CaCO3	mg/L	67.5	77.0 J	64.0	68.0	61.0	58.0
	Ammonia	mg/L	---	---	---	---	---	---
	Ammonia as nitrogen	mg/L	ND (0.5)	---	---	---	0.12	ND (0.1)
	Bicarbonate	mg/L	---	93.9 J	---	---	---	---
	Carbonate	mg/L	---	ND (5.0)J	---	---	---	---
	Deuterium	0/00	---	---	---	---	---	---
	Dissolved organic carbon	mg/L	---	---	---	---	---	---
	Iodide	µg/L	---	---	---	---	---	---
	Orthophosphate	mg/L	---	---	---	---	---	---
	Oxidation reduction potential	mV	---	---	---	---	---	---
	Oxygen 18	0/00	---	---	---	---	---	---
	Perchlorate	µg/L	---	---	---	---	---	---
	pH	pH units	7.99 J	8.14 J	7.44 **(b)**	7.91 **(b)**	7.44 **(b)**	7.70 **(b)**
	Phosphate	mg/L	---	---	---	---	---	---
	Soluble silica	mg/L	---	---	---	---	---	---
	Specific conductance	µS/cm	1530	1720	1700	1800	1700	1800
	Sulfide	mg/L	ND (2.0)	---	---	---	---	---
	Total dissolved solids	mg/L	928	---	---	---	---	---
	Total Kjeldahl Nitrogen	mg/L	---	---	---	---	---	---
	Total organic carbon	mg/L	0.376	---	---	---	---	---
	Total suspended solids	mg/L	---	---	---	---	---	---
	Tritium	pCi/L	---	---	---	---	---	---

Notes:

(a) The nitrate result of 2.8 mg/L is from a sample collected from PM-04 on July 18, 2007 in response to the anomalous nitrate result of 25.9 mg/L reported from the May 2, 2007 sample.

(b) pH results from October 2008 onward are field measurements.

^ From May 2, 2007 onward, samples were collected for total (unfiltered) chromium rather than dissolved chromium.

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mg/L milligrams per liter (parts per million).
0/00 differences from global standards in parts per thousand.
NTU nephelometric turbidity units.
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General								
	Turbidity	NTU	---	---	---	---	---	---
Metals (Dissolved)								
	Aluminum, dissolved	µg/L	---	---	---	---	---	---
	Antimony, dissolved	µg/L	ND (2.0)	---	---	---	---	---
	Arsenic, dissolved	µg/L	ND (1.0)	---	---	---	---	---
	Barium, dissolved	µg/L	112	---	---	---	---	---
	Beryllium, dissolved	µg/L	ND (1.0)	---	---	---	---	---
	Boron, dissolved	µg/L	---	---	---	---	---	---
	Cadmium, dissolved	µg/L	ND (1.0)	---	---	---	---	---
	Calcium, dissolved	µg/L	---	89300	72000	88000	93000	91000
	Chromium, Hexavalent	µg/L	ND (0.2)	21.4	20.6	21.0	21.0	18.9
	Chromium, total dissolved	µg/L	---	---	---	---	---	---
	Cobalt, dissolved	µg/L	ND (1.0)	---	---	---	---	---
	Copper, dissolved	µg/L	1.96	---	---	---	---	---
	Iron (+2)	µg/L	---	---	---	---	---	---
	Iron, dissolved	µg/L	---	617	ND (20)	ND (20)	ND (20)	60.0
	Lead, dissolved	µg/L	ND (1.0)	---	---	---	---	---
	Magnesium, dissolved	µg/L	---	22300	12400	14000	15000	15000
	Manganese, dissolved	µg/L	---	ND (20)	ND (10)	ND (10)	ND (10)	ND (10)
	Mercury, dissolved	µg/L	ND (0.2)	---	---	---	---	---
	Molybdenum, dissolved	µg/L	6.02	---	---	---	---	---
	Nickel, dissolved	µg/L	6.30	---	---	---	---	---
	Potassium, dissolved	µg/L	---	---	---	---	---	---
	Selenium, dissolved	µg/L	1.45	---	---	---	---	---
	Silver, dissolved	µg/L	ND (1.0)	---	---	---	---	---
	Sodium, dissolved	µg/L	---	280000	234000	220000	230000	260000
	Thallium, dissolved	µg/L	ND (1.0)	---	---	---	---	---
	Vanadium, dissolved	µg/L	1.57	---	---	---	---	---
	Zinc, dissolved	µg/L	605 J	---	---	---	---	---
Metals (Total)								
	Aluminum	µg/L	---	---	---	---	---	---
	Antimony	µg/L	---	---	---	---	---	---

Notes:

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Metals (Total)								
	Arsenic	µg/L	---	---	---	---	---	---
	Barium	µg/L	---	---	---	---	---	---
	Beryllium	µg/L	---	---	---	---	---	---
	Boron	µg/L	---	---	---	---	---	---
	Cadmium	µg/L	---	---	---	---	---	---
	Calcium	µg/L	---	---	---	---	---	---
	Chromium, total	µg/L	ND (1.0)	23.5	18.5	18.0	20.6	18.2
	Cobalt	µg/L	---	---	---	---	---	---
	Copper	µg/L	---	---	---	---	---	---
	Iron	µg/L	---	---	---	---	---	---
	Lead	µg/L	---	---	---	---	---	---
	Magnesium	µg/L	---	---	---	---	---	---
	Manganese	µg/L	---	---	---	---	---	---
	Mercury	µg/L	---	---	---	---	---	---
	Molybdenum	µg/L	---	---	---	---	---	---
	Nickel	µg/L	---	---	---	---	---	---
	Potassium	µg/L	---	---	---	---	---	---
	Selenium	µg/L	---	---	---	---	---	---
	Silver	µg/L	---	---	---	---	---	---
	Sodium	µg/L	---	---	---	---	---	---
	Thallium	µg/L	---	---	---	---	---	---
	Vanadium	µg/L	---	---	---	---	---	---
	Zinc	µg/L	---	---	---	---	---	---

Notes:

(a) The nitrate result of 2.8 mg/L is from a sample collected from PM-04 on July 18, 2007 in response to the anomalous nitrate result of 25.9 mg/L reported from the May 2, 2007 sample.

(b) pH results from October 2008 onward are field measurements.

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mg/L milligrams per liter (parts per million).
0/00 differences from global standards in parts per thousand.
NTU nephelometric turbidity units.
µS/cm microSiemens per centimeter.
mV millivolts.
pci/L pico curies per liter.
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TABLE 3-6
Summary Statistics of Surface Water Sampling Results, July 1997 through June 2011
Freshwater Source Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

	Hexavalent Chromium (µg/L)		Dissolved Chromium (µg/L)		Dissolved Arsenic (µg/L)		Dissolved Manganese (µg/L)		Dissolved Iron (µg/L)		Dissolved Selenium (µg/L)		Dissolved Molybdenum (µg/L)		Dissolved Nitrate (µg/L)		Specific Conductance (µS/cm)		pH (pH Units)	
Chemical-Specific ARAR[1]	11 (a)		NA		150 (a)		NA		NA		5 (b)		NA		NA		NA		NA	
Station ID[2]	**Frequency of Detection (Number of Detects/Number of Samples) and Average Concentration[3]**																			
Shoreline Surface Water Monitoring Locations																				
A-Dock	0 \ 6	ND	0 \ 6	ND	0 \ 0	---	0 \ 1	ND	0 \ 0	---	0 \ 0	---	0 \ 1	ND	0 \ 0	---	4 \ 4	944	4 \ 4	8.02
CON	0 \ 75^	ND	6 \ 76	3.23	0 \ 0	---	2 \ 4	65.0	0 \ 1	ND	0 \ 0	---	2 \ 3	4.93	1 \ 1	370	41 \ 41	1120	39 \ 39	8.12
C-TM-1	0 \ 3	ND	0 \ 3	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---
C-TM-2	0 \ 3	ND	0 \ 3	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---
R63	0 \ 13	ND	1 \ 13	0.554	1 \ 1	2.40	0 \ 1	ND	0 \ 1	ND	0 \ 1	ND	0 \ 1	ND	0 \ 1	ND	13 \ 13	979	13 \ 13	8.21
I-3	0 \ 70^	ND	7 \ 71	3.13	0 \ 0	---	3 \ 5	54.1	0 \ 2	ND	0 \ 0	---	3 \ 3	4.73	3 \ 4	488	40 \ 40	957	38 \ 38	8.20
Needles Gauge	0 \ 2	ND	0 \ 2	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---
NR-1	0 \ 48	ND	1 \ 49	0.614	0 \ 0	---	0 \ 1	ND	0 \ 1	ND	0 \ 0	---	0 \ 0	---	0 \ 1	ND	18 \ 18	1020	17 \ 17	8.22
NR-2	0 \ 48	ND	1 \ 49	0.635	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	18 \ 18	1010	17 \ 17	8.23
NR-3	0 \ 46	ND	0 \ 47	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	18 \ 18	1000	17 \ 17	8.22
R-19	0 \ 17	ND	0 \ 17	ND	1 \ 1	2.40	0 \ 1	ND	0 \ 1	ND	0 \ 1	ND	0 \ 1	ND	0 \ 1	ND	17 \ 17	957	17 \ 17	8.27
R-19-B	0 \ 2	ND	0 \ 2	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	1 \ 1	901	1 \ 1	7.82
R-19-C	0 \ 2	ND	0 \ 2	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	2 \ 2	892	2 \ 2	7.84
R-20	0 \ 1	ND	0 \ 1	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	1 \ 1	902	1 \ 1	7.95
R-20-B	0 \ 2	ND	0 \ 2	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	2 \ 2	893	2 \ 2	7.84
R-20-C	0 \ 2	ND	0 \ 2	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	2 \ 2	891	2 \ 2	7.77
R-22	0 \ 69^	ND	7 \ 70	2.68	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	35 \ 35	974	35 \ 35	8.23
R-27	0 \ 70^	ND	6 \ 71	2.67	0 \ 0	---	0 \ 3	ND	0 \ 3	ND	0 \ 0	---	0 \ 0	---	4 \ 18	320	35 \ 35	960	34 \ 34	8.20
R-28	0 \ 83^	ND	7 \ 84	2.74	1 \ 1	2.10	0 \ 4	ND	0 \ 4	ND	0 \ 1	ND	1 \ 2	5.20	6 \ 27	562	51 \ 51	999	50 \ 50	8.25
RRB	0 \ 78^	ND	8 \ 79	2.68	1 \ 1	2.70	1 \ 2	5.00	0 \ 1	ND	0 \ 1	ND	1 \ 2	6.00	0 \ 1	ND	49 \ 49	1190	48 \ 48	8.07
Seasonal Wetlands	0 \ 8	ND	0 \ 8	ND	0 \ 0	---	1 \ 1	8.00	0 \ 0	---	0 \ 0	---	1 \ 1	5.00	0 \ 0	---	8 \ 8	4800	8 \ 8	7.97
River Channel Surface Water Monitoring Locations																				
C-BNS	0 \ 14	ND	0 \ 14	ND	1 \ 1	2.80	0 \ 1	ND	0 \ 1	ND	0 \ 1	ND	0 \ 1	ND	0 \ 1	ND	14 \ 14	959	14 \ 14	8.22
C-CON	0 \ 99	ND	0 \ 99	ND	2 \ 2	2.45	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	71 \ 71	1000	71 \ 71	8.25
C-I-3	0 \ 99	ND	0 \ 99	ND	2 \ 2	2.65	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	3 \ 5	423	71 \ 71	977	71 \ 71	8.27
C-MAR	0 \ 63	ND	0 \ 63	ND	2 \ 2	2.45	2 \ 2	16.9	1 \ 2	25.5	0 \ 2	ND	0 \ 2	ND	1 \ 4	657	46 \ 46	1150	46 \ 46	7.93
C-NR1	0 \ 99	ND	0 \ 99	ND	2 \ 2	2.15	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	71 \ 71	994	71 \ 71	8.32
C-NR3	0 \ 99	ND	0 \ 99	ND	2 \ 2	2.25	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	71 \ 71	995	71 \ 71	8.31
C-NR4	0 \ 99	ND	0 \ 99	ND	2 \ 2	2.20	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	71 \ 71	991	71 \ 71	8.31
C-R22	1 \ 74	0.115	0 \ 74	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	3 \ 3	538	39 \ 39	1000	39 \ 39	8.25
C-R22a	0 \ 31	ND	0 \ 31	ND	2 \ 2	2.70	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	31 \ 31	962	31 \ 31	8.30
C-R27	0 \ 94	ND	0 \ 94	ND	2 \ 2	2.50	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	3 \ 5	420	67 \ 67	979	67 \ 67	8.27
C-TAZ	0 \ 96	ND	0 \ 99	ND	2 \ 2	2.50	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	0 \ 2	ND	3 \ 5	421	71 \ 71	982	71 \ 71	8.28
Other Surface Water Monitoring Locations																				
SW2	0 \ 12	ND	0 \ 12	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	12 \ 12	987	12 \ 12	7.83
SW1	1 \ 20	0.107	0 \ 20	ND	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	0 \ 0	---	18 \ 18	1020	18 \ 18	7.79

TABLE 3-6
Summary Statistics of Surface Water Sampling Results, July 1997 through June 2011
Freshwater Source Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

Notes:

ND	not detected
NA	not available
(a)	Freshwater aquatic life protection, continuous concentration 4-day average; expressed as dissolved.
(b)	Freshwater aquatic life protection, continuous concentration 4-day average; expressed as total recoverable.
^	According to the data quality review for the June 2002 monitoring, the results were determined to be false positive due to unidentified interference for these samples, and no action should be taken or project decisions made based on the results. These results were not included in the statistical analyses.
µS/cm	microsiemens per centimeter
µg/L	micrograms per liter
---	not analyzed

At each of the river channel surface water locations, depth specific samples were collected at shallow (1 foot from water surface), middle (middle samples no longer collected after 6/18/2008), and deep depths (1 foot from river bottom). Results for each location summarize the samples collected at depth.

At locations R-19B, R-19C and R-20B, multiple samples were collected at surface, 5-foot, and 10-foot depths and locations. Results for each location summarized the samples collected at depth.

Refer to Appendix A for complete analytical data for surface water sampling.

1 Source: Groundwater Record of Decision, Table 2, Federal Chemical-Specific ARAR #3, Citation: Federal Water Pollution Control Act (Clean Water Act) - 33 USC §§ 1251-1387; 40 CFR 131.38.
2 Surface water locations are listed in order of their position on the river, from north to south.
3 Average concentrations of all results (including estimated concentrations) in micrograms per liter, with half the reporting limit used for non detects. Detected results are the maximum concentrations from primary or duplicate samples.

TABLE 3-7

Summary of Select Contaminants and Compounds in Pharmaceuticals and Personal Care Products in Colorado River Samples Collected by Others (2008-2012)

Freshwater Source Evaluation Technical Memorandum

PG&E Topock Compressor Station, Needles, California

Contaminants	Detection Limit	Units	Lake Havasu Contact Point				Lake Havasu Intake				Lake Havasu Inlet				Lake Havasu				Lake Mead Out Structure				Colorado Stream Below Davis Dam				Colorado Stream Wildlife Refuge_NWB				Colorado Stream Topock Above Railroad				Colorado Stream Topock Bat Cave Wash				Colorado Stream Topock Down River				Colorado Stream Topock Near Park Moabi				Hoover Dam			
			Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples
Select Contaminants with Primary MCLs																																																		
Perchlorate	2	µg/L	--	--	--	--	2.3	ND	16	48	--	--	--	--	--	--	--	--	4.6	ND	143	189	3.0	ND	5	19	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nitrate	0.1	mg/L	2.4	1.1	0	85	2.4	0.9	0	162	--	--	--	--	--	--	--	--	--	--	--	--	2.5	1.4	0	23	2.5	1.3	0	46	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nitrite-Nitrogen	0.005	mg/L	0.007	ND	68	77	0.022	ND	127	144	--	--	--	--	--	--	--	--	--	--	--	--	0.005	ND	20	21	0.009	ND	36	41	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Contaminants with Secondary MCLs																																																	
Calcium	0.1	mg/L	--	--	--	--	80	71	0	50	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Magnesium	0.1	mg/L	--	--	--	--	31	25	0	50	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MTBE	0.5	µg/L	--	--	--	--	ND	ND	75	75	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Thiobencarb	1	µg/L	--	--	--	--	ND	ND	3	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Turbity	--	NTU	2.6	0.26	0	85	2	0.21	0	106	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5	0.26	0	41	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chloride	2	mg/L	--	--	--	--	95	81	0	49	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sulfate	4	mg/L	260	219	0	79	262	216	0	144	--	--	--	--	--	--	--	--	--	--	--	--	257	215	0	19	258	218	0	38	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Specific Conductance	--	umho/cm	1060	1040	0	6	1060	932	0	56	--	--	--	--	--	--	--	--	1100	895	0	196	--	--	--	--	1060	1030	0	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Threshold Odor	1	--	--	--	--	--	20	17	0	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Foaming Agents (MBAS)	0.05	mg/L	--	--	--	--	ND	ND	3	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Color	1	color units	--	--	--	--	6.0	2	0	17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Trace Elements																																																		
Aluminum	10	µg/L	--	--	--	--	150	ND	3	55	--	--	--	--	--	--	--	--	--	--	--	--	18	ND	1	2	--	--	--	--	540	13	0	7	69	31	0	2	62	14	0	7		12	0	7	--	--	--	--
Antimony	2	µg/L	--	--	--	--	ND	ND	7	7	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	2	2	--	--	--	--	ND	ND	7	7	ND	ND	2	2	ND	ND	7	7	ND	ND	7	7	--	--	--	--
Arsenic	0.5	µg/L	--	--	--	--	3.0	2.4	0	55	--	--	--	--	--	--	--	--	--	--	--	--	2.7	2.6	0	2	--	--	--	--	2.8	2.6	0	7	2.9	2.8	0	2	2.7	2.6	0	7	2.8	2.6	0	7	--	--	--	--
Barium	5	µg/L	--	--	--	--	154	125	0	7	--	--	--	--	--	--	--	--	--	--	--	--	147	139	0	2	--	--	--	--	153	136	0	7	152	151	0	2	156	135	0	7	151	141	0	7	--	--	--	--
Beryllium	0.5	µg/L	--	--	--	--	ND	ND	7	7	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	2	2	--	--	--	--	ND	ND	7	7	ND	ND	2	2	ND	ND	7	7	ND	ND	7	7	--	--	--	--
Boron	0.02	mg/L	--	--	--	--	0.14	0.12	0	10	--	--	--	--	--	--	--	--	--	--	--	--	0.13	0.13	0	2	--	--	--	--	0.18	0.13	0	7	0.15	0.13	0	2	0.14	0.13	0	7	0.14	0.13	0	7	--	--	--	--
Cadmium	0.1	µg/L	--	--	--	--	ND	ND	6	6	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	2	2	--	--	--	--	ND	ND	9	9	ND	ND	2	2	ND	ND	7	7	ND	ND	7	7	--	--	--	--
Copper	10	µg/L	--	--	--	--	ND	ND	55	55	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	2	2	--	--	--	--	ND	ND	7	7	ND	ND	2	2	ND	ND	7	7	ND	ND	7	7	--	--	--	--
Iron	50	µg/L	--	--	--	--	120	ND	1	6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lead	1	µg/L	--	--	--	--	ND	ND	7	7	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	2	2	--	--	--	--	ND	ND	7	7	ND	ND	2	2	ND	ND	7	7	ND	ND	7	7	--	--	--	--
Manganese	5	µg/L	--	--	--	--	ND	ND	7	7	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	2	2	--	--	--	--	ND	ND	7	7	ND	ND	2	2	ND	ND	7	7	ND	ND	7	7	--	--	--	--
Mercury	0.2	µg/L	--	--	--	--	ND	ND	7	7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Molybdenum	2	µg/L	--	--	--	--	6	4	0	7	--	--	--	--	--	--	--	--	--	--	--	--	6	6	0	2	--	--	--	--	6	6	0	6	6	6	0	2	6	6	0	6	6	6	0	6	--	--	--	--
Nickel	2	µg/L	--	--	--	--	3.0	ND	2	7	--	--	--	--	--	--	--	--	--	--	--	--	4.0	3.0	0	2	--	--	--	--	4.0	ND	1	7	3.0	2.0	0	2	4.0	2.0	0	7	4.0	ND	1	7	--	--	--	--
Potassium	0.1	mg/L	--	--	--	--	5.2	4.3	0	49	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Selenium	5	µg/L	--	--	--	--	ND	ND	7	7	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	2	2	--	--	--	--	ND	ND	7	7	ND	ND	2	2	ND	ND	7	7	ND	ND	7	7	--	--	--	--
Silver	5	µg/L	--	--	--	--	ND	ND	7	7	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	2	2	--	--	--	--	ND	ND	7	7	ND	ND	2	2	ND	ND	7	7	ND	ND	7	7	--	--	--	--
Sodium	0.1	mg/L	--	--	--	--	100	85	0	50	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

TABLE 3-7
Summary of Select Contaminants and Compounds in Pharmaceuticals and Personal Care Products in Colorado River Samples Collected by Others (2008-2012)
Freshwater Source Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

Contaminants	Detection Limit	Units	Lake Havasu Contact Point				Lake Havasu Intake				Lake Havasu Inlet				Lake Havasu			
			Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples
Thallium	1	µg/L	--	--	--	--	ND	ND	6	6	--	--	--	--	--	--	--	--
Vanadium	1	µg/L	--	--	--	--	2.7	2.2	0	7	--	--	--	--	--	--	--	--
Zinc	20	µg/L	--	--	--	--	ND	ND	7	7	--	--	--	--	--	--	--	--
Compounds in Pharmaceuticals and Personal Care Products (PPCP)																		
Caffeine	5	ng/L	--	--	--	--	338	ND	1	4	1370	ND	1	3	29.6	ND	2	6
Carbamazepine	1	ng/L	--	--	--	--	3.4	2	0	5	3.3	2	0	4	5	ND	1	6
DEET	20	ng/L	--	--	--	--	28.0	ND	3	4	297	ND	0	3	--	--	--	--
Ibuprofen	10	ng/L	--	--	--	--	ND	ND	4	4	35.6	ND	2	3	--	--	--	--
4-n-Nonylphenol	50	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	3	3	--	--	--	--
o,p-DDD	20	ng/L	--	--	--	--	44.0	ND	3	4	23.0	ND	2	3	--	--	--	--
Diuron	5	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	ND	ND	5	5
Methylparaben	20	ng/L	--	--	--	--	35.0	ND	3	4	ND	ND	3	3	--	--	--	--
Primidone	2	ng/L	--	--	--	--	4.0	2	0	4	4.0	ND	1	3	4.5	ND	2	6
Sulfamethoxazole	1	ng/L	--	--	--	--	13.3	ND	0	4	14.4	ND	0	3	--	--	--	--
TCEP	5	ng/L	--	--	--	--	9.0	ND	2	4	5.0	ND	2	3	--	--	--	--
Acetaminophen	10	ng/L	--	--	--	--	14.0	ND	1	4	5.3	ND	0	3	--	--	--	--
Azithromycin	1	ng/L	--	--	--	--	5.5	ND	3	4	ND	ND	3	3	--	--	--	--
17a-Estradiol	10	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
17b-Estradiol	10	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
2,4,6-Trichlorophenol	1000	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
4-n- and 4-t-Octylphenol	20	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
4-Phenylphenol	1000	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Anthracene	10	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Atrazine	1	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Atrazine-Desethyl	20	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Atrazine-Desisopropyl	20	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Benzo(a)pyrene	25	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Bisphenol A	30 (MWD)	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Butylparaben	20	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Ciprofloxacin	10	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Cyanazine	20	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Cyprazine	20	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Diclofenac	5	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Diethylstilbestrol	10	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Dilantin	5	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--

Contaminants	Lake Mead Out Structure				Colorado Stream Below Davis Dam				Colorado Stream Wildlife Refuge_NWB				Colorado Stream Topock Above Railroad			
	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples
Thallium	--	--	--	--	ND	ND	2	2	--	--	--	--	ND	ND	7	7
Vanadium	--	--	--	--	2.6	2.4	0	2	--	--	--	--	2.8	2.4	0	7
Zinc	--	--	--	--	ND	ND	2	2	--	--	--	--	ND	ND	7	7
Compounds in Pharmaceuticals and Personal Care Products (PPCP)																
Caffeine	--	--	--	--	109	ND	6	9	5.0	ND	1	6	--	--	--	--
Carbamazepine	--	--	--	--	4	2	0	9	5	ND	1	6	--	--	--	--
DEET	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Ibuprofen	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
4-n-Nonylphenol	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
o,p-DDD	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Diuron	--	--	--	--	ND	ND	8	8	ND	ND	5	5	--	--	--	--
Methylparaben	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Primidone	--	--	--	--	4	ND	2	9	4.3	ND	2	6	--	--	--	--
Sulfamethoxazole	--	--	--	--	15	ND	0	4	--	--	--	--	--	--	--	--
TCEP	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Acetaminophen	--	--	--	--	ND	ND	3	3	--	--	--	--	--	--	--	--
Azithromycin	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
17a-Estradiol	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
17b-Estradiol	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
2,4,6-Trichlorophenol	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
4-n- and 4-t-Octylphenol	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
4-Phenylphenol	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Anthracene	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Atrazine	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Atrazine-Desethyl	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Atrazine-Desisopropyl	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Benzo(a)pyrene	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Bisphenol A	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Butylparaben	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Ciprofloxacin	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Cyanazine	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Cyprazine	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Diclofenac	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Diethylstilbestrol	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Dilantin	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--

Contaminants	Colorado Stream Topock Bat Cave Wash				Colorado Stream Topock Down River				Colorado Stream Topock Near Park Moabi				Hoover Dam			
	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples
Thallium	ND	ND	2	2	ND	ND	7	7	ND	ND	7	7	--	--	--	--
Vanadium	2.5	2.5	0	2	2.6	2.4	0	7	2.6	2.5	0	7	--	--	--	--
Zinc	ND	ND	1	1	ND	ND	7	7	ND	ND	7	7	--	--	--	--
Compounds in Pharmaceuticals and Personal Care Products (PPCP)																
Caffeine	--	--	--	--	--	--	--	--	--	--	--	--	28.1	ND	1	10
Carbamazepine	--	--	--	--	--	--	--	--	--	--	--	--	9	ND	1	10
DEET	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Ibuprofen	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
4-n-Nonylphenol	--	--	--	--	--	--	--	--	--	--	--	--	143	ND	3	4
o,p-DDD	--	--	--	--	--	--	--	--	--	--	--	--	31	ND	3	4
Diuron	--	--	--	--	--	--	--	--	--	--	--	--	6.91	ND	8	9
Methylparaben	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Primidone	--	--	--	--	--	--	--	--	--	--	--	--	3.8	ND	1	10
Sulfamethoxazole	--	--	--	--	--	--	--	--	--	--	--	--	17.05	ND	0	4
TCEP	--	--	--	--	--	--	--	--	--	--	--	--	8	ND	2	4
Acetaminophen	--	--	--	--	--	--	--	--	--	--	--	--	2.5	ND	2	4
Azithromycin	--	--	--	--	--	--	--	--	--	--	--	--	13	ND	3	4
17a-Estradiol	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
17b-Estradiol	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
2,4,6-Trichlorophenol	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
4-n- and 4-t-Octylphenol	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
4-Phenylphenol	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Anthracene	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Atrazine	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Atrazine-Desethyl	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Atrazine-Desisopropyl	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Benzo(a)pyrene	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Bisphenol A	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Butylparaben	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Ciprofloxacin	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Cyanazine	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Cyprazine	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Diclofenac	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Diethylstilbestrol	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Dilantin	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4

TABLE 3-7
Summary of Select Contaminants and Compounds in Pharmaceuticals and Personal Care Products in Colorado River Samples Collected by Others (2008-2012)
Freshwater Source Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

			Lake Havasu Contact Point				Lake Havasu Intake				Lake Havasu Inlet				Lake Havasu			
Contaminants	Detection Limit	Units	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples
Epitestosterone	10	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Estriol	10	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Estrone	10	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Ethylparaben	20	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Ethynylestradiol (EE2)	10	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Gemfibrozil	5	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Lindane	10	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Linuron	5	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Methoxychlor	20	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Nonylphenol ethoxylates (total)	10000	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Pentachlorophenol	1000	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Progesterone	10	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Propazine	20	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Propylparaben	20	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Simazine	20	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Testosterone	10	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Tetrabromobisphenol A	1000	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--
Triclosan	5	ng/L	--	--	--	--	ND	ND	4	4	ND	ND	4	4	--	--	--	--

	Lake Mead Out Structure				Colorado Stream Below Davis Dam				Colorado Stream Wildlife Refuge_NWB				Colorado Stream Topock Above Railroad			
Contaminants	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples
Epitestosterone	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Estriol	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Estrone	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Ethylparaben	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Ethynylestradiol (EE2)	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Gemfibrozil	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Lindane	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Linuron	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Methoxychlor	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Nonylphenol ethoxylates (total)	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Pentachlorophenol	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Progesterone	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Propazine	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Propylparaben	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Simazine	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Testosterone	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Tetrabromobisphenol A	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--
Triclosan	--	--	--	--	ND	ND	4	4	--	--	--	--	--	--	--	--

	Colorado Stream Topock Bat Cave Wash				Colorado Stream Topock Down River				Colorado Stream Topock Near Park Moabi				Hoover Dam			
Contaminants	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples	Maximum	Minimum	Number of Non-Detects	Total Number of Samples
Epitestosterone	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Estriol	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Estrone	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Ethylparaben	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Ethynylestradiol (EE2)	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Gemfibrozil	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Lindane	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Linuron	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Methoxychlor	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Nonylphenol ethoxylates (total)	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Pentachlorophenol	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Progesterone	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Propazine	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Propylparaben	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Simazine	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Testosterone	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Tetrabromobisphenol A	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4
Triclosan	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND	4	4

Source: Metropolitan Water District

TABLE 3-8
Summary of Tracers for Pharmaceuticals and Personal Care Products in Colorado River Samples (July 2009-October 2010)
Freshwater Source Evaluation Technical Memorandum
PG&E Topock Compressor Station, Needles, California

Sample Name	Sampling Date	Caffeine	Primidone (Drug)	Carbamazepine (Drug)	Diuron (Herbicide)
		Maximum Reporting Limit (ng/L)			
		5	2	1	5
Hoover Dam	Jul-09	6	2	2	ND
	Nov-09	8	2	3	ND
	Jan-10	10	3	4	ND
	Apr-10	10	3	3	7
	Jul-10	13	2	ND	ND
	Oct-10	6	3	3	ND
Below Davis Dam	Jul-09	59	4	3	ND
	Nov-09	NS	NS	NS	NS
	Jan-10	ND	2	2	ND
	Apr-10	ND	3	3	ND
	Jul-10	109	2	2	ND
	Oct-10	ND	ND	ND	ND
Wildlife Refuge	Jul-09	8	4	3	ND
	Nov-09	9	ND	1	ND
	Jan-10	10	2	2	ND
	Apr-10	8	2	3	ND
	Jul-10	48	2	ND	ND
	Oct-10	ND	ND	ND	ND
Lake Havasu	Jul-09	10	4	2	ND
	Nov-09	16	ND	2	ND
	Jan-10	ND	2	2	ND
	Apr-10	ND	2	3	ND
	Jul-10	12	2	ND	ND
	Oct-10	30	ND	ND	ND

Notes:
ND=Not detected
NS=Not sampled

Source: Metropolitan Water District

Attachment A
LeRoy Crandall and Associates Reports

REC'D 12/22/86

*COUNTY OF SAN BERNARDINO
REGIONAL PARKS DEPT.
825 EAST THIRD ST.
SAN BERNARDINO CA
92415-0733

RESULTS OF EXPLORATORY DRILLING FOR A WATER SUPPLY SOURCE AT PARK MOABI SAN BERNARDINO COUNTY, CALIFORNIA

LeRoy Crandall & Associates — Report (2)

April 1986

Prepared For
General Services Agency
Facilities Management Department
Architecture and Engineering Division
San Bernardino County, California
Purchase Order No. J5259-M
Our Job No. E-85417-B

ATTACHMENT B-2

TABLE OF CONTENTS

Text	Page No.
INTRODUCTION	1
GEOLOGIC CONDITIONS	2
EXPLORATORY DRILLING	3
GROUND WATER QUALITY	4
CONCLUSIONS AND RECOMMENDATIONS	9

Tables

1.	Chemical Analyses of Water Samples	5
2.	Concentration of Minor Elements	8

Figures		Following Page
1.	Location of Wells	1
2.	Geologic Section	2
3.	Well Construction Details	10

Appendices

A. Lithologic Logs

B. Laboratory Analyses of Water Samples

C. Technical Specifications <not included in L-W word copy>

RESULTS OF EXPLORATORY DRILLING FOR A WATER SUPPLY SOURCE AT PARK MOABI SAN BERNARDINO COUNTY, CALIFORNIA

INTRODUCTION

This report presents a summary of our exploration program for a water supply well at Park Moabi, California. The exploration program commenced on March 26, 1986, and concluded on March 27, 1986. Drilling was carried out on a subcontract basis by Becker Drills, Inc. of Denver, Colorado. One exploratory boring was located near the Reverse Osmosis (R.O.) unit and is designated Boring No. 1. Two other exploratory borings were drilled southwest of the trailer park area, and are designated Boring Nos. 2 and 3. Figure 1, Location of Wells, shows the location of these exploratory borings and existing wells. All rocks penetrated by the borings were logged by a staff geologist from our company. Electrical conductivities (EC) of the water encountered were measured at approximately 10-foot intervals. Lithologic logs of borings are presented in Appendix A.

Our professional services have been performed using that degree of care and skill ordinarily exercised, under similar circumstances, by reputable geologists practicing in this or similar localities. No other warranty, expressed or implied, is made as to the professional advice included in this report.

GEOLOGIC CONDITIONS

Water-bearing and nonwater-bearing rocks in the area can be divided into four units: bedrock, fanglomerate, Bouse Formation and Recent alluvium. Figures 1 and 2 illustrate the areal extent and x-section stratigraphic relationship of the rocks that occur above the bedrock.

The bedrock is exposed in the Chemehuevi Mountains located south to southwest of the park. It is comprised of metamorphic, igneous and volcanic rocks which are considered nonwater-bearing. They are overlain by a fanglomerate composed of bedrock and meta-sedimentary gravels, sands and clays derived from the local mountains and areas northwest of the Park. The fanglomerate is exposed south of Interstate Highway 40. It is areally extensive and forms a ground water recharge area for the aquifers that occur beneath the Park. It also appears to include the Toa deeper aquifer that was penetrated by exploration Borings 1 and 3 at depths of 177 and 69 feet, respectively. The depth of the contact between the bedrock and fanglomerate beneath the Park is unknown, but it may reach a depth of 1,000 feet.

The fanglomerate is overlain by gray to blue silt and clay deposits of the Bouse Formation that were observed in all borings. They have a very low permeability that forms an aquitard which confines the aquifer within the underlying fanglomerate, and isolates it from the overlying Recent Alluvium.

The Bouse Formation is overlain by Recent Alluvium that is exposed at ground surface throughout the Park and in the adjacent

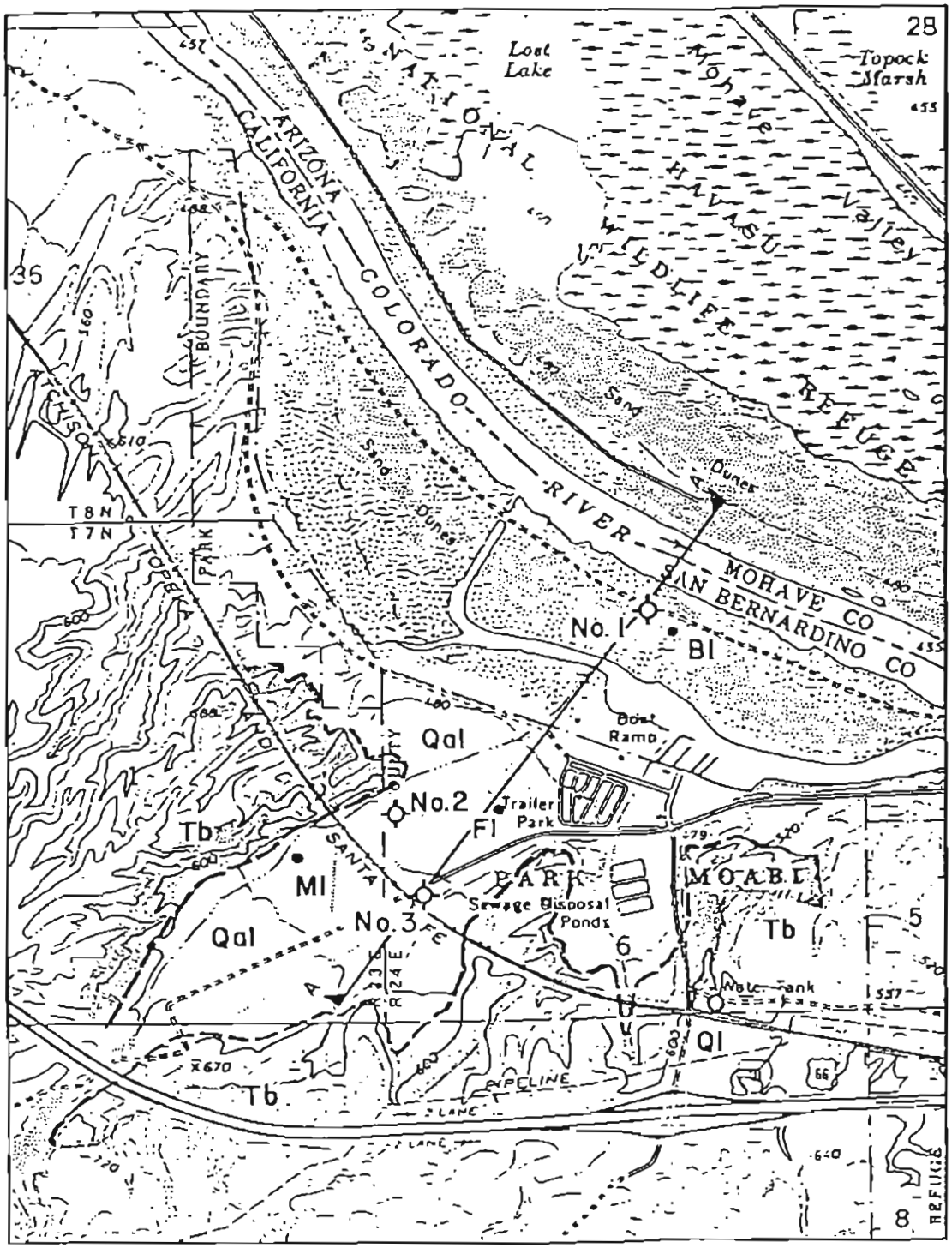
canyons. The alluvium is composed of eroded bedrock fragments, fanglomerate and Colorado River sediments that form an unconfined aquifer. The aquifer is 20 to 60 feet thick, and generally yields poor quality ground water beneath most of the Park property.

EXPLORATORY DRILLING

Boring No. 1 was drilled from ground surface to a depth of 250 feet. This boring penetrated 115 feet of recent Colorado River alluvium consisting primarily of sand and gravel with a few interbeds of organic rich silts and clays. A clayey zone was penetrated between 115 to 177 feet. Below this unit are fanglomerates consisting of sand and gravels derived from the local mountains to the west. A small quantity of good quality ground water was encountered from approximately 40 to 70 feet. Below 70 feet to a depth of 250 feet, conductivity measurements indicated the presence of poor quality ground water.

Boring No. 2 was drilled to a depth of 80 feet without encountering a viable source of ground water. The borehole penetrated 10 feet of Recent Alluvium before encountering silts and clays of the Bouse Formation.

Boring No. 3 revealed the probable presence of good quality ground water. This boring penetrated Recent alluvium from ground surface to a depth of 35 feet. Silts and clays were found between 35 and 69 feet, which probably are lower members of the Bouse Formation. A fanglomerate occurs below these deposits which extends from 69 feet to a depth greater than 250 feet. The conductivity of water samples obtained



EXPLANATION

Qal — ALLUVIUM
Recent sand, gravel and silt

Tb — BOUSE FORMATION
Pliocene sand, silt, clay, limestone and tufa.

GEOLOGIC CONTACT
Approximately located

Fl • WATER WELL

Ql ○ EXPLORATORY BORING

No.2 ⊙ EXPLORATORY BORING BY LC&A

A — A' GEOLOGIC SECTION

Reference: Base map from U.S.G.S. 7½' Whale Mtn. Quadrangle, 1971.

N

SCALE IN FEET
0 1000 2000 3000 4000

LOCATION OF WELLS

PARK MOABI

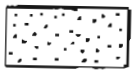
SAN BERNARDINO COUNTY, CALIF.

Figure 2

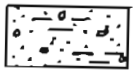
EXPLANATION



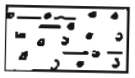
CLAY, SILT



SAND



SAND AND GRAVEL (WITH SOME CLAY)



GRAVEL WITH SOME CLAY

DEPTH TO WATER

NaCl

CHEMICAL CHARACTER OF GROUND WATER

ELEVATION IN FEET

0 550 1100

SCALE IN FEET

GEOLOGIC SECTION

PARK MOABI,

SAN BERNARDINO COUNTY

LeROY CRANDALL AND ASSOCIATES

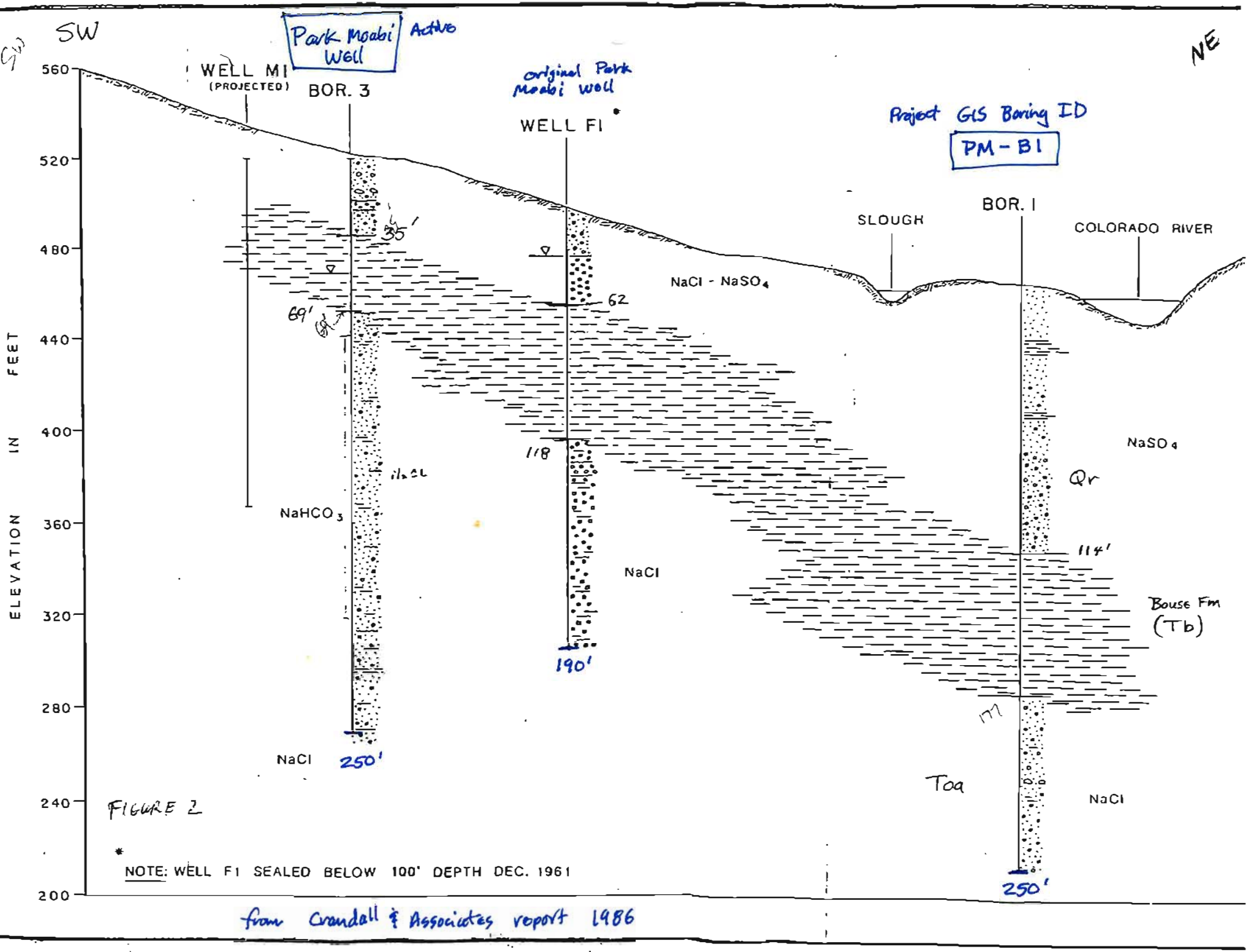
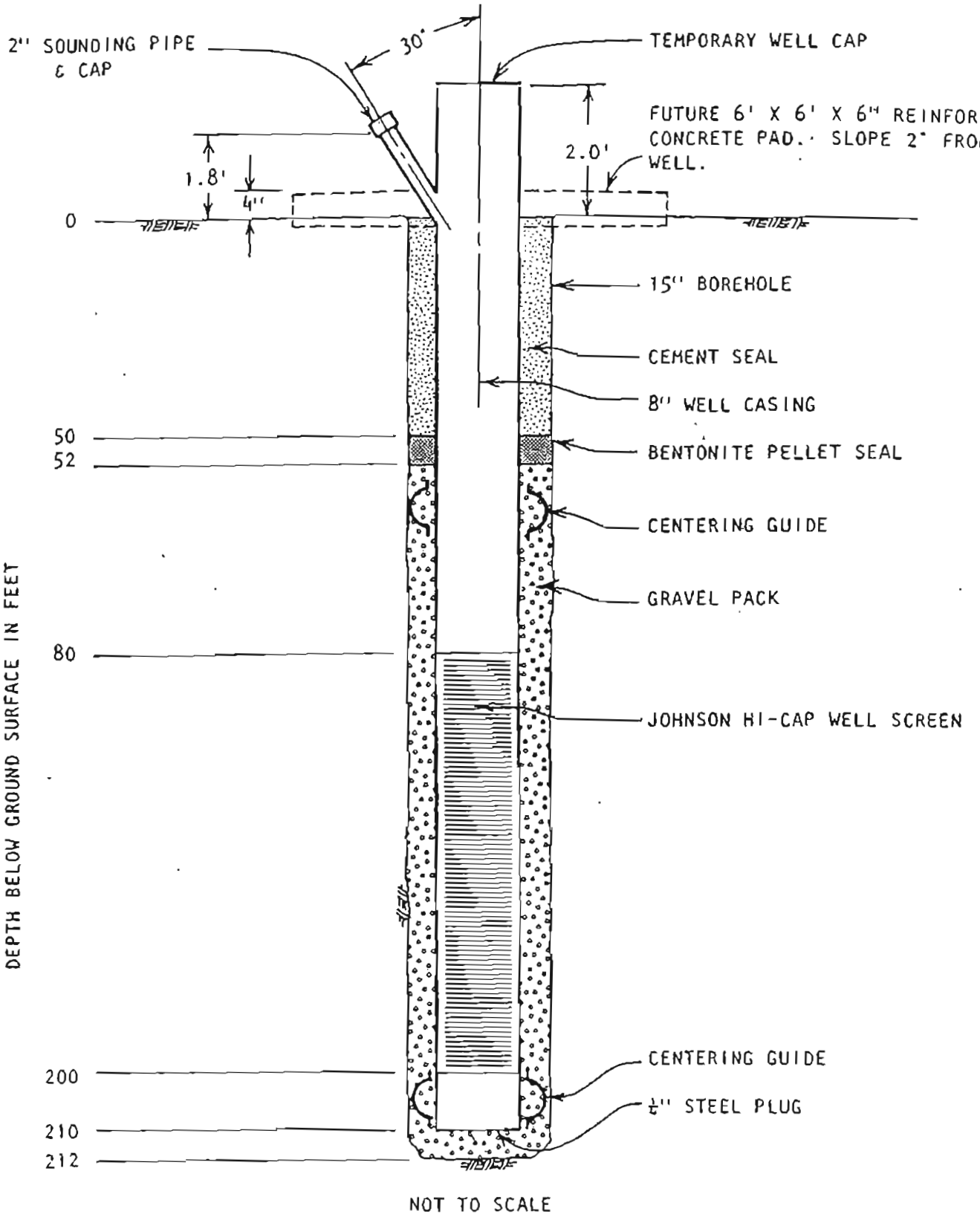


FIGURE 2

from Crandall & Associates report 1986

JOB E-85152-B

FIGURE 3



WELL CONSTRUCTION DETAILS

LeROY CRANDALL AND ASSOCIATES

during drilling indicates that good quality water exists from 69 to 220 feet. Below 220 feet, ground water becomes poorer in quality with increasing depth.

GROUND WATER QUALITY

The chemical character of ground water within the Park is variable. Water samples from the Colorado River between Davis Dam and Parker Dam indicate the water to be sodium sulfate in character. During the period 1967-1985, mineral concentrations ranged between 600 and 700 milligrams per liter (mg/l), but have been occasionally higher. Water samples from the Park's gravel collector (B1), which provides feed water for the RO plant, have been similarly sodium sulfate in chemical character. However, samples have had a much higher mineral concentration, with electrical conductances ranging from 2,340 micromhos/cm in 1961, to over 3,000 micromhos/cm in 1977.

Water samples from the unused Park well (F1) have differed in chemical character and contained more dissolved minerals. They have been sodium chloride in character with electrical conductances ranging between 2,370 and 4,130 micromhos/cm (equivalent to mineral concentrations of 1,540 and 2,680 mg/l). The source of the high salinity appears to be directly related to salts contained within the Bouse Formation. However, it could be partially related to decaying vegetation. Discharge from the well is reported to have had a hydrogen sulfide odor and an elevated temperature. As shown by the SO_4/Cl ratios in Table 1, the chemical character of the well discharge is related to the duration of

TABLE 1

CHEMICAL ANALYSES OF WATER SAMPLES

Well Number	Date Sampled	EC x 10^6 at 25°C	pH	Mineral constituents in milligrams per liter											SO_4/Cl
				Ca	Mg	Na	K	CO	HCO_3	SO_4	Cl	NO_3	F	B	
7N/24E-6F1 Pumping:															
15 Min.	10-12-61	2,050	7.9	100	1	340	6.6	0	100	170	485	13.0	0.98	0.37	0.26
9 Hrs.	10-13-61	2,970	7.5	107	57	440	10.4	0	164	385	655	16.0	1.18	0.48	0.43
72 Hrs.	10-23-61	3,960	7.5	142	87	569	14.0	0	217	582	838	11.4	1.00	0.54	0.51
89 Hrs.	10-24-61	4,130	7.6	91	101	600	14.0	0	227	607	895	19.3	0.72	0.58	0.50
	12- -61		(Well Sealed Below 100 Foot Depth)												
1 Hr.	01-29-62	2,380	7.9	86	27	364	9.2	0	112	241	554	11.9	1.17	0.38	0.32
Boring 1 at 40'	03-27-86	1,270	7.8	70	30	170	8.0	0	192	288	151	0.0		1.27	1.41
Boring 2 at 200'	03-27-86	2,290	8.0	41	7	455	7.0	0	106	158	610	12.0		0.47	0.19
Boring 3* at 160'	03-27-86	525	8.1	45	8	66	5.0	1	138	40	63	2.8	1.8		0.47
Boring 3 at 250'	03-27-86	1,190	7.8	67	13	162	7.0	0	83	110	270	18.0		0.21	0.30

E-85417-B

pumping. Initial discharge was chloride in character, but after a few hours of pumping, the sulfate concentration almost doubled. It appears that long duration pumping had the effect of inducing a westward migration of sulfate water that must be present between Well F1 and the RO plant.

Initially, Well F1 obtained water from two separate aquifers, as shown on Figure 2. The aquifers are separated by a silt and clay aquitard 40 to 70 feet in thickness that probably occurs beneath most of the Park. Both aquifers yield a chloride water, but after the deeper confined aquifer was sealed during December 1961, ground water could only be obtained from the upper unconfined aquifer which contains high concentrations of sulfate.

As shown by Figure 2 and Table 1, Exploratory Boring No. 1 encountered a sodium sulfate water in the upper aquifer and a sodium chloride water in the deeper aquifer. Water in the upper aquifer has a lower concentration of dissolved minerals than water yielded by the gravel collector, but would still require some demineralization to be suitable for drinking water. Ground water in the deeper aquifer is more mineralized and would similarly require demineralization prior to use for drinking water.

Exploratory Boring No. 3 also penetrated the two aquifers penetrated by Well F1 and Boring No. 1, but the upper aquifer was unsaturated. Ground water in the deeper aquifer above a depth of 200 feet is considerably different in chemical character and mineralization

than the water obtained from Well F1 and Boring No. 1. It is a sodium bicarbonate water with a low total dissolved mineral concentration of 525 micromhos/cm. It is generally suitable for drinking water with several restrictions. Below a depth of 200 feet, ground water is sodium chloride in character which is similar to the water encountered in the deeper aquifer at Well F1 and Boring No. 1. The water sample collected at 250 feet had an electrical conductance of 1,190 micromhos/cm and would be only marginally suitable for drinking water.

The water sample collected from Boring No. 3 at a depth of 160 feet indicates that the ground water in the vicinity of the boring site is suitable for drinking water with several exceptions. As shown in Table 1, the sample had a fluoride concentration of 1.8 mg/l, which is slightly above the recommended maximum contaminant level (MCL) of 1.4 mg/l for the average of maximum daily air temperature of 86.4 degrees F which has been recorded at Needles. However, the EPA is proposing a recommended MCL of 4.0 mg/l. If the MCL is adopted in California, the fluoride concentration in ground water in the vicinity of Boring No. 3 would be acceptable. An MCL is the highest concentration of a particular contaminant that is allowed in drinking water. The sample also contained excessively high concentrations of iron (6.8 mg/l) and manganese (0.52 mg/l). Concentrations of other elements found in the sample from 160 feet for which MCL's have been established are shown in Table 2. The laboratory report is presented in Appendix B.

Table 2
CONCENTRATIONS OF MINOR ELEMENTS
(concentrations in mg/l)

Element	Concentration	MCL
Copper	< 0.007	1.0
Iron	6.8	0.3
Manganese	0.52	0.05
Zinc	0.019	5.0
Arsenic	0.002	0.05
Barium	0.19	1.0
Cadmium	< 0.003	0.01
Chromium	< 0.029	0.05
Silver	< 0.005	0.05
Lead	0.004	0.05
Mercury	< 0.0002	0.02
Selenium	0.005	0.01

As shown in the table, only iron and manganese concentrations exceeded MCL's. Water containing these elements may be objectionable to an appreciable number of people, but they are not generally hazardous to health. The high concentrations of iron and manganese may be related to incomplete filtering of the sample prior to analysis. Additional analyses of samples from the proposed test well will be required for confirmation.

Exploratory drilling at Site No. 2 was terminated at a depth of 80 feet without encountering ground water. The deeper aquifer may be present at the site, but it would probably be thinner than it is at Site No. 3.

CONCLUSIONS AND RECOMMENDATIONS

Exploratory drilling at three sites within the Park boundaries indicate that a test well drilled in the vicinity of Boring No. 3 should be capable of yielding about 100 gallons per minute. It may be possible to pump at higher rates for short periods of time, but the safe yield of the ground water reservoir would be exceeded. In any event, we recommend that ground water not be used for irrigation because of the limited supply available. Pumping at rates greater than 100 gpm would probably also induce migration of poor quality water that is present in the vicinity of the trailer park, and the old water well. Excessive pumping could also induce an upward flow of poor quality water that is present at depths below 200 feet. A water sample collected from Boring No. 3 indicated the presence of generally good quality water between the depths of 70 and 220 feet. The sample had a total dissolved solids concentration of 300 milligrams per liter (mg/l), considerably below the recommended maximum concentration limit of 500 mg/l for drinking water. However, the sample contained a fluoride concentration of 1.8 mg/l which is slightly above the recommended maximum contaminant level (MCL) of 1.4 mg/l. The sample also contained moderately high concentrations of iron and manganese which exceed MCL's. These two elements may be objectionable to some people, but they are not generally hazardous to health. In view of the only occasional use of ground water by Park visitors, the County could probably obtain a waiver of the requirements from the California Department of Health Services or the designated health officer for San Bernardino County.

The high iron and manganese concentrations could be related to incomplete filtration of the water sample from Boring No. 3 prior to analysis. In order to verify the concentration of these elements and test the yield of the aquifer, we recommend the construction of a test well at the site. The test well should be constructed to a depth of about 210 feet. In the event the water quality and tested well yields are acceptable, the test well can be completed as a production well at a modest additional cost. Proposed well construction details are shown on the following Figure 3. Technical specifications are presented in Appendix C. Prior to construction of the well, the County should verify that the well site is not within the Santa Fe Railroad right-of-way.

Appendix A

LITHLOGIC LOG

1986

PM-B1

Park Moabi Water Supply Investigation
Crandall & Assoc.

Boring only ~~Well~~ No. 1

Depth	Graphic Log	EC (umhos)		Description of Materials
				Road base material
			SAND	Brown silty sand, very fine to medium grained sand, soft, damp to moist, few rounded gravels
10				
20				
			CLAY	Black silty clay, soft
30		790	SAND	Brown silty sand Decaying organic odor
40		950		Gravels increase, rounded, pebble size to 3/4", 3 gpm, collect water sample
50		600		Clayier
			CLAY	Black sandy silty clay, soft
60		500	SAND	Brown clayey silty sand, very fine to medium grained sand, soft, some fine gravels
70		980		Gravels increase, angular to rounded, caving
		1,000		5 gpm, collect water sample

LITHLOGIC LOG

1986
PM-B1

Park Moabi — Crandall & Associates Water Supply Investigation

Well No. 1

Depth	Graphic Log	EC (umhos)		Description of Materials
				Caving gravels
90		1,200		
100		1,900		
				Gravels decrease, sands increase
110		3,500		
			CLAY	Grey silty clay, moderately firm, plyable
120		1,800		
130		3,500		
140		7,000		Some fine sand
150		4,100		
		5,200		

LITHLOGIC LOG

Well No. 1

Depth	Graphic Log	EC (umhos)	Description of Materials	
170		4,350		
180		2,400	SAND & GRAVEL	Green to brown silty gravelly sand, very fine to coarse grained sand, fine angular gravels predominately meta-igneous composition
190		2,200		
200		2,400		38 gpm, collect water sample
210		2,300		
220		2,400		50 gpm
230		3,600		
				236' to 238' sand bed
		3,200		

LITHLOGIC LOG

Well No. 1

Depth	Graphic Log	EC (umhos)	Description of Materials
		4,750	Total Depth: 250 ft., 60 gpm, water sample collected
250			
260			

LITHLOGIC LOG

Explor. Boring
~~Well~~ No. 2

Depth	Graphic Log	EC (umhos)		Description of Materials
			SAND & GRAVEL	Brown, fine to coarse grained sand with some fine gravels
				Gravel size increases
10			CLAY & SILT	Brown silts and grey clay, moderately firm, Bouse Formation
20				Some fine grained sand
30				Clayey silt, reddish-brown
40		2,000		Some coarse grained sand to fine gravel
50				Color changes to grey
60		2,550		Some very fine sand, decaying organic odor
70				Color changes to mottled grey and tan, grey clay, semiplastic
				Total Depth: (80 ft.), no water to collect for samples

LITHLOGIC LOG

Well No. 3

Depth	Graphic Log	EC (umhos)	Description of Materials	
			SAND & GRAVEL	Brown, fine to coarse grained sand with fine angular gravel, gravels are meta-igneous composition
10				
				Gravel size increases
20				Gravel bed
30				Clays increase
			CLAY	Brown, silty clay to clay, soft, with some very fine grained sand
40		1,700		
				Some fine gravels
50				
				Color changes to grey
60		1,600		Siltier, mottled tan and grey, decaying organic odor
				White clay, caliche
70			SAND & GRAVEL	Brown and green, fine to coarse grained sand and fine angular gravels, gravels are predominately meta-igneous composition
		820		Color changes to black, collect water

LITHLOGIC LOG

Well No. 3

Depth	Graphic Log	EC (umhos)	Description of Materials
			Predominately coarse grained sand, brown
90		800	Siltier, sands increase
100		850	
110		590	
120		720	Gravels increase 12 gpm
130		690	Silty sand bed, very fine to medium grained
140		540	20 gpm
			Siltier
150		650	
			Clayier
		550	30 gpm, collect water sample

LITHLOGIC LOG

Well No. 3

Depth	Graphic Log	EC (umhos)		Description of Materials
				Silts increase
170		700		
				Gravels increase
180		550		33 gpm
				Clays increase
				Siltier, clays decrease
190		850		
200		590		43 gpm
210		750	SAND & GRAVEL	Red sand and gravel, fine to coarse sand, fine angular gravel, some silts and clays, gravels are predominately volcanic and meta sediments
220		610		Collect water sample
				White clay bed with some fine gravel
230		850		Clays decrease
		1,000		38 gpm

LITHLOGIC LOG

Well No. 3

Depth	Graphic Log	EC (umhos)	Description of Materials
250		1,100	Color changes to brown, meta-igneous gravels Total Depth: 250 ft., 60 gpm, collect water sample
260			

Appendix B

Soil and Plant Laboratory, Inc.

P.O. Box 11744, Santa Ana, California 92711-1 (714) 558-8333
P.O. Box 153, Santa Clara, California 95052-0153/(408) 727-0330
P.O. Box 1648, Bellevue, Washington 98009-1648/(206) 746-6665

LEROY CRANDALL & ASSOCIATES
711 N. Alvarado
Los Angeles, CA 90026-4099

WATER AGRICULTURAL SUITABILITY ANALYSIS
(A71)

April 10, 1986
Lab No. 90045
P O No. E-85417-B

Sample Description: Bor No 1 3-27-86 40'

CATIONS

Sample #	Na ppm	Na meq/l	Ca ppm	Ca meq/l	Mg ppm	Mg meq/l	K ppm	K meq/l	NH_4 ppm	NH_4 meq/l	SUM OF CATIONS
1	170	7.39	70	3.05	30	2.50	8	0.21			13.66

ANIONS

Sample #	Cl ppm	Cl meq/l	SO_4 ppm	SO_4 meq/l	HCO_3 ppm	HCO_3 meq/l	CO_3 ppm	CO_3 meq/l	NO_3 ppm	NO_3 meq/l	PO_4 ppm	PO_4 meq/l	SUM OF ANIONS
1	151	4.25	288	6.00	192	3.15			0	0.00			13.40

Sample #	pH	pHc	Ecx10^3	SAR_{adj}	ppm Cu	Zn	Mn	Fe	B	F	Li
1	7.8	7.33	1.27	8.84					1.27		

ppm - parts per million parts water meq/l - milliequivalents per liter
*Below the detection limit for the element
Data are supplied without recommendation or comment.

LORI LITTLEFORD
Analytical Laboratory Director

Soil and Plant Laboratory, Inc.

P.O. Box 11744, Santa Ana, California 92711-17[illegible] 714) 558-8333
P.O. Box 153, Santa Clara, California 95052-015[illegible] (408) 727-0330
P.O. Box 1648, Bellevue, Washington 98009-1648/(206) 746-6665

LEROY CRANDALL & ASSOCIATES
711 N. Alvarado
Los Angeles, CA 90026-4099

WATER AGRICULTURAL SUITABILITY ANALYSIS
(A71)

April 10, 1986
Lab No. 90045
P O No. E-85417-B

Sample Description: Bor No 1 3-27-86 200'

CATIONS

Sample #	Na ppm	Na meq/l	Ca ppm	Ca meq/l	Mg ppm	Mg meq/l	K ppm	K meq/l	NH_4 ppm	NH_4 meq/l	SUM OF CATIONS
2	455	19.78	41	2.05	7	0.58	5	0.13			22.54

ANIONS

Sample #	Cl ppm	Cl meq/l	SO_4 ppm	SO_4 meq/l	HCO_3 ppm	HCO_3 meq/l	CO_3 ppm	CO_3 meq/l	NO_3 ppm	NO_3 meq/l	PO_4 ppm	PO_4 meq/l	SUM OF ANIONS
2	610	17.18	158	3.29	106	1.74			12	0.19			22.40

Sample #	pH	pHc	Ecx10^3	SAR_{adj}	ppm Cu	ppm Zn	ppm Mn	ppm Fe	ppm B	ppm F	ppm Li
1	8.0	8.01	2.29	23.98					0.47		

ppm - parts per million parts water meq/l - milliequivalents per liter
*Below the detection limit for the element
Data are supplied without recommendation or comment.

LORI LITTLEFORD
Analytical Laboratory Director

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LEROY CRANDALL & ASSOCIATES
711 N. Alvarado
Los Angeles, CA 90026-4099

WATER AGRICULTURAL SUITABILITY ANALYSIS
(A71)

April 10, 1986
Lab No. 90045
P O No. E-85417-B

Sample Description: Bor No 3 3-27-86 250'

CATIONS

Sample #	Na ppm	Na meq/l	Ca ppm	Ca meq/l	Mg ppm	Mg meq/l	K ppm	K meq/l	NH_4 ppm	NH_4 meq/l	SUM OF CATIONS
3	162	7.04	67	3.35	13	1.08	7	0.18			11.65

ANIONS

Sample #	Cl ppm	Cl meq/l	SO_4 ppm	SO_4 meq/l	HCO_3 ppm	HCO_3 meq/l	CO_3 ppm	CO_3 meq/l	NO_3 ppm	NO_3 meq/l	PO_4 ppm	PO_4 meq/l	SUM OF ANIONS
3	270	7.61	110	2.29	83	1.36			18	0.29			11.55

Sample #	pH	pHc	Ecx10^3	SAR_{adj}	ppm Cu	Zn	Mn	Fe	B	F	Li
3	7.8	7.81	1.19	7.52					0.21		

ppm - parts per million parts water meq/l - milliequivalents per liter
*Below the detection limit for the element
Data are supplied without recommendation or comment.

LORI LITTLEFORD
Analytical Laboratory Director

MONTGOMERY LABORATORIES
a division of James M. Montgomery, Consulting Engineers, Inc.
555 East Walnut Street, Pasadena, California 91101
(818) 796-9141 / (213) 681-4255 Telex 67-5420

Report of General Mineral Analysis

Crandall & Assoc., Leroy
711 N. Alvarado
Los Angeles, CA 90026
Attn: Richard Shatz

Job#/PO#: 437.0184
Workorder#: W06913
Report#: R26460
Phone #: 213-413-3550

Date Sampled: 3/27/86
Date Completed: 4/22/86

Date Received: 4/2/86

Sample Lab Number: G46029 Sample ID: # E-85417-B (BORING #3-160')

CATIONS:	(mg/l)	(meq/l)	ANIONS:	(mg/l)	(meq/l)
			Bicarbonate	138	2.26
Sodium	69.7	3.03	Carbonate	1.1	0.0365
Potassium	4.6	0.118	Chloride	63	1.77
Calcium	27	1.35	Sulfate	40	0.833
Magnesium	6.2	0.517	Nitrate-N	2.8	0.20
			Fluoride	1.8	0.0947
			Hydroxide	0.00	0.00

CATION SUM = 5.01 meq/l ANION SUM = 5.19 meq/l

OTHER WATER QUALITY PARAMETERS DETERMINED (mg/l):

pH (unitless)	8.1	Copper	<0.007
Conductance (umho/cm)	525	Iron	6.8
Alkalinity	115	Manganese	0.52
TDS	300	Surfactants	<0.02
Hardness	93.4	Zinc	0.019
Langelier Index	0.15	Arsenic	0.002
pH of CaCO3 saturation (25C)	7.95	Barium	0.19
pH of CaCO3 saturation (60C)	7.43	Cadmium	<0.003
Free CO2 (25C)	2.19	Total Chromium	<0.029
		Silver	<0.005
Mercury	<0.0002	Lead	0.004
Total Selenium	0.005		

NA: Not Analyzed ND: Not Detected

Approved by

APR 22 1986

APPROVED
QC OFFICER

Appendix C

Tech. Specifications

(not included in CH2M copy)

COMPLETION REPORT

CONSTRUCTION AND TESTING OF TEST WELL NO. 3

PARK MOABI, COUNTY OF SAN BERNARDINO

(OUR JOB NO. E-85417-C)

LeRoy Crandall & Associates

Sept. 17, 1986 — Report (3)

ATTACHMENT B-3

LeROY CRANDALL AND ASSOCIATES geotechnical consultants □ 900 grand central avenue □ glendale, california 91201-3009 □ (818) 243-4140
a subsidiary of Law Engineering Testing Company

September 17, 1986

General Services Agency
Facilities Management Department
Architecture and Engineering Divisions
County of San Bernardino
200 South Lena Road
San Bernardino, California 92415

(Our Job No. E-85417-C)

Attention: Mr. Robert G. Wilkinson
Project Manager

The attached report describes the drilling, construction and testing of the recently completed Test Well No. 3 located at Park Moabi, County of San Bernardino. The report also contains recommendations for long-term pumping of the well.

Respectfully submitted,

LeROY CRANDALL AND ASSOCIATES

by
Richard Shatz
Staff Geologist

by
Donald L. McCann, C.E.G. 395
Senior Hydrogeologist

SE8/sle
(5 copies submitted)

cc: (1) John Eagan & Associates
Attn: Mr. Lloyd Lapp

TABLE OF CONTENTS

Text	Page No.
Introduction	1
Hydrogeologic Conditions	2
Test Well Construction	2
Well Testing	3
Ground Water Quality	4
Recommendations	6

Tables

1. Summary of Well Testing	4
2. Chemical Analyses of Water Samples	7

Figures	Following Page
1. Location of Wells	1
2. Well Construction Details	2
3. Plot of Well Test Data	4
4. Plot of Well Test Data	4
5. Water Level Recovery	4

Appendices

A. Well Data and Lithologic Log

B. Chemical Analyses of Water Samples

COMPLETION REPORT
CONSTRUCTION AND TESTING OF TEST WELL NO. 3
PARK MOABI, COUNTY OF SAN BERNARDINO

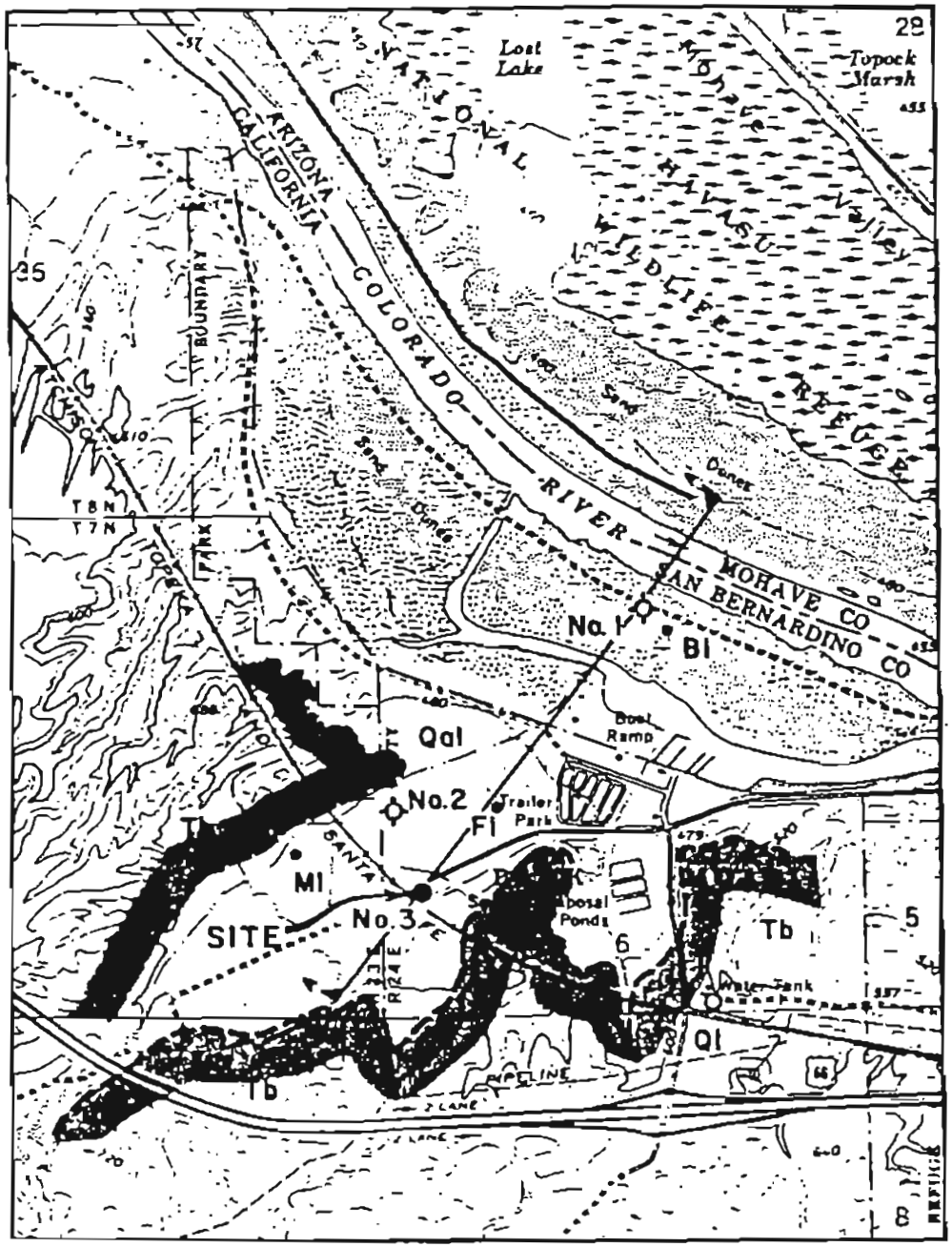
INTRODUCTION

This report presents a summary of drilling, construction and testing of Test Well No. 3 at Park Moabi, County of San Bernardino. All work related to construction of the test well was carried out during the period July 28, 1986 through August 12, 1986. Figure 1, Location of Wells, shows the location of the test well and other wells in the vicinity of the park.

The test well location was selected as the basis of information obtained from a previous exploration drilling program that was summarized in our report "Results of Exploratory Drilling" dated April 25, 1986. Historic records indicate that the aquifer penetrated by the well is not being utilized within the immediate area. The aquifer selected for development occurs between the depths of 70 to 210 feet below ground surface.

Well drilling and construction services were provided by Rottman Drilling Company of Lancaster, California. Well design, observation of test well construction, and testing were provided by LeRoy Crandall and Associates of Glendale, California.

Our professional services have been performed using that degree of care and skill ordinarily exercised, under similar circumstances, by reputable geologists practicing in this or similar localities. No other



EXPLANATION

Qal — ALLUVIUM
Recent sand, gravel and silt

Tb — BOUSE FORMATION
Pliocene sand, silt, clay, limestone and tufa.

GEOLOGIC CONTACT
Approximately located

Fl ● WATER WELL

Ql ○ EXPLORATORY BORING

No.2 ☼ EXPLORATORY BORING BY LC&A

A — A' GEOLOGIC SECTION

Reference: Base map from U.S.G.S. 7½' Whale Mtn. Quadrangle, 1971.

N

SCALE IN FEET
0 1000 2000 3000 4000

LOCATION OF WELLS

PARK MOABI

SAN BERNARDINO COUNTY, CALIF.

Figure 1

LeROY CRANDALL AND ASSOCIATES

warranty, expressed or implied, is made as to the professional advice included in this report.

HYDROGEOLOGIC CONDITIONS

The lithologic log of Test Well No. 3 is presented in Appendix A. The materials penetrated by the boring consist of sandy gravel from ground surface to a depth of 35 feet. Silts and clays separate this unit from the underlying aquifer which yields water to the well. The aquifer is composed of sandy gravels to clayey gravels and occurs from 69 feet to depths greater than 250 feet. Field measurements of the electrical conductivity of water samples obtained during March 1986, between 90 to 210 feet, indicated the presence of good quality water which was subsequently confirmed by laboratory analyses presented in our report dated April 25, 1986.

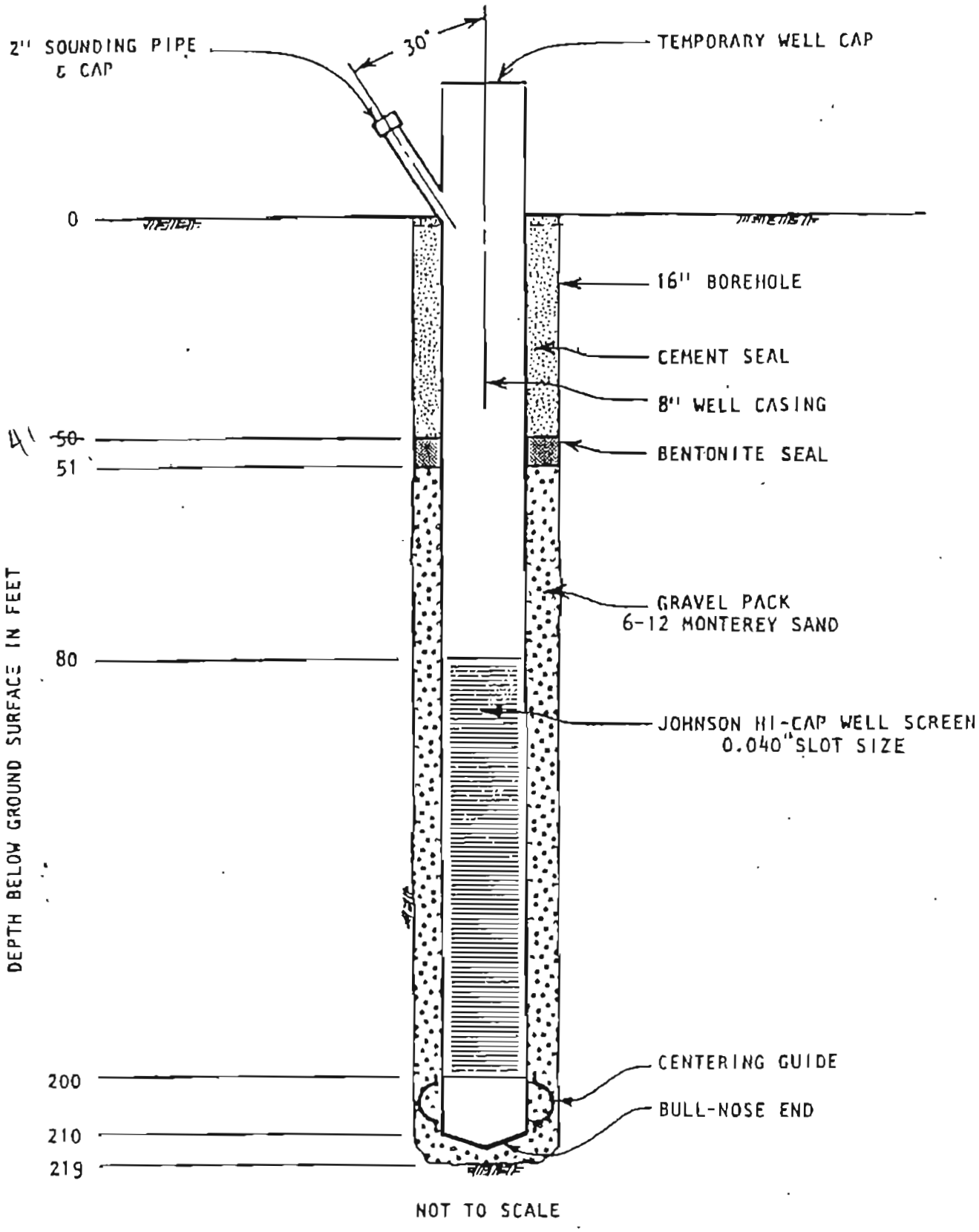
TEST WELL CONSTRUCTION

Drilling of the well borehole commenced on July 29, 1986, by drilling a 12¼-inch-diameter pilot borehole to a depth of 220 feet. On July 30, 1986 through July 31, 1986, the pilot hole was then reamed to 16 inches to a depth of 219 feet. The borehole was drilled by the conventional rotary method using bentonite drilling mud to stabilize the borehole and to remove drill cuttings.

Following completion of the boring, an 8-inch-diameter casing was installed to a total depth of 210 feet. A Johnson hi-cap well screen was installed between the depths of 80 to 200 feet with a 10-foot sediment sump set at the bottom of the well between 200 to 210 feet. Well Construction Details are illustrated by Figure 2. Centering guides

JOB E-85417-C

FIGURE 2



PARK MOABI WELL NO. 3
WELL CONSTRUCTION DETAILS

were placed at 20-foot centers on the screened interval. The annulus between the borehole and well screen was packed with sieve size 6-12 Monterey sand while circulating clear water upwards through the annulus. A 10-foot bentonite slurry was placed on top of the sand filter through a tremie pipe from 41 to 51 feet. A concrete sanitary seal was installed after well testing was completed. The well was preliminarily developed by high velocity jetting until most of the colloidal and fine sediments were removed from the well.

A shaft-turbine test pump was then installed for further development and well testing. A Rossum sand tester was installed for measuring sand content. Development consisted of pumping and surging the well until the discharge became clear and sand-free. During the latter part of the development process, the sand content was less than 1 ppm, 20 minutes after surging.

The electrical conductance of well discharge was measured periodically during well development and testing. Conductance ranged from 1,300 micromhos/cm at the beginning of development and then declined to 820 micromhos/cm at the end of the testing.

WELL TESTING

Well testing commenced on August 6, 1986 and was conducted for a period of 24 hours. The well was tested using a shaft-turbine pump driven by a 150 horsepower diesel engine. The pump intake was set at 169 feet below ground surface. Discharge from the well was measured by a flowmeter that was periodically checked with a 5-gallon container. The test consisted of pumping the well at two discharge rates and

observing the water level drawdown in the well. Throughout the test, only traces of sand were measured in the Rossum sand tester. The following Table 1 summarizes test results.

TABLE 1

SUMMARY OF WELL TESTING

Discharge Rate gpm	Pumping Level Feet	Drawdown Feet	Specific Capacity gpm/ft	Electrical Conductance µmhos/cm	Sand Content ppm
40	87.18	33.60	1.19	1,150	<1 ppm
60	121.19	77.75	0.77	820	<1 ppm

At the end of the 24-hour period, the well discharge was increased to determine the maximum flow without breaking suction. This rate was found to occur between 67 to 70 gpm.

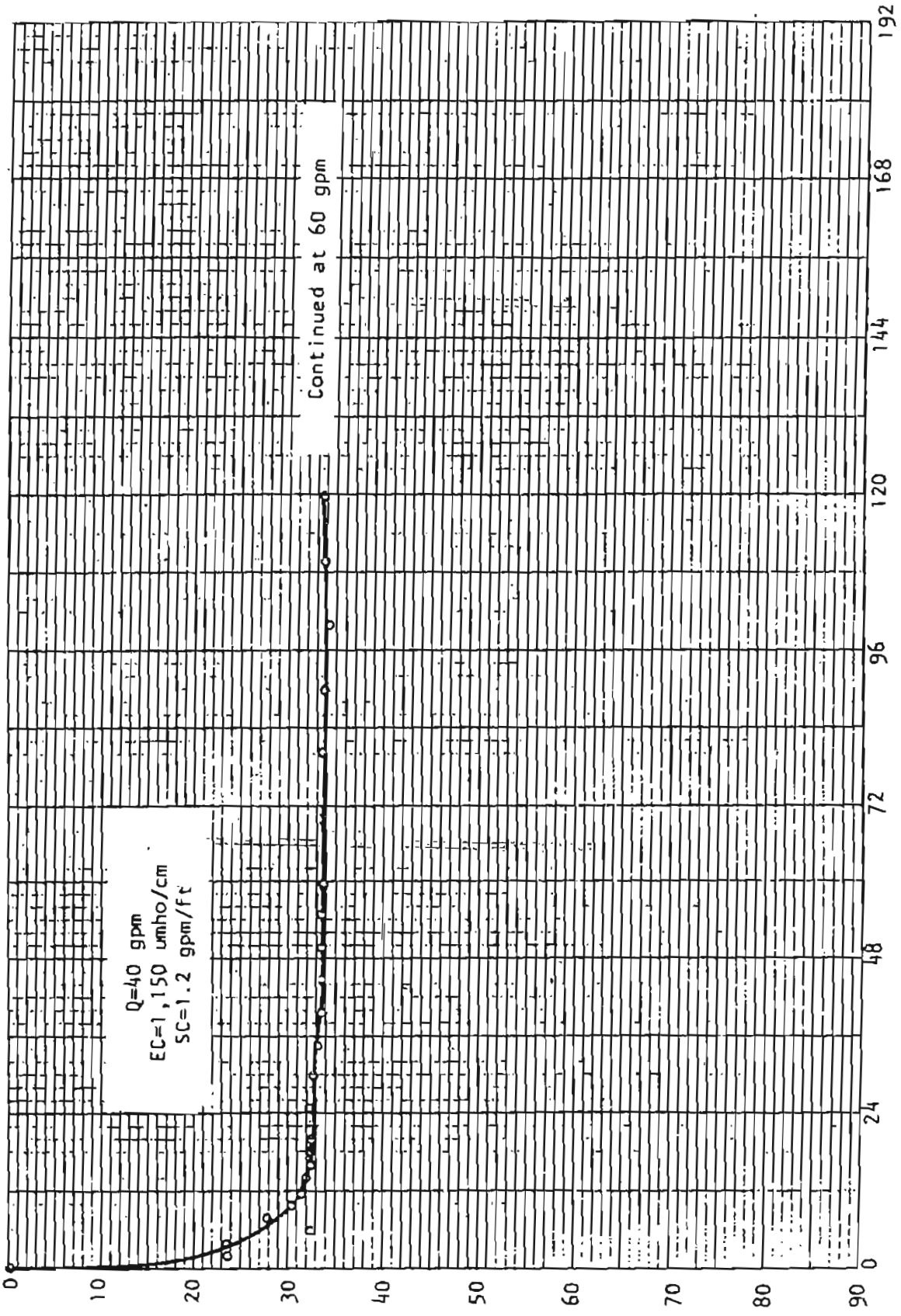
Water level measurements were made for 70 minutes after the pumping was stopped to determine the water level recovery rate. Recovery was found to be about 52 percent complete after 10 minutes and 96 percent complete after 70 minutes. Recovery measurements are illustrated graphically by Figure 5, Water Level Recovery.

GROUND WATER QUALITY

Previous chemical analyses of water samples from the test hole drilled at the site during March 1986 indicted that the site was underlain by alluvial materials containing a shallow sodium bicarbonate water and a deeper sodium chloride water. The shallow water sample had a

E-85417 -C

FIGURE 3

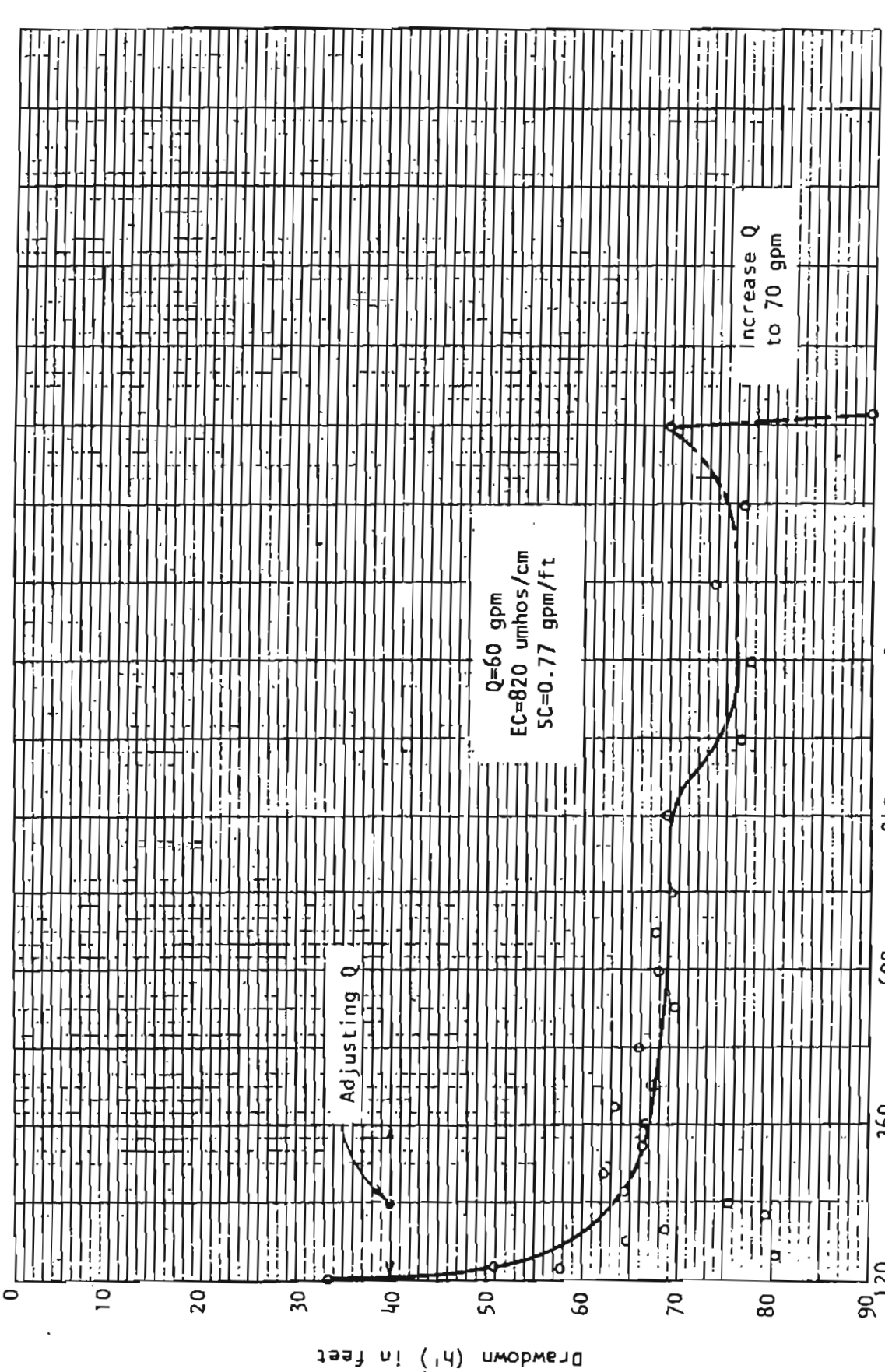


PARK MOABI TEST WELL 3

PLOT OF WELL TEST DATA

E-85417-C

FIGURE 4

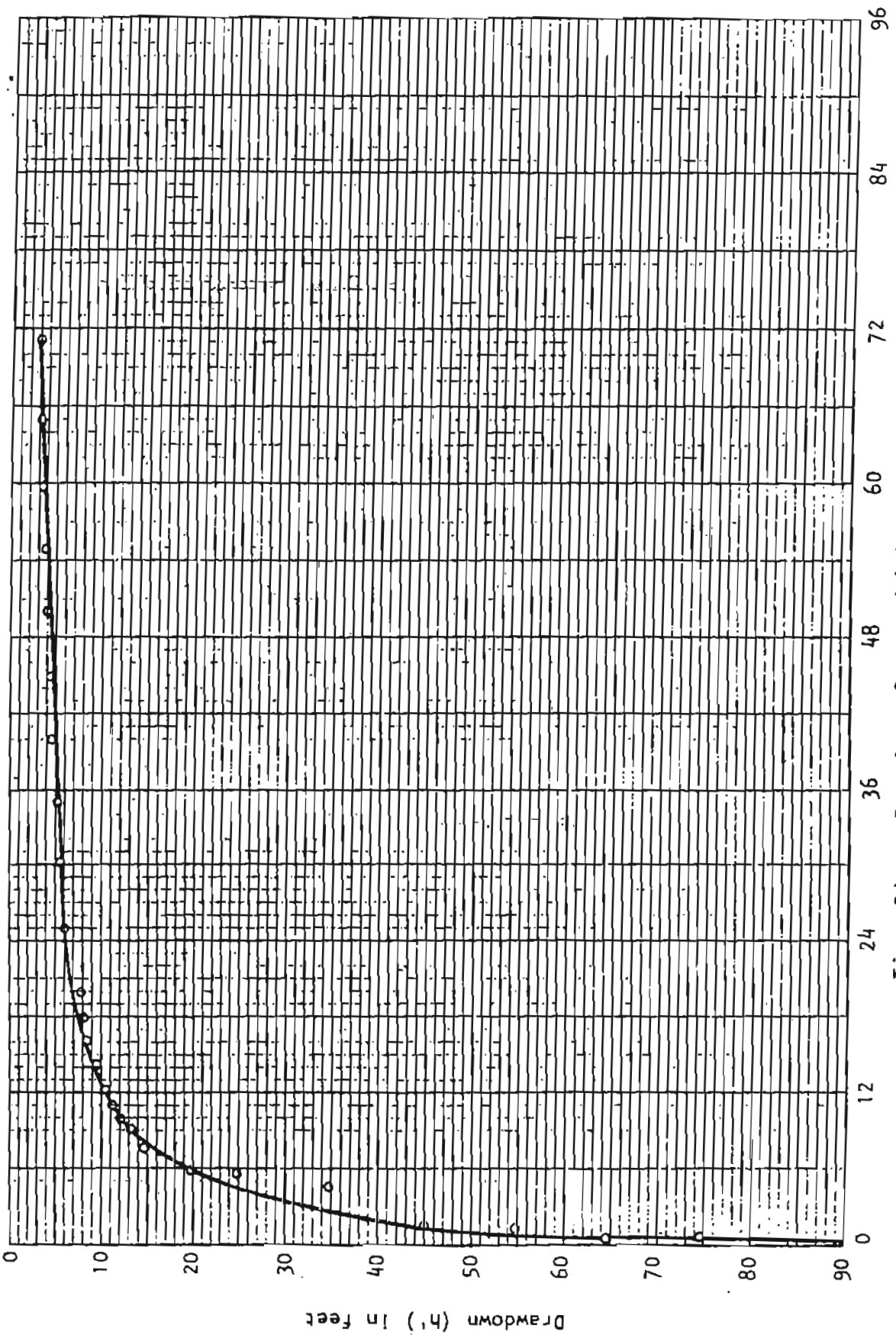


PARK MOABI TEST WELL 3

PLOT OF WELL TEST DATA

E-85417-C

FIGURE 5



PARK MOABI TEST WELL 3

WATER LEVEL RECOVERY

total dissolved solids (TDS) concentration of 300 mg/l, while the deeper sample had a higher concentration of 780 mg/l.

Two water samples were collected during the August 1986 24-hour well pumping test for chemical analyses. The first sample was collected after pumping for two hours at a rate of 40 gpm. It had an electrical conductance of 1,140 micromhos/cm (about 740 mg/l TDS) and was sodium chloride in character. The salinity and chemical character of the discharge at this time were similar to that of the sample collected from the test well at a depth of 250 feet during March 1986. The salinity of the discharge diminished as pumping progressed and after 24 hours the TDS content declined to 490 mg/l. The chemical character at this time remained sodium chloride, but the chloride/bicarbonate ratio decreased. It appears that as pumping progressed, development of the well was continuing and a proportionally larger amount of bicarbonate water entered the well from the shallow portion of the aquifer.

With the exception of fluoride, chemical analyses of the water sampler collected from the well at the conclusion of the test indicate that it is suitable for drinking water. General mineral, physical and organic chemical analyses all indicated that constituent concentrations were below maximum contaminant levels (MCLs) prescribed by the California Health and Safety Code. However, the fluoride concentration was 1.8 mg/l, slightly above the recommended MCL of 1.4 mg/l. The elevated fluoride concentration probably would not be detrimental to the occasional Park visitor, but would not be suitable for the permanent

Park resident. This problem could be mitigated by providing the permanent residents with bottled water for drinking and culinary uses, or blending with water from the RO unit. The August 1986 sample had a Langelier Index of -0.12 which indicates water from the well has a corrosive tendency. The earlier March sample had a positive index and less of a tendency toward corrosion.

Chemical analyses of samples collected from the test well borehole during March and those collected during the well test are summarized on the following Table 2. Laboratory reports are presented in Appendix B.

RECOMMENDATIONS

Pump testing of Test Well No. 3 was carried out August 6 and 7, 1986 at rates of 40 and 60 gpm. The test indicates that the well should not be pumped at rates in excess of 60 gpm, preferable 50 gpm until long-term sustained yield can be determined after several months of pumping. It may be possible to pump at higher rates for short periods of time, but the safe yield of the ground water reservoir would be exceeded. In any event, we recommend that ground water not be used for irrigation because of the limited supply available. Pumping at rates greater than 60 gpm could also induce migration of poor quality water that is present in the vicinity of the trailer park and the old water well. Excessive pumping could also induce an upward flow of poor quality water that is present at depths below 200 feet.

TABLE 5

CHEMICAL ANALYSES OF WATER SAMPLES

Well Number	Date Sampled	EC x 10^6 at 25°C	pH	Mineral constituents in milligrams per liter											TDS in mg/l
				Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3	F	B	
Boring 3 at 160'	03-27-86	525	8.1	45	8	66	5.0	1	138	40	63	2.8	1.8		300
at 250'	03-27-86	1,190	7.8	67	13	162	7.0	0	83	110	270	18.0		0.21	780*
Test Well 3 Pumping 120 min. @ 40 gpm	08-06-86	1,140		57	12	165			78	72	291	16.0			740*
Pumping 1,440 min. @ 60 gpm	08-07-86	790	7.9	42	9	111	5.3	0	84	49	172	3.4	1.9		490

*NOTE: (*) Estimated from EC.

The static water level in the well was 54 feet from ground surface. At a discharge rate of 60 gpm, the pumping level from ground surface may reach a depth of 145 feet after six months of continuous pumping. In view of the large drawdown anticipated, we recommend that the pump intake be set at a depth of 160 feet. Since motor cooling may be marginal, we recommend that a shroud be installed over the pump intake and motor to insure adequate cooling. Since the pump will be set within the well screen, nonabrasive (rubber) centering guides should be installed on the riser pipe at 20-foot intervals below a depth of 80 feet. We also suggest that a liquid level control system be installed. The low level cutoff could be set at 150 feet, and the high level start set at 80 feet.

After the well is placed in operation, static and pumping water levels should be made on a monthly basis. It would also be desirable to measure the electrical conductance on a monthly basis. The data obtained would be most useful in a future evaluation of the long-term yield of the aquifer.

Chemical analyses of the water sample collected at the end of the test indicate that, with the exception of fluoride, water from the well is generally suitable for drinking water. The sample was sodium chloride in character and had a total dissolved mineral content of 490 mg/l. Fluoride concentration was 1.8 mg/l which is slightly above the recommended maximum contaminant level of 1.4 mg/l. The slightly elevated concentration probably would not be harmful to the occasional Park visitor, but it would not be suitable for the long-term permanent



resident. However, they could be provided with bottled water for drinking and culinary uses. In view of the only occasional use of ground water by Park visitors, the County should ascertain if a waiver of the fluoride requirement can be obtained from the California Department of Health Services or the designated health officer for San Bernardino County.

-oOo-

Appendix A

WELL DATA

PM
Active Supply well

Project No. E-85417-C

Well No. 3
USGS No.

Owner: County of San Bernardino
Address of Owner: Park Moabi
Well Location: 1,200' N and 300' E of SW corner Sec. 6, T 7 N, R24E, SBB&M

Drilled by: Rottman Drilling Company, Inc.
Drilling Method: Mud Rotary Type of Well: Domestic
Drilling Commenced: 7-28-86 Date Completed: 8-4-86

WELL CONSTRUCTION
Borehole Depth: 219.2 feet Borehole Diameter: 16 In.
Conductor Casing: None
Well Casing: 8 5/8" O.D. - steel, 0-80.2'
Perforations: Johnson Hi-cap well screen, 0.040" slots, 80.2' - 200'
Gravel Pack: Monterey sand 6 x 12, 51' - 215'
Well Seal: Cement 0-51'

WELL TESTING
Static Water level: 53.58 ft. Pumping Water Level: 131.3 ft.
Duration of Test: 24 hours Date of Test: 8-6-86 & 8-7-86
Discharge: 60 gpm Drawdown: 77.75 ft.
Specific Capacity: 0.77 gpm/ft. Electrical Conductance: 820 micromhos

REFERENCE ELEVATIONS
Ground Elevation: ft. Top of Casing Elevation: ft.
Description of Reference Point Elevations for Water Level Measurements:

Date: 8-4-86 Elevation ft. Description: Ground surface

Date: Elevation ft. Description:

Date: Elevation ft. Description:

Remarks:

LITHLOGIC LOG

Explor. Borings for PM Supply Well Well No. 3

Depth	Graphic Log	EC (umhos)	Description of Materials	
			SAND & GRAVEL	Brown, fine to coarse grained sand with fine angular gravel, gravels are meta-igneous composition
10				
				Gravel size increases
20				Gravel bed
30				Clays increase
			CLAY	Brown, silty clay to clay, soft, with some very fine grained sand
40		1,700		
				Some fine gravels
50				
				Color changes to grey
60		1,600		Siltier, mottled tan and grey, decaying organic odor
				White clay, caliche
70			SAND & GRAVEL	Brown and green, fine to coarse grained sand and fine angular gravels, gravels are predominately meta-igneous composition
		820		Color changes to black, collect water

LITHLOGIC LOG

Well No. 3

Depth	Graphic Log	EC (umhos)	Description of Materials
			Predominately coarse grained sand, brown
90		800	Siltier, sands increase
100		850	
110		590	
120		720	Gravels increase 12 gpm
130		690	Silty sand bed, very fine to medium grained
140		540	20 gpm
			Siltier
150		650	Clayier
		550	30 gpm, collect water sample

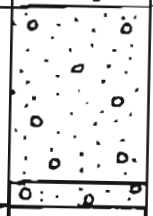
LITHLOGIC LOG

Well No. 3

Depth	Graphic Log	EC (umhos)		Description of Materials
				Silts increase
170		700		
				Gravels increase
180		550		33 gpm
				Clays increase
				Siltier, clays decrease
190		850		
200		590		43 gpm
210		750	SAND & GRAVEL	Red sand and gravel, fine to coarse sand, fine angular gravel, some silts and clays, gravels are predominately volcanic and meta sediments
220		610		Collect water sample
				White clay bed with some fine gravel
230		850		Clays decrease
		1,000		38 gpm

LITHLOGIC LOG

Well No. 3

Depth	Graphic Log	EC (umhos)	Description of Materials
			
250		1,100	Color changes to brown, meta-igneous gravels Total Depth: 250 ft., 60 gpm, collect water sample
260			

Appendix B

Soil and Plant Laboratory, Inc.

P.O. Box 11744, Santa Ana, California 92711-174 558-8333
P.O. Box 153, Santa Clara, California 95052-0153/(408) 727-0330
P.O. Box 1648, Bellevue, Washington 98009-1648/(206) 746-6665

LE ROY CRANDALL
& ASSOCIATES
900 Grand Central Avenue
Glendale, CA 91201-3009

WATER AGRICULTURAL SUITABILITY ANALYSIS
(A71)

August 18, 1986
Lab No. 91270
P O No. E-85417-B C

Sample Description: Park Moabi Well No 3 8-6-86 After 120 minutes at 40 gpm

CATIONS

Sample #	Na ppm	Na meq/l	Ca ppm	Ca meq/l	Mg ppm	Mg meq/l	K ppm	K meq/l	NH_4 ppm	NH_4 meq/l	SUM OF CATIONS
1	165	7.17	57	2.85	12	1.00					

ANIONS

Sample #	Cl ppm	Cl meq/l	SO_4 ppm	SO_4 meq/l	HCO_3 ppm	HCO_3 meq/l	CO_3 ppm	CO_3 meq/l	NO_3 ppm	NO_3 meq/l	PO_4 ppm	PO_4 meq/l	SUM OF ANIONS
1	291	8.20	72	1.50	78	1.28			16	0.26			

Sample #	pH	pHc	Ecx10^3	SAR_{adj}	ppm Cu	ppm Zn	ppm Mn	ppm Fe	ppm B	ppm F	ppm Li
			1.14								

ppm - parts per million parts water meq/l - milliequivalents per liter
*Below the detection limit for the element

Data are supplied without recommendation or comment.

LORI LITTLEFORD

RECEIVED
LeRoy Crandall and Associates
AUG 21 1986
File:

MONTGOMERY LABORATORIES
a division of James M. Montgomery, Consulting Engineers, Inc.
555 East Walnut Street, Pasadena, California 91101
(818) 796-9141 / (213) 681-4255 Telex 67-5420

Report of General Mineral Analysis

Crandall & Associates, Leroy
900 Grand Central Ave.
Glendale, CA 90201-3009
Attn: Tom Regan

Job#/PO#: 437.0687
Workorder#: W08323
Report#: R32808
Phone #: 818-243-4140

Date Sampled: 8/7/86
Date Completed: 9/2/86

Date Received: 8/8/86

Sample Lab Number: G85159 Sample ID: WELL #3 (E85417-C)

CATIONS:	(mg/l)	(meq/l)	ANIONS:	(mg/l)	(meq/l)
			Bicarbonate	84.4	1.38
Sodium	111	4.83	Carbonate	0.463	0.0154
Potassium	5.3	0.136	Chloride	172	4.85
alcium	41.7	2.09	Sulfate	49	1.02
agnesium	8.7	0.725	Nitrate-N	3.4	0.243
			Fluoride	1.9	0.10
			Hydroxide	0.00	0.00

CATION SUM = 7.78 meq/l ANION SUM = 7.61 meq/l

OTHER WATER QUALITY PARAMETERS DETERMINED (mg/l):

pH (unitless)	7.9	Copper	<0.007
Conductance (umho/cm)	790	Iron	0.27
Alkalinity	70	Manganese	<0.012
TDS	490	Surfactants	<0.02
Hardness	141	Zinc	0.039
Langelier Index	-.12	Arsenic	0.003
pH of CaCO3 saturation (25C)	8.02	Barium	0.087
pH of CaCO3 saturation (60C)	7.51	Cadmium	<0.003
Free CO2 (25C)	2.13	Total Chromium	<0.029
		Silver	<0.005
Mercury	<0.0002	Lead	<0.002
Total Selenium	0.002		

A: Not Analyzed ND: Not Detected

Approved by

APPROVED
E85417-C
SEP 03 1986
QC OFFICER

MONTGOMERY LABORATORIES
a division of James M. Montgomery, Consulting Engineers, Inc.
555 East Walnut Street, Pasadena, California 91101
(818) 796-9141 / (213) 681-4255 Telex 67-5420

Report on Analysis of Water for National Primary Drinking Water Regulation Pesticides

Crandall & Associates, Leroy		Job#/PO#:	437.0687
900 Grand Central Ave.		Workorder#:	W08323
Glendale, CA 90201-3009		Report#:	R32810
Attn: Tom Regan		Phone #:	818-243-4140

Date Sampled:	8/7/86	Date Received:	8/8/86
Date Extracted:	8/11/86	Date Analyzed:	8/13/86

Lab Number: G85159 c
Sample I.D.: WELL #3 (E85417-B)

Compound	Concentration (micrograms/liter)	Detection Limit (micrograms/liter)
Gamma-BHC (Lindane)	ND	0.01
Aldrin	ND	0.01
Methoxychlor	ND	0.5
Toxaphene	ND	0.5

RECEIVED
LeRoy Crandall and Associates
AUG 25 1986
File: E85417-C
GAB ☒ ☐
☐ ☐

ND: Not Detected
NA: Not Analyzed

Approved by Carole J. Lung

APPROVED
AUG 21 1986
QC OFFICER

MONTGOMERY LABORATORIES
a division of James M. Montgomery, Consulting Engineers, Inc.
555 East Walnut Street, Pasadena, California 91101
(818) 796-9141 / (213) 681-4255 Telex 67-5420

Report of General Physical Analysis

Crandall & Associates, Leroy
900 Grand Central Ave.
Glendale, CA 90201-3009
Attn: Tom Regan

Job#/PO#: 437.0687
Workorder#: W08323
Report#: R32809
Phone #: 818-243-4140

Date Sampled: 8/7/86
Date Completed: 8/19/86

Date Received: 8/8/86

Lab#	Sample I.D.	Turb NTU	ODOR TON	Color ACU
G85159	WELL #3 (E85417-C)	1.1	2	5

RECEIVED
LeRoy Crandall and Associates
AUG 22 1986
File: E85417-C

I: Not Analyzed

Approved by A Eaton

APPROVED
AUG 20 1986
QC OFFICER

INVESTIGATION OF POTENTIAL WATER SUPPLY SOURCES FOR PARK MOABI SAN BERNARDINO COUNTY, CALIFORNIA (OUR JOB NO. E-85417)

LeRoy Crandall & Associates — Report (1)
Feb. 11, 1986

Prepared For
General Services Agency
Facilities Management Department
Architecture and Engineering Division
San Bernardino County, California
Purchase Order No. J5078-M

ATTACHMENT B-1

LeROY CRANDALL AND ASSOCIATES consulting geotechnical engineers, 711 n. alvarado st., los angeles, ca. 90026, (213) 413-3550

February 11, 1986

General Services Agency
Facilities Management Department
Architecture and Engineering Divisions
County of San Bernardino
200 South Lena Road
San Bernardino, California 92415

P.O. No. J5078-M
(Our Job No. E-85417)

Attention: Mr. Robert G. Wilkinson,
Project Manager

Gentlemen:

The attached report "Investigation of Potential Water Supply Sources for Park Moabi, San Bernardino County, California" describes the hydrogeologic and water quality conditions in the vicinity of Park Moabi. It also contains a description of various options that could be adopted to provide a long term water supply for the park. In the event you choose to adopt one of the options, we would be pleased to assist the County in implementing your decision.

Yours very truly,

LeROY CRANDALL AND ASSOCIATES

by
Donald L. McCann, C.E.G. 395
Principal Hydrogeologist

by
Glenn A. Brown, C.E.G. 3
Director of Geological Services

G/jj
(5 copies submitted)

cc: Environmental Public Works Agency
Attn: Mr. Edward Ciabattini

TABLE OF CONTENTS

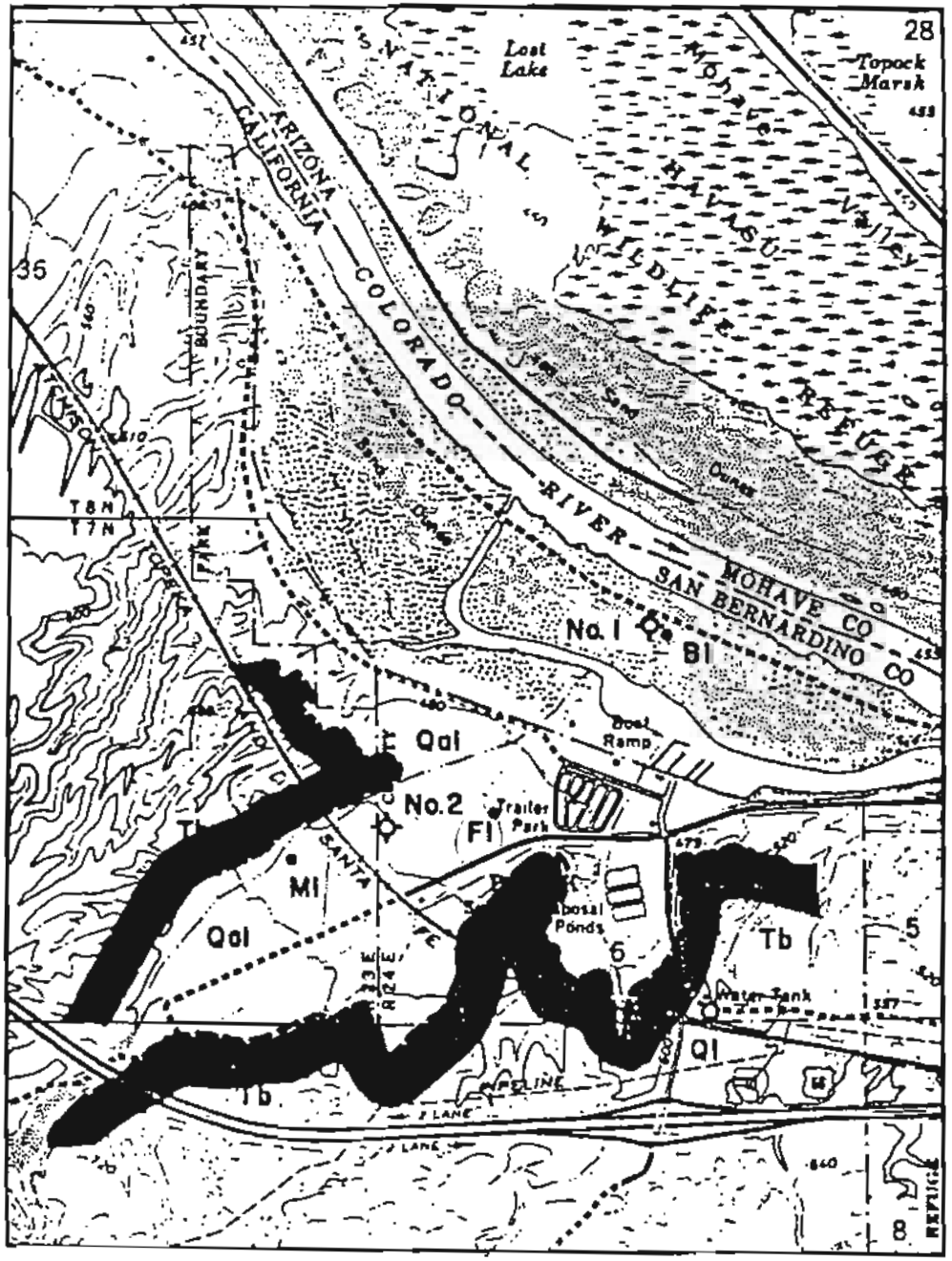
Text	Page No.
BACKGROUND	1
HYDROGEOLOGIC CONDITIONS	2
GROUND WATER DEVELOPMENT	4
GROUND WATER LEVELS	6
WATER QUALITY	6
RECOMMENDATIONS	9

Tables

1. Description of Water Wells	4
2. Chemical Analyses of Water Samples	8

Plate

1. Location of Wells	Following Page 1



EXPLANATION

Qal — ALLUVIUM
Recent sand, gravel and silt

Tb — BOUSE FORMATION
Pliocene sand, silt, clay, limestone and tufa.

GEOLOGIC CONTACT
Approximately located

F1 ● WATER WELL

Q1 ○ EXPLORATORY BORING

No.2 ◇ PROPOSED EXPLORATORY DRILLING SITE

Reference: Base map from U.S.G.S. 7½' Whale Mtn. Quadrangle, 1971.

N

SCALE IN FEET
0 1000 2000 3000 4000

PLATE 1

LOCATION OF WELLS

PARK MOABI

SAN BERNARDINO COUNTY, CALIF.

LeROY CRANDALL AND ASSOCIATES

BACKGROUND

Park Moabi is located along the west bank of the Colorado River about 10 miles southeast of Needles, California. The Park provides a variety of recreational activities including camping, boating and fishing. Water supply for the Park has been a continuing problem. Several attempts have been made to develop ground water, but all have been unsuccessful because of high ground water salinity. The locations of previously constructed wells are shown on Plate 1, Location of Wells.

At present, the Park obtains its water supply from an underground gravel collector (7N/24E-6B1) that has been constructed a few hundred feet from the River. However, pumpage from the collector well must be treated because of occasional bacterial contamination and the high mineralization that has ranged from 1,000 to over 2,000 milligrams per liter (mg/l). A reverse osmosis (RO) process is used to reduce the high mineralization to a level of about 200 mg/l. The RO plant is expensive to operate, and has only a capacity of about 40,000 gallons per day (gpd) which is inadequate to meet the park's peak demand of 80,000 gpd.

This report presents the results of our investigation of ground water conditions in the vicinity of the Park and the various options available for providing a long-term water supply. The investigation was authorized by the General Services Agency of the County of San Bernardino by Purchase Order J5078-M, dated December 19, 1985.

HYDROGEOLOGIC CONDITIONS

Park Moabi is located adjacent to the Colorado River at the foot of the Sacramento Mountains to the west and the Chemehuevi Mountains to the south. The mountain blocks are comprised of pre-Tertiary sedimentary, igneous and metamorphic rocks. These rocks underlie the Park at depths exceeding 1,000 feet, and probably are not capable of yielding an adequate water supply. They are overlain by a Miocene Fanglomerate comprised of cemented sand, gravel and silt. Water wells drilled in the vicinity of the Park have not penetrated the Fanglomerate, but elsewhere it has been reported to yield small to moderate supplies of water to wells. If present beneath the Park, it probably occurs at depths approaching 800 to 1,000 feet.

The Bouse Formation (Tb) of Pliocene age is exposed in the bluffs that rise several hundred feet above the River near the Park boundary and beneath most of the Park facilities at depths ranging from 0 to 100 feet. Locally, it is comprised of horizontally bedded clays, silts and fine sands that yield small quantities of water to wells. The Park Moabi Well No. 1 (7N/24E-6F1) penetrated the Bouse Formation at a depth of 44 feet. The well was constructed during March 1961. It is located adjacent to the Park maintenance building west of the trailer Park. The only lithologic log of rocks underlying the Park was recorded during the drilling of the well borehole. The log, which was published in the U.S. Geological Survey Professional Paper 486J, shows the following sequence of alluvial deposits.

Park Moabi #1
PM-01

SEQUENCE OF ALLUVIAL DEPOSITS

Description of Material	Thickness	Depth
Alluviums of Colorado River and its tributaries:		
Gravel, 3 in. to sand	22	22
Gravel, 2 to 8 in. rock	22	44
Bouse Formation:		
Clay	18	62
Shale	8	70
Clay, blue	32	102
Clay, gray, with rock	10	112
Rock, gray solid	6	118
Clay, gray, with rock	20	138
Clay, with softer rock	16	154
Rock, with clay	36	190

44 — 102
44
58

The log indicates the Bouse Formation at the well site is comprised of rather thick clay beds that would yield very little water. The well is reported to have yielded about 300 gpm, but well effluent contained excessively high concentrations of dissolved minerals that approached 3,000 mg/l. Other water wells north of the Park that have penetrated the Bouse Formation have also often yielded poor quality water.

Recent alluvial deposits (Qal) overlie the Bouse Formation. They are comprised of fine to coarse sands, gravels, and silts and are exposed throughout most of the flat-lying Park property, as shown on Plate 1, Location of Wells. Most of the water yielded by the Park Moabi Well No. 1 (7N/24E-6F1) was probably obtained form these deposits. The log of the borehole indicates they reach a depth of 44 feet at the well

site. They are probably much thicker several hundred feet to the north where surface runoff from the Chemehuevi Mountains is conveyed in a broad stream channel toward the Colorado River.

Recent sand dunes occur between the Park boundary and the River. They have little topographic relief and support a dense growth of native vegetation. The gravel collector and RO plant described previously are located within this area.

GROUND WATER DEVELOPMENT

Information on ground water development in the vicinity of the Park is limited to the incomplete construction records of four wells and one deep exploratory boring. The location of one of the wells, Park Moabi No. 2 (7N/24E-6X1) is unknown, but it apparently was never used because of the highly saline water it yielded. Construction details are summarized in the following Table 1.

Table 1
DESCRIPTION OF WATER WELLS

Well No.	Borehole Depth	Casing Depth	Casing Diameter	Perforated Interval	Capacity (gpm)
7N/23E-1M1 Abandoned	153'	86'	12"	Unknown	<5
7N/24E-6B1 Park Moabi	26'	26'	4'±	NA	
7N/24E-6F1 Park Moabi #1	190'	190'	10"	1 - 189'	300
7N/24E-6Q1 Test Hole	512'	None	None	None	Dry
7N/24E-6X1 Park Moabi #2	?	114'	10"	86 - 106'	430

Ground water for Park use is now obtained from a gravel collector located about 500 feet from the River. Construction details are not available, but it is reported to be about 300 feet in length which drains into a large diameter 26 foot deep sump. The sump is referred to as well 7N/24E-6B1 in Tables 1 and 2. Ground water is pumped from the sump to the adjacent RO plant where mineral concentration is reduced to about 200 mg/l at a production rate of 18 gpm. Storage is provided by an 80,000 gallon tank located near the Park entrance as shown on Plate 1.

Well No. 1 (T7N/24E-6F1) was constructed during March 1961. Well records are rather vague, but it apparently was constructed to a depth of 190 feet with perforations from 1 to 189 feet. The well is reported to have yielded 300 gpm with a drawdown of 12 feet from a static water level of 22 feet. If the records are valid, the well would have a moderately high specific capacity of 16 gpm/ft. When the well was tested during October 1961, the discharge had an electrical conductance ranging from 2,370 micromhos at the beginning of the test to 4,130 micromhos when the test was terminated after pumping 89 hours.

A test hole (7N/24E-6Q1) was drilled to a reported depth of 512 feet near the water storage tank. A small amount of water was encountered at a depth of about 150 feet, but the hole was dry when the total depth of 512 feet was reached. The test hole apparently only penetrated the Brouse Formation which is only known to yield small quantities of ground water.

MW-17
base of silts 365'
water @ 131
TD 150'

An abandoned well (7N/23E-1M1) was constructed about one-half mile west of the Park during the 1970's to provide water for highway construction. Construction details are unknown, but the well is reported by the Park ranger to have yielded less than 5 gpm.

I-40 in 1965

GROUND WATER LEVELS

Ground water levels in water wells in the vicinity of the Park are related primarily to the elevation of the Colorado River, and have probably varied within a range of 10 feet. Water levels have not been systematically recorded, but recent measurements made during January 1986 show that the water table within the recent alluvial materials to have a northeasterly slope toward the River. January measurements indicate the depth to the water table ranged from about 16 feet at the RO plant to 89 feet at the abandoned well (M1) located west of the Park. At that time, the depth to the water table in the Park unused well (F1) was 23.3 feet.

WATER QUALITY

Water samples collected from the Colorado River between Davis Dam and Parker Dam indicate River water to be sodium sulfate in chemical character. During the period 1967-85 mineral concentrations ranged between 600 and 700 mg/l. It is generally suitable for drinking water with little treatment required. Water samples from the parks gravel collector surveys (B1) have been similarly sodium sulfate in chemical character, but samples have had electrical conductances ranging from 2,340 micromhos in 1961 to over 3,000 micromhos in 1977. Water from the

sump during this time would have an equivalent mineral concentration of 1,500 to 2,000 mg/l, which has required the costly removal of minerals before being used for domestic use. A recent sample collected during January 1986 had a rather low electrical conductance of 1,300 micromhos, which would be marginally suitable for drinking water. The source of high salinity water from the well is unknown, but it may be related to inflow from the embayment south of the well, decaying vegetation, or a consequence of leaching salts from alluvium and sand dune deposits in the vicinity of the well.

Water samples from the unused well (E1) have differed in chemical character and contained more dissolved minerals. They have been sodium chloride in character with electrical conductances ranging between 2,370 and 4,130 micromhos (equivalent to mineral concentrations of 1,540 and 2,680 mg/l). The source of the high salinity appears to be directly related to salts contained within the Bouse Formation. However, it could be partially related to decaying vegetation. Discharge from the well is reported to have had a hydrogen sulfide odor and an elevated temperature.

The best quality ground water in the vicinity of the Park occurs in the shallow alluvial deposits that traverse a large portion of the Park, and extend southwesterly toward the Chemehuevi Mountains. A January 1986 sample from the abandoned well (M1) east of the Park had an electrical conductance of 450 micromhos. A chemical analysis was not made, but ground water at the well site is probably sodium or calcium bicarbonate in character with a mineral concentration of about 300 mg/l.

CHEMICAL ANALYSES OF WATER SAMPLES
PARK MOABI

Well Number	Date Sampled	ECx10^6 at 25°C	pH	Mineral constituents in milligrams per liter											TDS in mg/l
				Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3	F	B	
7N/23E-1M1	01-15-86	450													
7N/24E-6B1	11-08-61	2,340	7.6	127	57	319	8.5	0	351	492	310	1	0.8	0.38	
	06-16-62	2,430	7.2												
	01-19-77	3,082	7.7	140	73	480	4.4		424	695	430	3	0.7	0.43	2,055
	01-15-86	1,300													
7N/24E-6F1	10-09-61	2,370	7.8	78	30	375	7.6	0	124	234	554	14	1.0		
	10-13-61	2,970	7.5	107	57	440	10.4	0	164	385	655	16	1.2		
	10-24-61	4,130	7.6	91	101	600	14.0	0	227	607	895	19	0.7		
	03-07-62	2,520	7.6	104	34	378			124	288	595		1.2		1,470
7N/24E-6X1	05-31-62	5,490													
	06-07-62	6,580													
Colorado River, 6 miles downstream from Davis Dam															
	01-09-85	930	8.2	76	27	81	4.0	0	169	244	66	4			608*
Colorado River, at Needles															
	06-19-79	1,050*		92	25	106	–	–	143	295	91				685
Colorado River, near Parker Dam															
	09-09-67	1,090	8.5	75	29	100	5.0	2	123	289	90	0.6	0.4		663

*NOTE: (*) = Estimated

RECOMMENDATIONS

Our investigation of ground water conditions in the vicinity of Park Moabi indicates that there are only two viable sources of long-term water supply:

1. The shallow alluvium that traverses the Park.
2. The Colorado River.

Plate 1 shows the location of two well sites that may yield good quality ground water. Site No. 1 is located near the existing RO plant well. The poor quality water at the site may be related to mineralization within the upper 20 to 30 feet of alluvium. If so, this zone could be sealed during well construction, which would permit the development of deeper good quality water. Since the site is near the RO plant, pipeline and power transmission costs would be minimized. Site No. 2 is located near the western Park property boundary. If the recent alluvial deposits at the site exceed 150 feet in thickness, it should be possible to construct a well capable of yielding about 100 gpm.

We recommend that exploratory drilling be undertaken at both sites before well design and construction is undertaken. Exploratory drilling should be undertaken using the dual-tube reverse air drilling method. This method permits the collection of point source water samples during the drilling process which is of considerable assistance in defining zones of poor quality water. If an adequate supply of good quality water is found to be present within the Park, a well design can

then be prepared for the preferred site. The cost of exploratory drilling should be relatively inexpensive, probably less than 20 percent of well construction costs.

Other options are related to the Colorado River diversions. It is our understanding that there are two programs being managed by the Bureau of Reclamation that permit taking water directly from the River. One program permits users to take water during years of excess flow. Under provisions of this program, the County could negotiate a contract with the Bureau to obtain the right to take water during the calendar year of 1986. The County could presumably continue to take water from the River during future years when excess flow occurs.

Another program under study by the Bureau would authorize participation in a project that envisions pumping seepage losses from the All American Canal in California, returning the losses to the canal, and establishing a credit for River diversions. This program is scheduled for implementation in 1988. The cost of participation would be based on the volume of water diverted, which has been estimated to range from $40 to $60 per acre foot, plus modest annual fees. Additional information on both programs can be obtained from:

Edward Hallenbeck, Regional Director
Lower Colorado River Region
U.S. Bureau of Reclamation
P.O. Box 427
Boulder City, Nevada 89005

Alden Briggs, Chief
Water Scheduling Branch
U.S. Bureau of Reclamation
P.O. Box 427
Boulder City, Nevada 89005
Telephone (702) 293-8677

We have not made an economic appraisal of the various options available to the County, but participation in one or both of the Bureau programs would probably be the least expensive. The County should also consider the cost of water treatment, as some will be required to meet drinking water standards. In view of the forecast water shortage, a decision to participate in the project to recover seepage losses from the All American Canal should include consideration of the Bureau's ability to implement the project on a timely basis.

In the event the County elects to proceed with ground water exploration and development, the services of LeRoy Crandall and Associates will be available for preparing technical specifications for exploratory drilling, water well construction, and the design of related facilities.

-oOo-

Attachment B
Engineering Evaluation of River Intake Structure/Fish Screen

Preliminary Engineering Evaluation of Colorado River Intake and Fish Screen

PREPARED FOR: Pacific Gas and Electric

PREPARED BY: CH2M HILL

DATE: 15 April 2012

Purpose and Scope

The purpose of this Technical Memorandum (TM) is to describe the Colorado River freshwater source alternative in support of the fresh water source evaluation for the Pacific Gas & Electric (PG&E) Topock Compressor Station (TCS) Basis of Design Report / Preliminary (30%) Design Submittal for the Final Groundwater Remedy. This evaluation included the following components:

- Identification of design criteria
- Development of site location evaluation criteria
- Identification of potential site locations
- Comparison and evaluation of potential site locations
- Conclusion

These evaluation components are described below.

Design Criteria

The selected groundwater remedy includes injection of freshwater to assist with flushing the plume through the treatment zone at a rate of 600 to 1,200 gallons per minute (gpm). Extracting water from the Colorado River as the source of this freshwater would require an intake structure and fish screen. Water from the intake would be pumped for treatment adjacent to the existing TCS freshwater storage tanks (Figure 1) then stored in new tanks prior to injection.

Intake Structure

The river intake would include a concrete structure, 12-inch intake pipe, a slide gate, and two submersible pumps, duty and standby, sized to deliver 1200 gpm.

Construction of the river intake structure would require a coffer dam at the base of the river bank to allow for dewatering of the work area. Further up the bank, construction would require trenching and/or a shoring system within the area excavated for the river intake structure. The coffer dam would be approximately ten feet by ten feet if constructed using sheet piles and the trenched area further up the bank could be as wide as 50 feet; the exact footprint of these construction areas would depend on the contractor's means and methods.

Fish Screen

The fish screen would also be sized to deliver 1200 gpm and designed to meet the California Department of Fish and Game (CDFG) and National Marine Fisheries Service (NMFS) fish screen design criteria for maximum approach velocity. Preliminary analysis indicates that a 30-inch diameter cylinder end of pipe type screen would work (Figure 2). The screen should have a minimum submergence of 1-foot below the river water surface elevation (WSE) and a minimum of 1-foot clearance from the screen to the river channel invert.



FIGURE 1
Potential River Intake and Fish Screen Locations

The screen unit would be an all stainless-steel unit using wedgewire screens with 50 percent open area. The wedgewire openings would also be sized to meet CDFG and NMFS fish screen design criteria. A baffled suction tube inside the screen will be used to support the screens and to distribute the intake flows uniformly across the entire screen surface. The screen cylinders will be cleaned using an automated brush cleaning system powered by a hydraulic power unit.



Source: http://intakescreensinc.com/projects/delta-cove/

FIGURE 2
Photographs of an End of Pipe Type Fish Screen

Operations and maintenance (O&M) activities would be minimal for an end of pipe type fish screen. Routine O&M would include a short weekly inspection similar to typical pumping facilities. Annual maintenance would include changing the oil filter on the power unit. The screen itself should be visually inspected when the river WSE is low; more frequent visual inspections would be required in areas where the debris exposure is high.

Site Location Evaluation Criteria

Evaluation criteria were developed to assess the feasibility of each potential river intake locations and to allow for comparison across the evaluated sites. The evaluation criteria fall into three main categories:

- Long-term siting
- Construction
- Permitting

Evaluation criteria are described below.

Long-Term Siting Criteria

Water Depth. As described above, the fish screen requires a minimum submergence of 1-foot below the river WSE to meet fish screen design criteria. Because the Colorado River WSE varies between 6 to 8 feet, the selected location must have sufficient depth at the lowest WSE.

Debris Protection. The fish screen should be located so as to minimize river debris damage potential.

Site Space Constraints. Sufficient space is required at top of bank (TOB) above the river intake and fish screen for a fence enclosure where the required cabinets, pumps, and other equipment can be located.

Operations and Maintenance Access. The river intake and fish screen must be accessible for long-term O&M activities.

Water Quality. Water from the river intake will have to be treated before it can be injected into the groundwater wells. Intake locations downstream of drainages and washes that enter the Colorado River and are known to experience high sediment loads after rain events will require more treatment to achieve water quality requirements.

Construction Criteria

Constructability. Issues impacting the constructability of the river intake and fish screen at a given site, particularly construction access.

Construction Impacts. Temporary impacts associated with construction, such as disturbed area.

Relative Cost. Comparative cost associated with the potential river intake and fish screen locations will be determined by proximity to the TCS storage tanks; the further from the tanks, the longer the pipeline.

Approvals, ARARs, and EIR Compliance

Visibility. The river intake and fish screen will be a visible addition and will require security and yard lighting.

Right-of-Way. Right-of-way (ROW) acquisition or easements may be required for construction or long-term O&M activities; depending on the property owner, obtaining the necessary rights could impede the project schedule.

Approvals/Compliance with ARARs and EIR.

Federal -- Compliance with substantive permitting requirements includes Section 404 of the Clean Water Act, Endangered Species Act (ESA) Section 7, and Section 10 River and Harbors Act.

State -- Compliance with substantive permitting requirements includes Section 1601 under the California Department of Fish and Game Code, California Endangered Species Act, Section 401 of the Clean Water Act, Clean Water Act Section 402 Construction SWPP, leases under State Lands Commission, etc. Additional consultation would be required if the project design included a log screen or upstream diversion structure to protect the intake from surface and submerged debris.

Potential Site Locations

Potential river intake locations are shown in Figure 1 and described below in Table 1. All locations are on the California side of the Colorado River. Photographs of each location are included in Attachment 1.

TABLE 1
Potential River Intake Locations
Freshwater Source Evaluation Technical Memorandum

Site No.	Location	Description
1	SoCal Gas Pipeline Bridge	Upstream of the natural gas pipeline and adjacent to the bridge structure located on the downstream edge of the project area.
2	Downstream of Arched Bridge	Just upstream from Site No. 1.
3	Historic Arched Bridge	On the bank upstream of the bridge.
4	North of Bat Cave Wash	Upstream of the Floodplain, downstream of the Moabi Regional Park Slough, and adjacent to the National Trails Highway (Historic Route 66).
5	Moabi Regional Park Peninsula	Upstream of the Moabi Park Slough.

It should be noted that some potential locations were not included due to identified fatal flaw(s). For example, there is a sand bar adjacent to the 20 Bench Floodplain that is exposed when the river WSE is low , making it infeasible to located the intake and fish screen along this section of river bank.

The area between the Arched Bridge and I-3 Pipeline Bridge was not evaluated. The Colorado River is shallow in this location and includes wetland type vegetation. Construction of a river intake and fish screen in this area would require significant disturbance of this vegetation in order to reach far enough into the river for the fish screen to have sufficient submergence during times of low WSE.

An intake and fish screen attached to the Arched Bridge was also not evaluated. While in theory this would minimize temporary construction and long-term impacts, this is not the case at this site. Steep slopes at the bridge would necessitate significant grading to facilitate site access during construction. Permanent vehicular access would need to remain after construction to facilitate O&M. O&M access would be particularly important as an intake and fish screen installed on a bridge pier is vulnerable to damage by river debris; a large log was seen caught against one of the Arched Bridge piers during a site visit.

Finally, the Arizona side of the Colorado River was not evaluated for a river intake and fish screen structure. River depths are not as great and turbidity is known to increase significantly following rainfall events along this side of the river.

Comparison and Evaluation of Potential Site Locations

Each site was compared and evaluated against the identified evaluation criteria as favorable, neutral, or unfavorable. This comparison and evaluation is summarized below in Table 2.

Site 5 was eliminated from further evaluation and not included in this analysis. A river intake and fish screen located at Site 5 would require constructing a pipe across or underneath the Moabi Park Slough in order to move water off the peninsula to the treatment facility. The slough is a navigable channel leading to a popular park. Therefore this is not a preferred site from a disturbance and compliance perspective.

TABLE 2
Comparison and Evaluation of Potential Site locations
Freshwater Source Evaluation Technical Memorandum

Evaluation Criteria	Site 1	Site 2	Site 3	Site 4	Comments
Water Depth	Favorable	Favorable	Favorable	Neutral	Sites with insufficient water depth are rated as unfavorable; sites with enough water depth are rated as neutral; sites with excess water depth are rated as favorable.
Debris Protection	Neutral	Favorable	Unfavorable	Neutral	Sites with limited debris protection are rated as unfavorable; sites with some debris protection are rated as neutral; sites with significant debris protection are rated as favorable.
Site Space Constraints	Unfavorable	Neutral	Unfavorable	Favorable	Sites with limited space are rated as unfavorable; sites with sufficient space are rated as neutral; sites with ample space are rated as favorable.
O&M Access	Neutral	Neutral	Unfavorable	Favorable	Sites with poor accessibility are rated as unfavorable; sites with sufficient accessibility are rated as neutral; sites with good accessibility are rated as favorable.
Water Quality	Unfavorable	Neutral	Neutral	Neutral	Sites with poor water quality are rated as unfavorable; sites with acceptable water quality are rated as neutral; sites with good water quality are rated as favorable.
Constructability	Neutral	Neutral	Unfavorable	Favorable	Sites with poor constructability are rated as unfavorable; sites with acceptable constructability are rated as neutral; sites with good constructability are rated as favorable.
Temporary Construction Impacts	Neutral	Neutral	Unfavorable	Favorable	Sites with significant temporary construction impacts are rated as unfavorable; sites with some temporary construction impacts are rated as neutral; sites with minimal temporary construction impacts are rated as favorable.
Relative Cost	Favorable	Favorable	Neutral	Neutral [a]	Sites with greater relative costs are rated as unfavorable; sites with average relative costs are rated as neutral; sites with less relative costs are rated as favorable.
Visibility	Unfavorable	Unfavorable	Unfavorable	Favorable	Sites with significant visibility are rated as unfavorable; sites with some visibility are rated as neutral; sites with sites with limited visibility are rated as favorable.
ROW	Unfavorable	Neutral	Neutral	Neutral	Sites with potentially significant ROW issues are rated as unfavorable; sites with manageable ROW issues are rated as neutral; sites with no ROW issues are rated as favorable.
Approvals and compliance with ARARs and EIR	Subject to consultation with Agencies	Subject to consultation with Agencies	Subject to consultation with Agencies	Subject to consultation with Agencies	Subject to consultation with Agencies.

[a.] It is assumed that water from the river intake and fish screen will be pumped for treatment adjacent to the existing TCS freshwater storage tanks. However, it is possible that freshwater from Site 4 could be treated directly adjacent to the river intake and fish screen structure. This would decrease the distance from intake to treatment and injection and, therefore, make the relative cost favorable.

Conclusion

Based on the above analysis, Site 4 appears to be a feasible location for a river intake and fish screen structure with the evaluation criteria being neutral or favorable. Easy site access at this location is a major driver of this result. Site 4 is close to the road and there is sufficient space at TOB for construction access and a fenced enclosure, which will minimize temporary construction and long-term impacts. It should be noted the applicable consultations and agency approvals will ultimately determine if Site 4 is feasible for a river intake and fish screen structure.

Attachments

1 Potential Site Location Photographs

Attachment 1



Picture 1: Site 1 from TOB.



Picture 2: Site 1 from the Colorado River.



Picture 3: Site 2 from TOB.



Picture 4: Site 2 from the Colorado River.



Picture 5: Site 3 from TOB.



Picture 6: Site 3 from the Colorado River.

Attachment 1

	
Picture 7: Site 4 from TOB.	**Picture 8:** Site 4 from the Colorado River.

Attachment C
Model Updates (Prepared by ARCADIS)

MODEL UPDATES

Incorporation of Manganese oxidation

Manganese is naturally present in the soil at Topock in the form of insoluble Mn(III)/(IV) oxides. In actively reducing zones, manganese can be released into solution as Mn(II) via reductive dissolution of these Mn oxides. This process occurs naturally within the Topock floodplain, and it is expected to occur as a result of organic carbon injections during IRZ treatment of Cr(VI).

Once released into solution, the transport of Mn(II) within reducing environments will primarily be limited by sorption to mineral surfaces. This is expected to be the dominant mechanism controlling Mn transport within Topock downgradient of the IRZ and within the floodplain, due to sustained reducing conditions. Mn sorption is well-characterized using the surface complexation model approach (see discussion for arsenic sorption below), and sorption of Mn(II) has been incorporated into the Topock solute transport model to describe Mn transport downgradient of the IRZ and within the floodplain. Details on how Mn sorption was incorporated into the Topock solute transport model can be found in Appendix B of the 30% design document.

In less reducing environments at Topock, including the uplands and the alluvial aquifer beneath the floodplain, Mn(II) oxidation is expected to play a stronger role in the attenuation of aqueous manganese. Aqueous Mn(II) can be reoxidized biotically and abiotically in the presence of oxygen, resulting in precipitation. Abiotic oxidation of Mn(II) is slow, with a rate that is dependent on Mn concentration, dissolved oxygen concentration, and pH. For example, at pH 8 with a dissolved oxygen content of 2 mg/L (~25% air-saturation), the half life for Mn(II) oxidation is approximately 400 days (Morgan, 2005). Although abiotic oxidation of Mn(II) is slow, microbially-catalyzed oxidation of Mn(II) is much faster. Biotic oxidation of Mn has been studied extensively in the context of mining-derived pollution of streams, where Mn(II) oxidation can occur at the sediment-surface water interface, or hyporheic zone (Gandy et al., 2006, Harvey and Fuller, 1998; Kay et al., 2001). These results demonstrate that metal oxidation can be rapid, particularly at redox interfaces with active microbial consortia and an adequate nutrient supply. Harvey and Fuller (1998) studied the oxidation Mn(II) within the hyporheic zone of Pinal Creek, AZ. Oxidation rates were observed to be first order with respect to Mn concentration, with Mn(II) half lives between 0.7 and 8 hours. Laboratory work further confirmed these rates, while demonstrating the importance of solid:solution ratio (highlighting the combined role of mineral surface and microbial catalysis) and nutrient availability. Further work (Marble et al., 1999) demonstrated that these rates were independent of dissolved oxygen concentration above 30% saturation (~2.5 mg/L) and first-order with respect to oxygen below 30%.

Oxidation of Mn(II) was incorporated in the Topock solute transport model assuming a half life of 29 days. This value was obtained by starting with a first-order rate coefficient of 0.1 h^{-1}, representing the slowest rate observed by Harvey and Fuller (1998) at the Pinal Creek, AZ site, and scaling it back by two orders of magnitude to conservatively account for potential differences in nutrient status and microbial population. This rate was used to simulate Mn(II) oxidation in the uplands and beneath the floodplain, at interfaces where geochemically-reducing water (e.g., fluvial groundwater) contacts less-reducing water (e.g., alluvial aquifer with higher dissolved oxygen). At these interfaces, biotic oxidation of Mn will occur due to the presence of organic carbon and naturally-occurring microorganisms.

Updated Manganese solute transport modeling results

The 30% design simulated manganese transport in the solute transport model using only sorption as a mechanism to attenuate manganese migration throughout the solute transport model domain. This manganese sorption was utilized for both the naturally occurring manganese concentrations present in the reducing rind as well as manganese concentrations generated as a byproduct from IRZ's.

The solute transport model for manganese behavior was recently refined to incorporate oxidation as described in the section above. This manganese oxidation reaction was only simulated to occur in the uplands and in the deeper portion of the aquifer below the naturally occurring reducing zone. No manganese oxidation was simulated within the IRZ footprint, downgradient of the IRZ footprint, or within the naturally occurring reducing rind.

Figure 1 depicts the relative change in the manganese concentrations based on the original 30% design parameters and the recently refined manganese oxidation model with respect to manganese generated as byproducts from active insitu remediation after 30 years of simulated transport in model layer 1. The manganese distribution downgradient of the NTH IRZ and the TCS injection wells is identical between the two models because there is no manganese oxidation simulated in these areas. The primary difference in the manganese distribution in Figure 1 is evident in the uplands. This is due to the byproduct manganese extracted from the riverbank extraction wells and injected into the two upland inner loop recirculation wells. In the original 30% design model (left panel) the upland manganese distribution is significantly larger because manganese migration is only controlled by sorption. The refined manganese oxidation model (right panel) has a much smaller manganese distribution in the uplands due to active oxidation simulated in this area. Figure 2 depicts the same manganese model comparison after 30 years of simulated transport for model layer 3. The resulting distribution patterns in model layer 3 are similar to those presented in model layer 1, with the primary difference being the smaller manganese footprint in the uplands in the updated model due to manganese oxidation.

Figure 3 compares the relative change in the manganese concentrations based on the original 30% design parameters with the recently refined manganese oxidation model. The results are shown for layer 1 after 30 years with the naturally occurring manganese liberated in the reducing rind. There is no difference seen in Figure 3 (model layer 1) in the shallow aquifer within the footprint of the reducing rind because the same mechanism (sorption) is present in both model runs. In the Uplands injection area, where manganese oxidation has been incorporated in the recent model simulation, the manganese introduced in the uplands injection wells attenuates through oxidation minimizing the footprint.

The 30 year comparative results for model layer 3 are presented in Figure 4. Both panels depict the projected impacts of manganese sourced in the reducing-zone rind that has migrated or been injected into model layer 3, after 30 years of remediation. The panel on the left is the projection using the 30% design model; the panel on the right is from the updated model that incorporates manganese oxidation. The incorporation of manganese oxidation in this layer results in simulations that demonstrate a much smaller manganese footprint in Layer 3 of the model.

Incorporation of Arsenic adsorption

Downgradient of the IRZ, the arsenic released into solution due to the reductive dissolution of oxide minerals will attenuate via co-precipitation with iron oxide phases that form as Fe(III) reoxidizes. This process has been included in the Topock solute transport model by allowing aqueous arsenic to attenuate when organic carbon concentrations decrease below a threshold level. The arsenic attenuation rate was calibrated based on pilot test observations of arsenic transport. Further details on the incorporation of

arsenic co-precipitation within the solute transport model can be found in Appendix B of the 30% design document. This co-precipitation mechanism, however, is only relevant within redox “recovery” zones where dissolved Fe(III) is available for oxidation and precipitation. In other areas, the mobility of aqueous arsenic in groundwater is limited by adsorption to mineral surfaces. Both arsenate (As(III), which tends to be dominant in suboxic environments) and arsenite (As(V), dominant under oxidizing conditions) are known to adsorb strongly to mineral surfaces, particularly iron oxides (e.g., Dixit and Hering, 2003). Electrostatic attraction also plays a role in this adsorption process; at a pH below 9, the iron oxides which are positively charged, and attract dissolved species that are negatively charged (e.g., Appelo et al., 2002). The strong adsorption between iron and arsenic is due to a specific, “inner-sphere” binding mechanism, where oxygen ligands on arsenic displace surface hydroxyl groups on iron oxides. This particular reaction consumes protons, and is therefore more favorable at the lowered pH within and downgradient of the reducing zones. In this way, arsenic sorption is dependent on solution pH. For arsenate adsorption on iron oxide, the adsorption affinity decreases (i.e., less sorption) with increasing pH. The relationship is more complicated for arsenite, where sorption may increase or decrease with pH depending on solution conditions and mineralogy (Dixit and Hering, 2003).

Other species in solution, such as oxoanions (e.g., sulfate) and cations (e.g., Ca^{2+} and Mg^{2+}) can also compete with the sorption sites on iron oxide surfaces. These interactions have been studied extensively for iron oxides, particularly ferrihydrite. By quantifying adsorption interactions separately for different ions under different solution conditions, a combined model can be constructed that includes specific geochemical adsorption reactions for multiple species simultaneously, thereby accounting for the effects of pH and ion competition. This model is referred to as a surface complexation model (SCM).

It was assumed that As(V) (arsenate) would be the dominant species in the freshwater injection, given the oxidizing conditions of both the freshwater and the Upland groundwater. Ferrihydrite was assumed as the dominant adsorbent in the system; although ferrihydrite is not the dominant iron oxide mineral by mass, it is the dominant phase in terms of surface reactivity, given its very high surface area and sorption site density. Adsorption reactions were defined in the model using the SCM for ferrihydrite developed by Dzombak and Morel (1990). Estimation of surface site concentrations followed a procedure similar to that outlined in Appendix B of the 30% design. The groundwater chemistry (including pH, alkalinity, and major ion composition) used in the PHREEQC model was based on the average solution composition observed in monitoring well data within the freshwater injection zone. Arsenic adsorption was then incorporated into the transport model using a Freundlich isotherm, with the specific isotherm parameters calibrated using the SCM approach described above. The isotherm was calibrated by performing batch PHREEQC simulations with varying total arsenic content under site-relevant geochemical conditions.

Updated Arsenic solute transport modeling results

The original 30% design solute transport model simulated arsenic transport using arsenic precipitation in both the uplands and downgradient of the IRZ’s; no precipitation was simulated in the naturally occurring reducing rind. This conceptual model was based on the principal that under oxidizing conditions, arsenic will co-precipitate with mobile iron in groundwater. The primary mechanism governing arsenic migration downgradient of the IRZ’s is still co-precipitation with iron because iron will be mobilized with arsenic under IRZ induced reducing conditions. As the reducing conditions return to oxic conditions, the mobile arsenic will readily co-precipitate with the mobile iron. For the freshwater injection areas the arsenic/iron co-precipitation mechanism was replaced with the adsorption process described in the section above. In addition to the arsenic sorption mechanism, additional refinements were made to the updated model to reflect observed site data. These refinements included the incorporation of a background arsenic concentration of 2 ppb and a freshwater injection concentration of 15 ppb.

Figure 5 depicts the relative change in the arsenic footprint based on the original 30% design model (left panel) and the updated model (right panel) after 30 years of simulated transport in model layer 1. It is evident that the refined arsenic parameters result in a slightly larger arsenic footprint emanating from the freshwater injection wells relative to the precipitation only 30% design model. This is because there is no active mechanism to remove simulated arsenic from groundwater in the uplands, it only migrates at a slower velocity than the groundwater due to sorption. Both versions of the arsenic model indicate that any arsenic generated at the NTH IRZ or TCS injection wells is lower than 5 ppb after 30 years of simulated transport. Figure 6 depicts the comparative arsenic results for model layer 3 after 30 years of simulated transport. Similar to the model layer 1 results, the relative difference between the two models is apparent in the freshwater injection wells. The updated arsenic sorption model results in a slightly larger footprint than the original 30% design.

After 30 years of simulated active remediation, all of the remedial design elements were turned off to allow the system to return to ambient conditions. Figures 7 depicts the first year of simulated recovery (year 31) in model layer 1. These figures indicate that with the 30% design (left panel), arsenic concentrations will drop below 5 ppb within 1 year. The revised arsenic sorption parameter simulation (right panel) also shows a decreased arsenic footprint, it just retracts at a slower rate than the original 30% design. Figure 8 depicts the first year of simulated recovery in model layer 3. Similar to the model layer 1, the original 30% design arsenic distribution in layer 3 drops below 5 ppb after 1 year of recovery, while the updated model indicates a receding arsenic footprint.

Figure 9 shows the simulated arsenic results for the original 30% design and the updated model after 12 years of recovery (year 42) in model layer 1. The right panel showing the updated model results indicates that after 12 years of simulated recovery, only a trace amount of arsenic remains above 10 ppb, and the 5 ppb arsenic footprint has further decreased in size. Figure 10 shows the 12 year arsenic results for model layer 3. Similar to Figure 9, the model layer 3 results indicate the majority of the remaining arsenic concentrations are below 10 ppb, and the 5 ppb arsenic footprint is decreasing in size.

ALTERNATIVE FRESHWATER SOURCE SOLUTE TRANSPORT MODELING RESULTS

The solute transport model was utilized to evaluate the alternative freshwater source options considered within the 30% design. These included, the existing Havasu Natural Wildlife Refuge well (HNWR-1), a hypothetical new well(s) in Park Moabi, and the Colorado River. In order to reflect the appropriate freshwater source within the submodel domain, the regional groundwater model was run for each freshwater source individually and the submodel boundary conditions were extracted directly from the respective regional groundwater model run. The submodel thus reflects the associated hydraulic stresses induced by each freshwater source. Next, the solute transport model was run for each freshwater source with the following water quality parameters:

- chromium,
- arsenic,
- manganese associated with IRZ byproduct, and
- manganese associated with the naturally occurring reducing rind.

Figures 11 presents the chromium transport results for each of the three freshwater sources after 30 years of transport in model layer 1. The HNWR-1 source results are shown on the left panel, the Park

Moabi source results are shown in the center panel, and the Colorado River source results are shown in the right panel. This figure indicates that the different freshwater sources have a minimal impact on the solute transport results for the chromium plume. There is slightly more chromium mass remaining in the Park Moabi freshwater source scenario after 30 years than in the other scenarios due to a slightly lower hydraulic gradient. This would result in a slightly longer remediation timeframe for a Park Moabi well source. Comparing the results between the HNWR-1 and River freshwater sources indicates that these two sources result in nearly identical results for the transport and remediation of the chromium plume. Figure 12 depicts the chromium transport results for each of the three freshwater sources after 30 years of transport in model layer 3. Similar to Figure 11, the chromium mass remaining for each of the freshwater sources is very similar in model layer 3. This indicates that with respect to the chromium plume migration and remediation timeframe, the source of freshwater does not produce significantly different results.

Figure 13 presents the manganese byproduct transport results for the three different freshwater sources after 30 years of transport in model layer 1. The manganese solute transport run for all three freshwater sources incorporated manganese oxidation as per the updated manganese model described in the previous section. Figure 13 indicates that despite the three different potential freshwater sources, the manganese byproduct distribution downgradient of the NTH IRZ, downgradient of the TCS injection, and in the uplands are similar for all three scenarios. Figure 14 depicts the manganese byproduct results for model layer 3. Similar to the results for model layer 1, there were minimal differences between the three different freshwater sources.

Figure 15 presents the manganese in the naturally occurring rind transport results for the three different freshwater sources after 30 years of transport in model layer 1.The manganese solute transport run for all three freshwater sources incorporated manganese oxidation as per the updated manganese model described in the previous section. Figure 15 indicates that the three different potential freshwater sources result in very similar manganese distribution in the rind. Figure 16 depicts the manganese rind results for model layer 3. Similar to the results for model layer 1, there were minimal differences between the three different freshwater sources.

Figure 17 presents the arsenic transport results for the three freshwater sources after 30 years of transport for model layer 1. With respect to arsenic concentrations present in the freshwater injection wells, 15 ppb arsenic was utilized for HNWR-1 and Park Moabi, while only 2.6 ppb was utilized for the River source. While the exact arsenic concentration for Park Moabi is unknown, a value of 15 ppb was assigned as an approximate value to directly compare the impact to the HNWR-1 modeling results. Figure 17 indicates very similar arsenic impacts between the HNWR-1 and Park Moabi sources, with only a slightly biased northwest flow component observed at FW-INJ-2 due to the Park Moabi extraction. Arsenic concentrations for the River source remained below 5 ppb for the duration of the model at the freshwater injection wells. Figure 18 depicts the 30 year freshwater source analyses for model layer 3. Similar to the layer 1 results, the model layer 3 results indicate similar arsenic distributions between HNWR-1 and Park Moabi freshwater sources, while the river freshwater source remained below 5 ppb throughout the model domain.

Freshwater Injection Well FW-INJ-1

During the freshwater source analysis, the importance of well FW-INJ-1 (northeast freshwater injection well near the river), was evaluated. In the original 30% design, FW-INJ-1 was injecting at a rate of 100 gpm. In order to evaluate the impact FW-INJ-1 has on the chromium plume migration and remedial timeframe, as well as the impact on manganese and arsenic, the flow and transport models were run with FW-INJ-1 turned off. With respect to the chromium plume, there was no difference in simulated chromium

plume migration or remedial timeframe with FW-INJ-1 turned off. With respect to the manganese there was no difference in the manganese byproduct or rind without FW-INJ-1 operating. The only significant difference was with respect to the arsenic contained within the freshwater injection. Due to the limited benefit of FW-INJ-1 and agency comments regarding freshwater injection at this location, it is recommended to further analyze the FW-INJ-1 location as part of the 60% design process.

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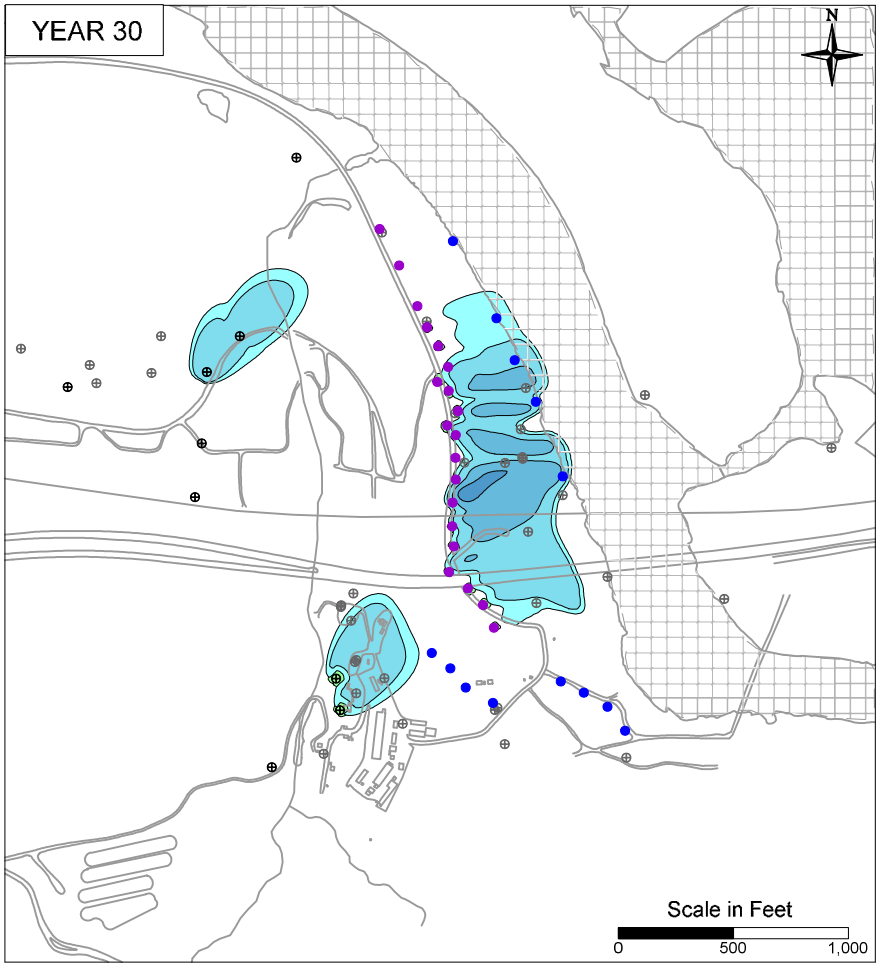
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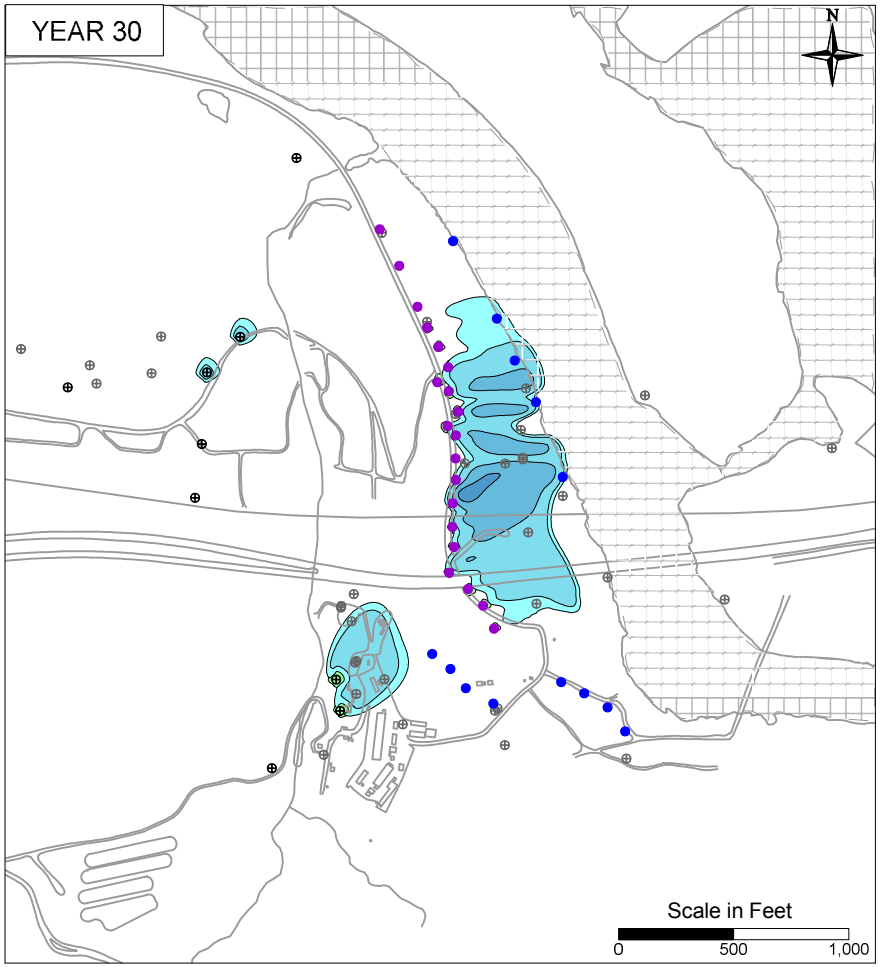
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30% Design: Byproduct Manganese



Update: Byproduct Manganese with Oxidation

Manganese Concentration (ppm)

0.13 0.25 0.5 0.75 1 2

Carbon Concentration (ppm)

1 25 50 75 100

LEGEND

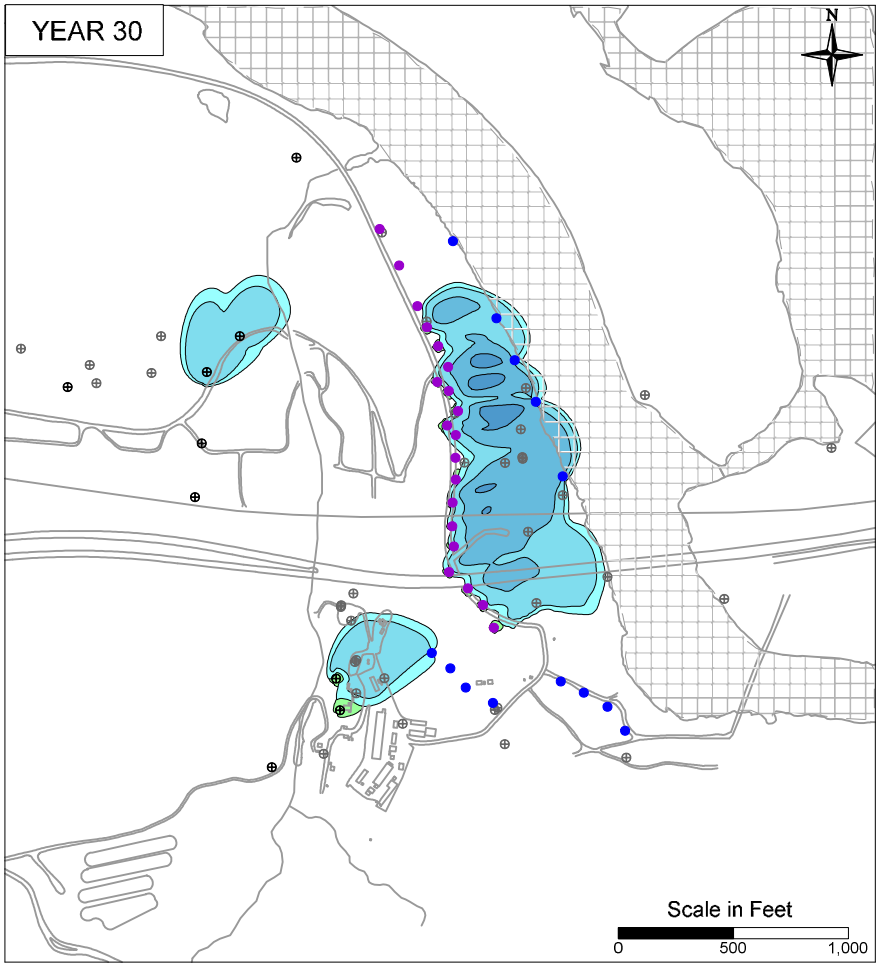
- IRZ WELLS
- UPGRADIENT INJECTION WELLS
- EXTRACTION WELLS
- MONITORING WELLS

PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
MODELING APPENDIX

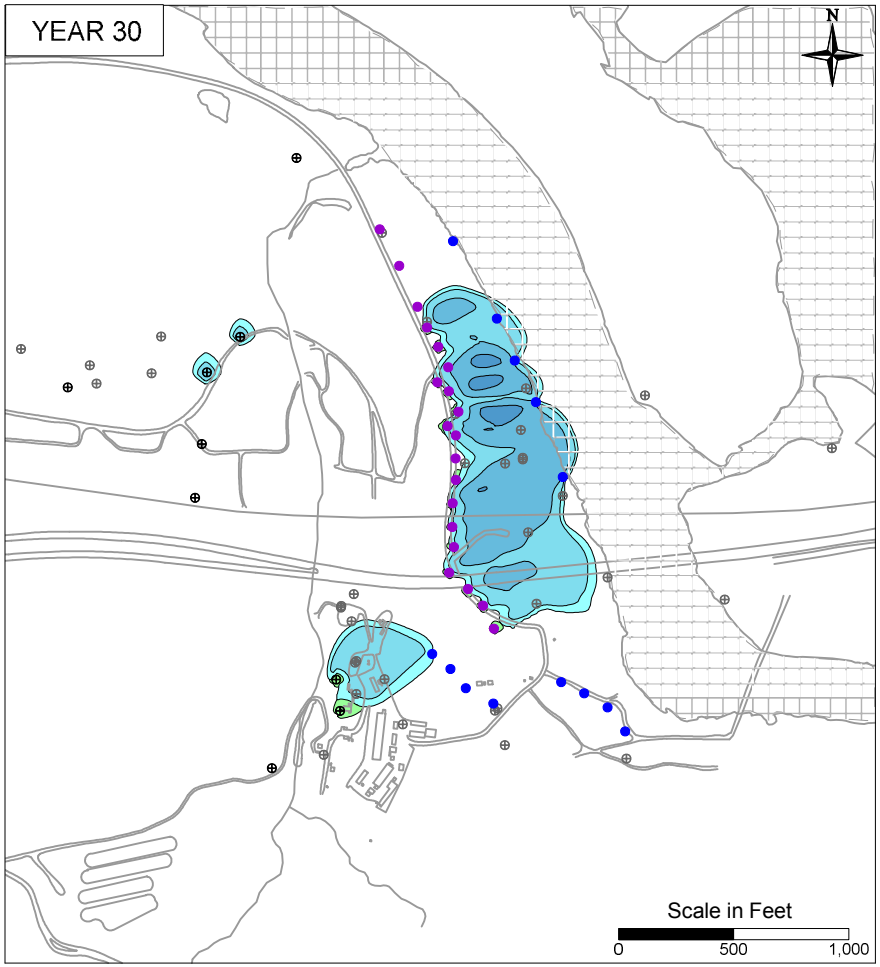
MANGANESE PARAMETER REFINEMENT:
30 YEAR SIMULATED BYPRODUCT MANGANESE
TRANSPORT RESULTS IN MODEL LAYER 1

ARCADIS

FIGURE
1



30% Design: Byproduct Manganese



Update: Byproduct Manganese with Oxidation

Manganese Concentration (ppm)

0.13 0.25 0.5 0.75 1 2

Carbon Concentration (ppm)

1 25 50 75 100

LEGEND

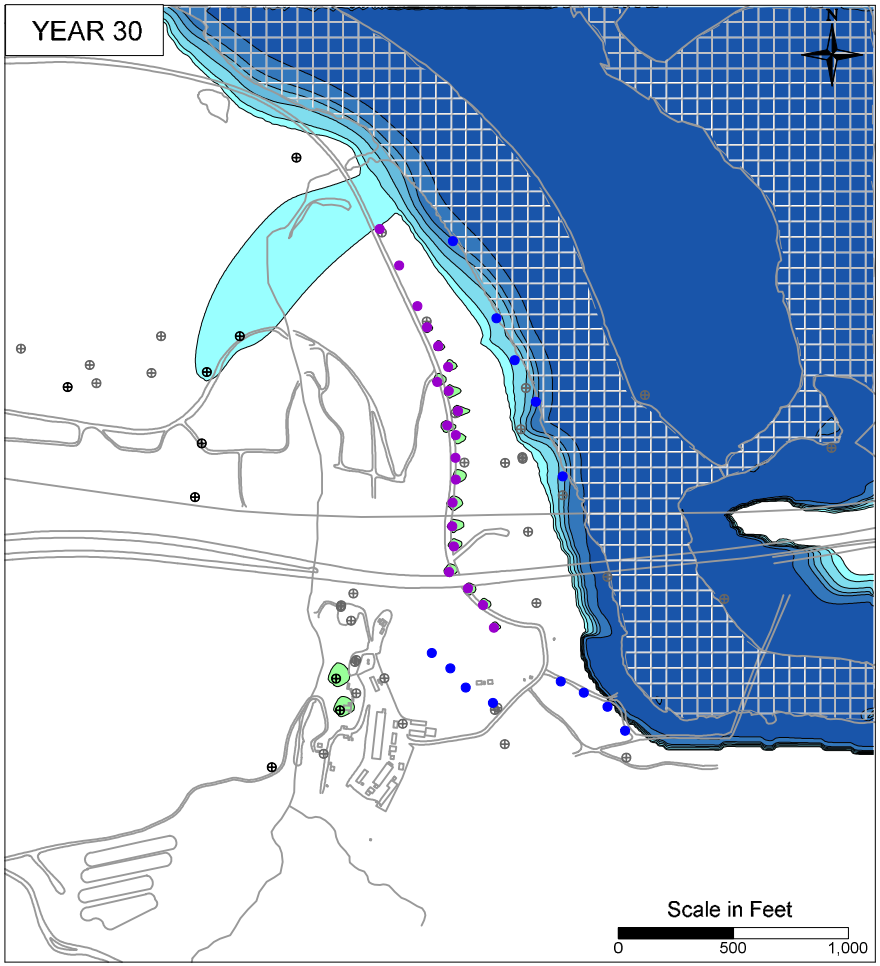
- IRZ WELLS
- UPGRADIENT INJECTION WELLS
- EXTRACTION WELLS
- MONITORING WELLS

PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
MODELING APPENDIX

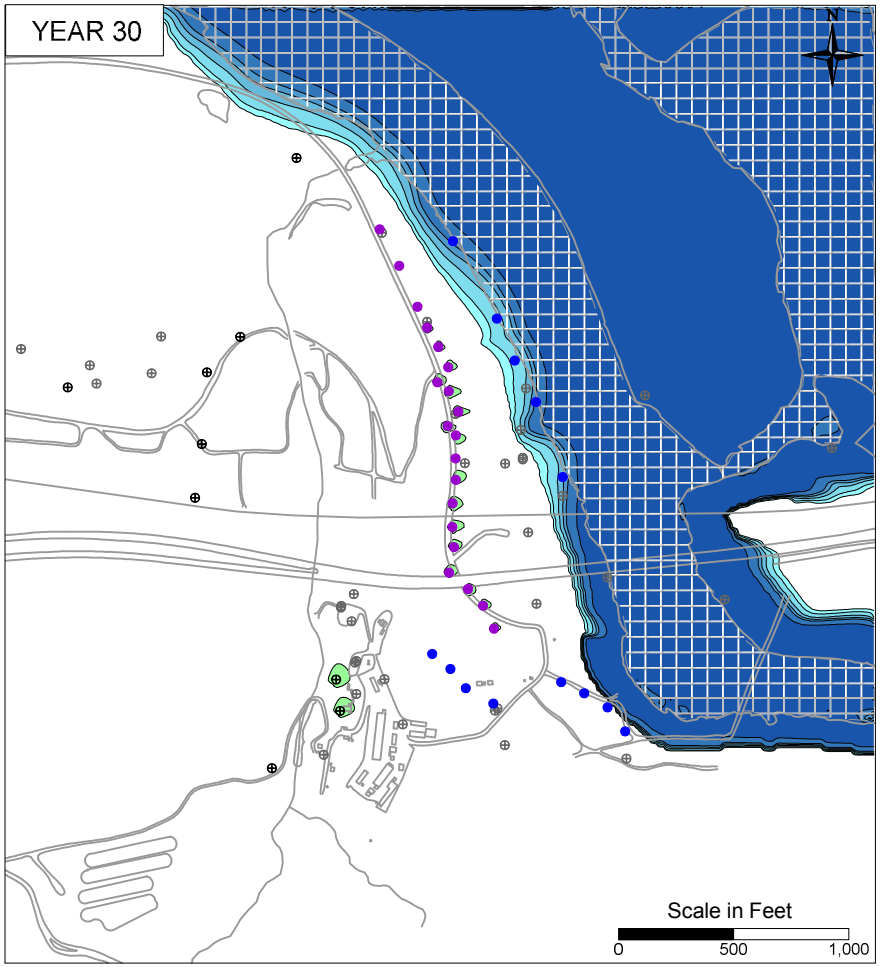
MANGANESE PARAMETER REFINEMENT:
30 YEAR SIMULATED BYPRODUCT MANGANESE
TRANSPORT RESULTS IN MODEL LAYER 3

ARCADIS

FIGURE
2



30% Design:Rind Manganese



Update: Rind Manganese with Oxidation

Manganese Concentration (ppm)

0.13 0.25 0.5 0.75 1 2

Carbon Concentration (ppm)

1 25 50 75 100

LEGEND

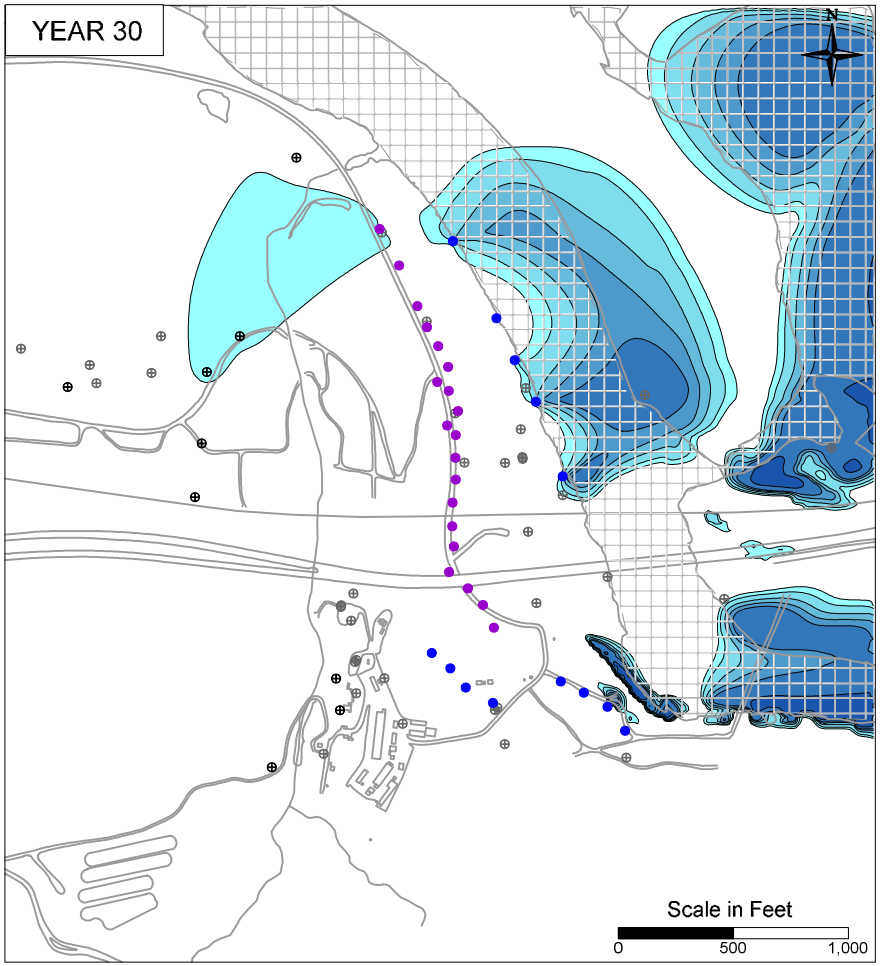
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- UPGRADIENT INJECTION WELLS
- EXTRACTION WELLS
- MONITORING WELLS

PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
MODELING APPENDIX

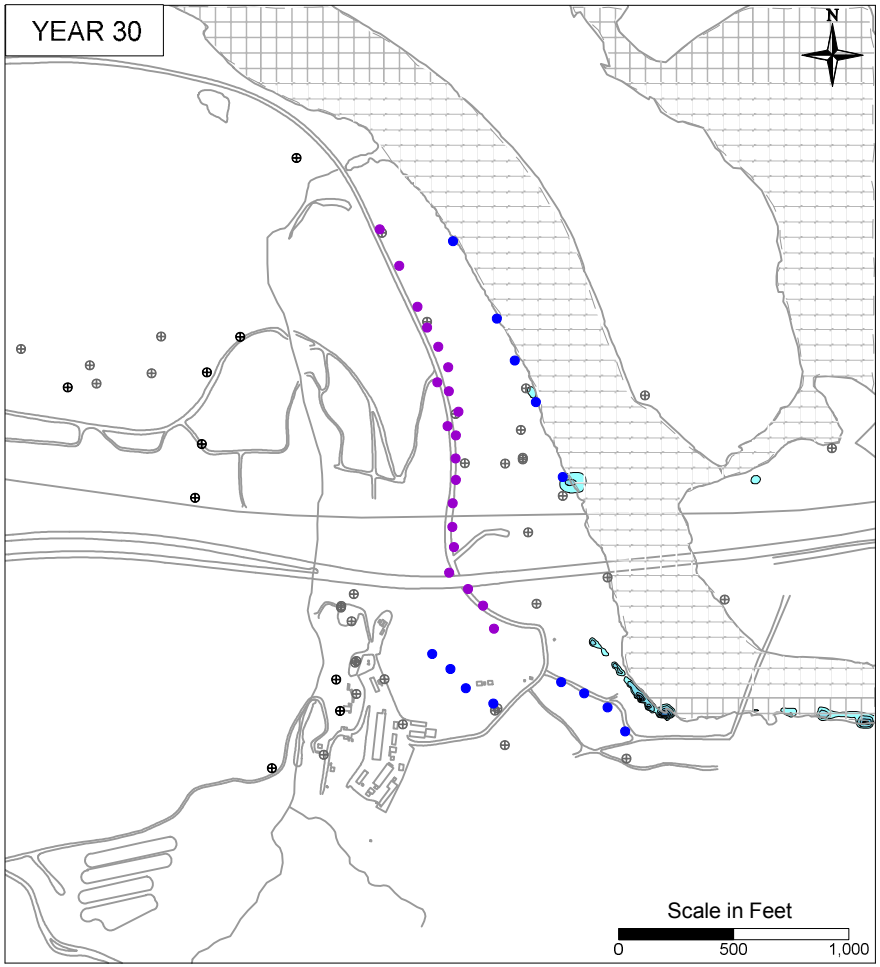
MANGANESE PARAMETER REFINEMENT:
30 YEAR SIMULATED RIND MANGANESE
TRANSPORT RESULTS IN MODEL LAYER 1

ARCADIS

FIGURE
3



30% Design:Rind Manganese



Update: Rind Manganese with Oxidation

Manganese Concentration (ppm)

0.13 0.25 0.5 0.75 1 2

Carbon Concentration (ppm)

1 25 50 75 100

LEGEND

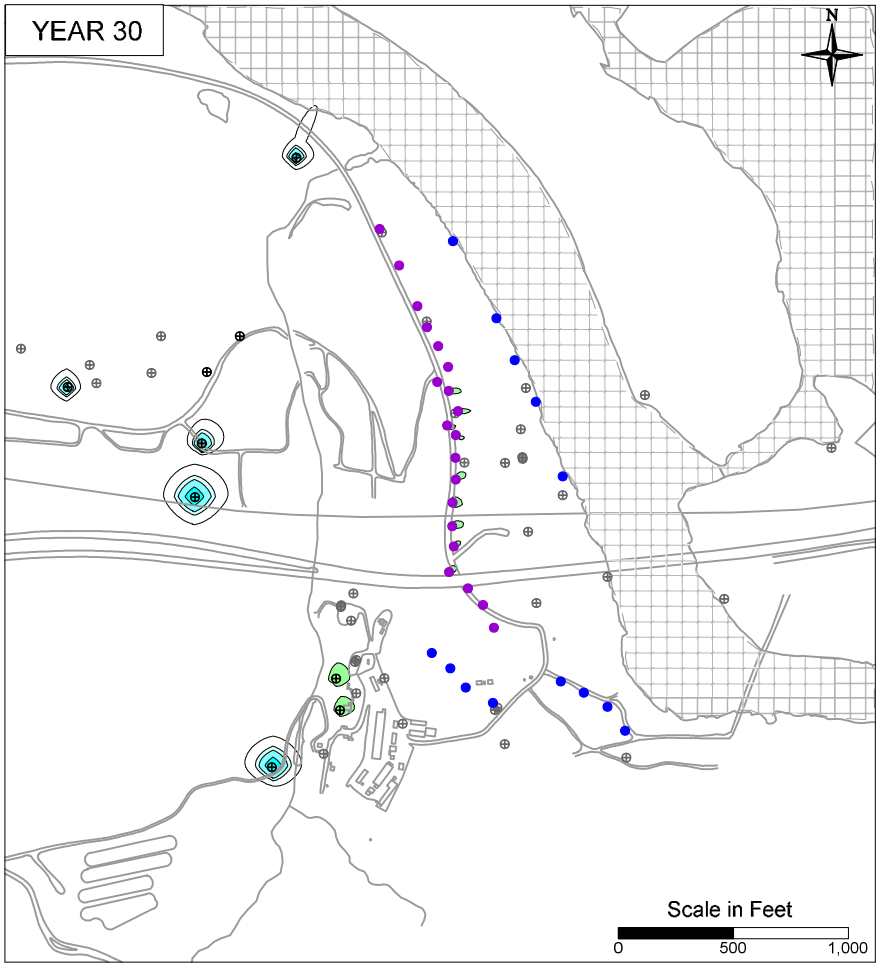
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- UPGRADIENT INJECTION WELLS
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- MONITORING WELLS

PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
MODELING APPENDIX

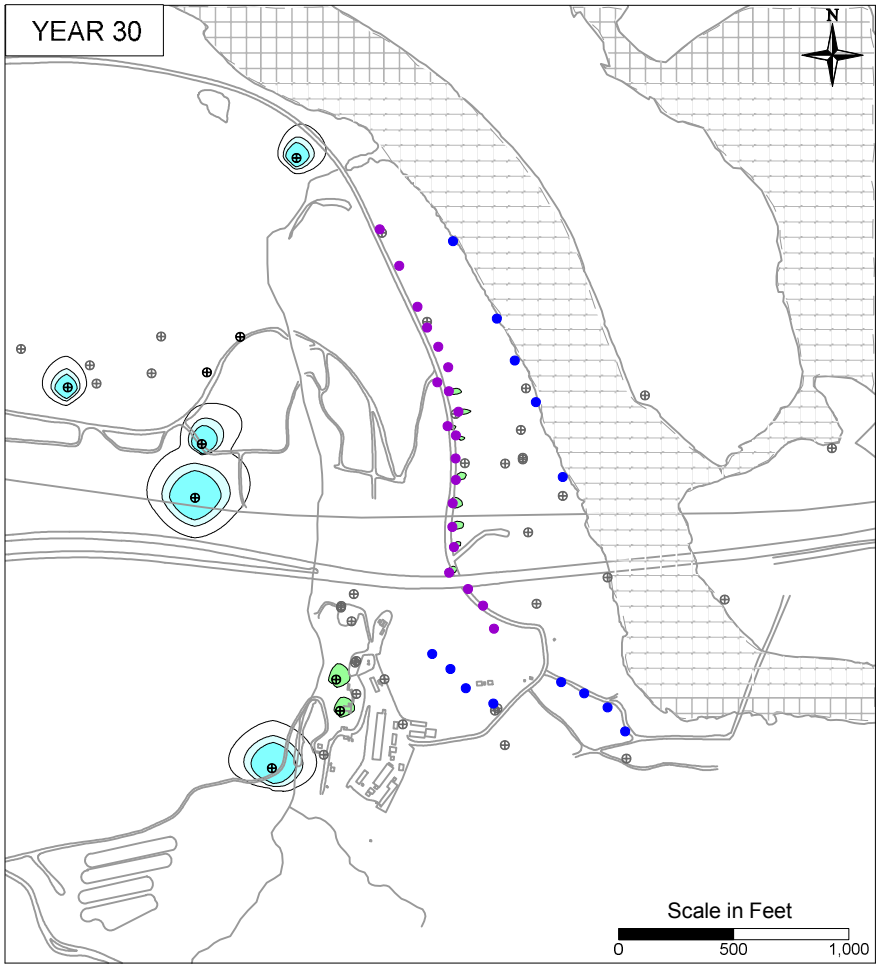
MANGANESE PARAMETER REFINEMENT:
30 YEAR SIMULATED RIND MANGANESE
TRANSPORT RESULTS IN MODEL LAYER 3

ARCADIS

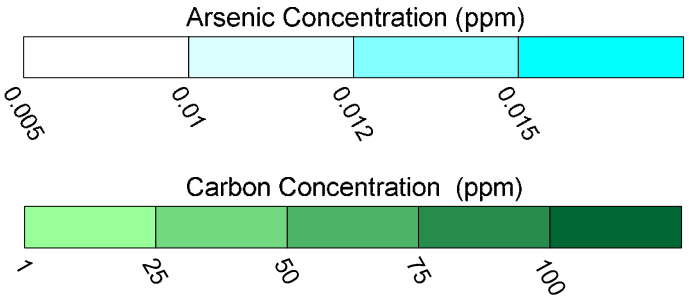
FIGURE
4



30% Design: Arsenic Precipitation Only



Update: Uplands Arsenic Sorption Only



LEGEND

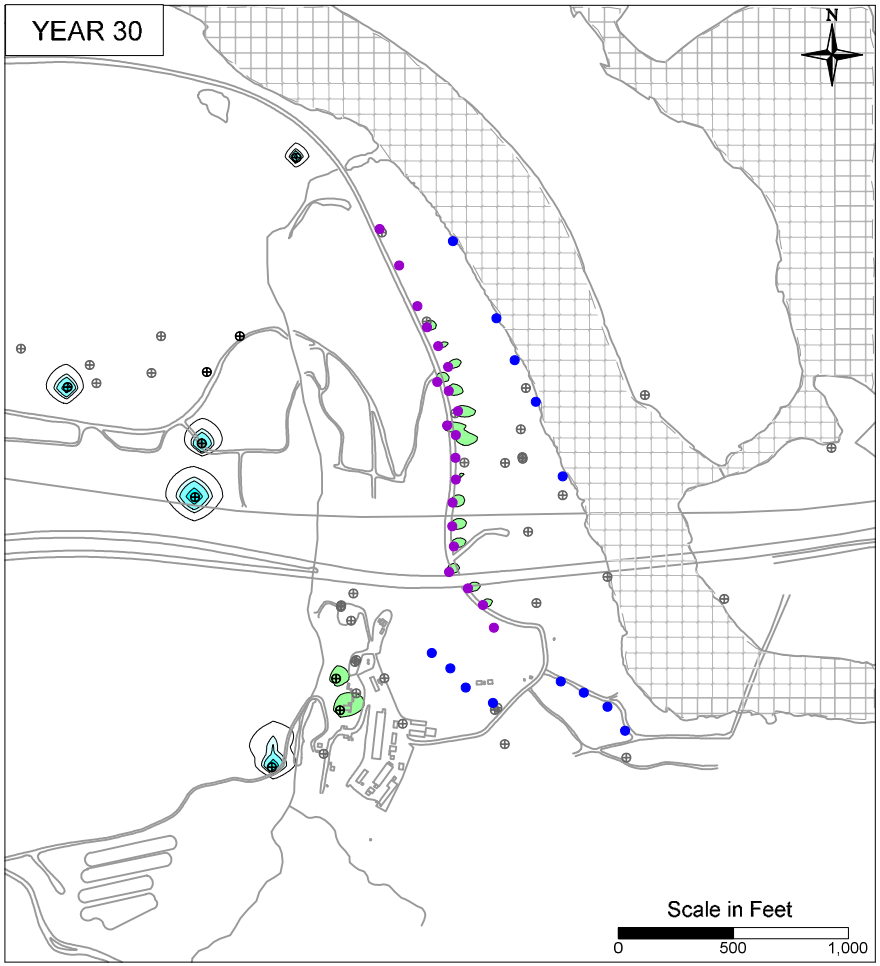
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- UPGRADIENT INJECTION WELLS
- EXTRACTION WELLS
- MONITORING WELLS

PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
MODELING APPENDIX

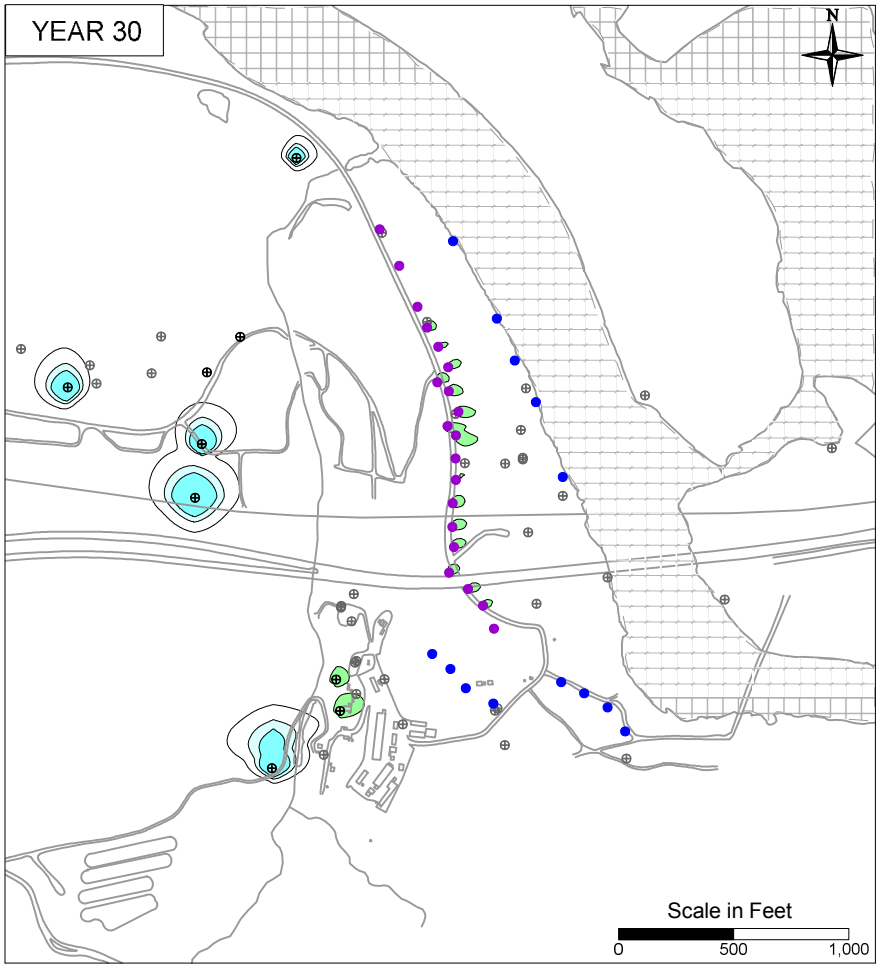
ARSENIC PARAMETER REFINEMENT:
30 YEAR SIMULATED ARSENIC TRANSPORT
RESULTS IN MODEL LAYER 1

ARCADIS

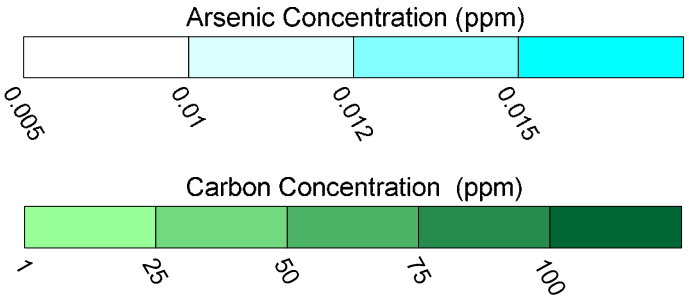
FIGURE
5



30% Design: Arsenic Precipitation Only



Update: Uplands Arsenic Sorption Only



LEGEND

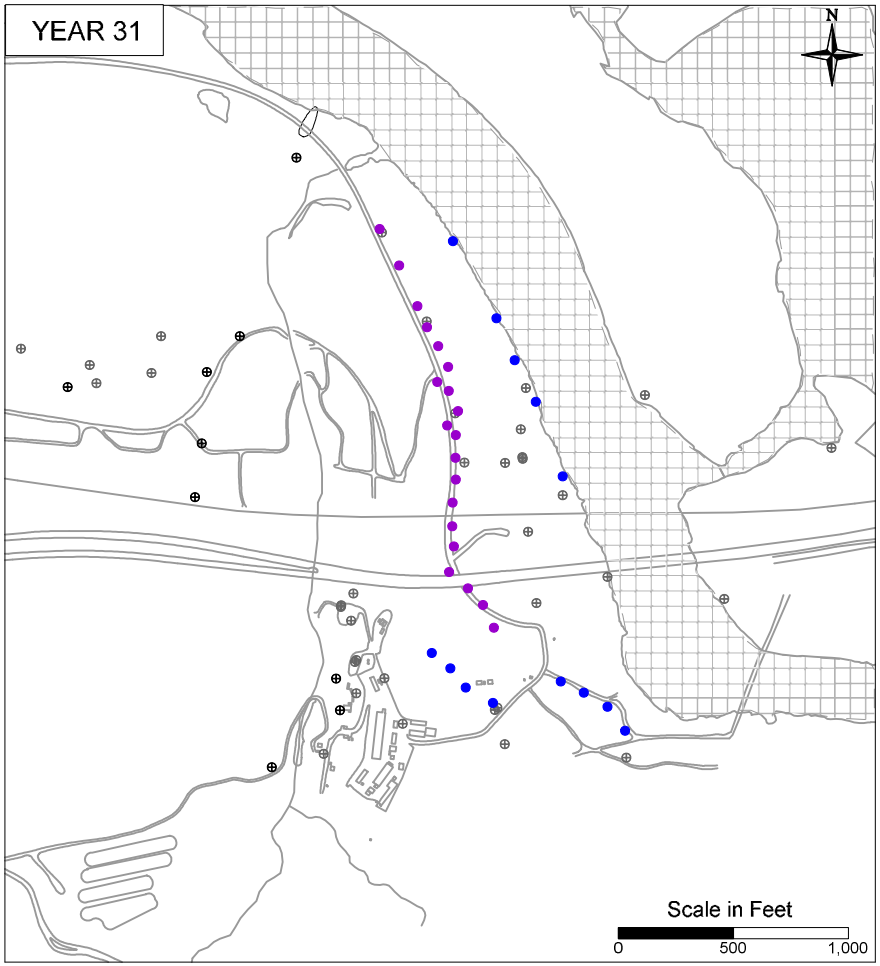
- IRZ WELLS
- UPGRADIENT INJECTION WELLS
- EXTRACTION WELLS
- MONITORING WELLS

PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
MODELING APPENDIX

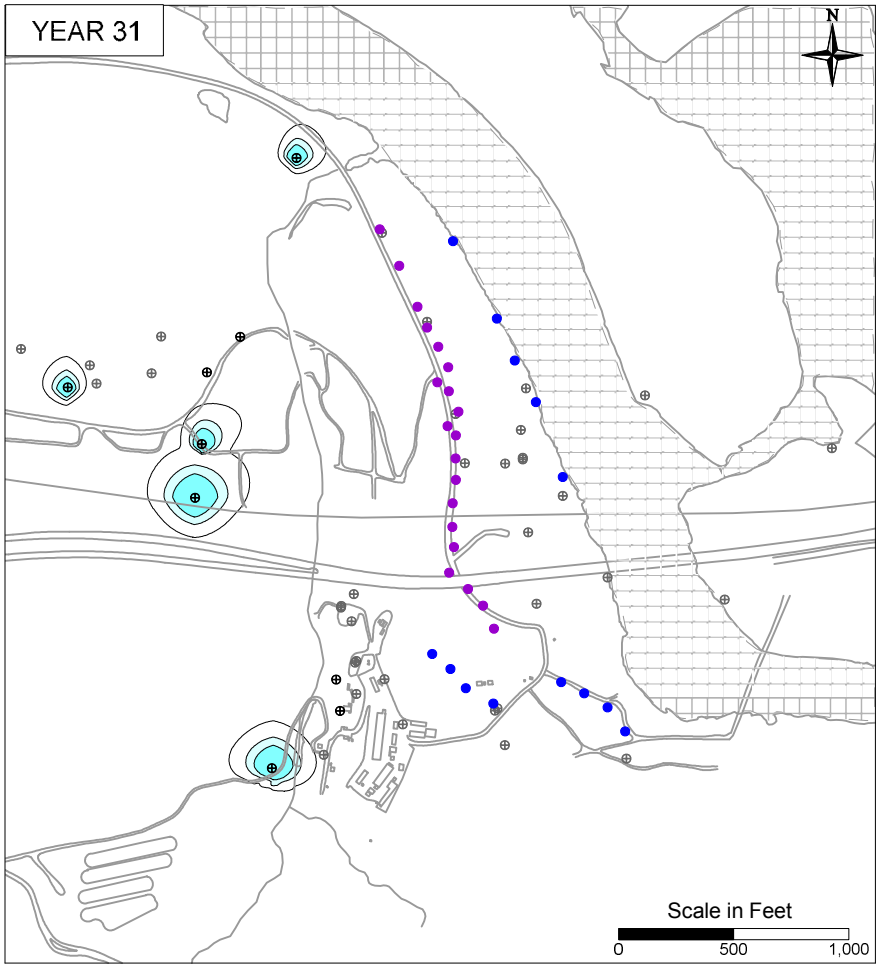
ARSENIC PARAMETER REFINEMENT:
30 YEAR SIMULATED ARSENIC TRANSPORT
RESULTS IN MODEL LAYER 3

ARCADIS

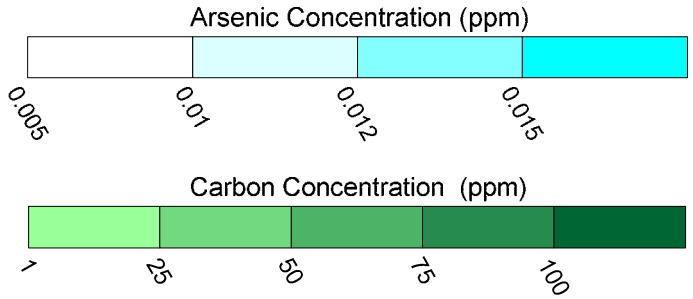
FIGURE
6



30% Design: Arsenic Precipitation Only



Update: Uplands Arsenic Sorption Only



LEGEND

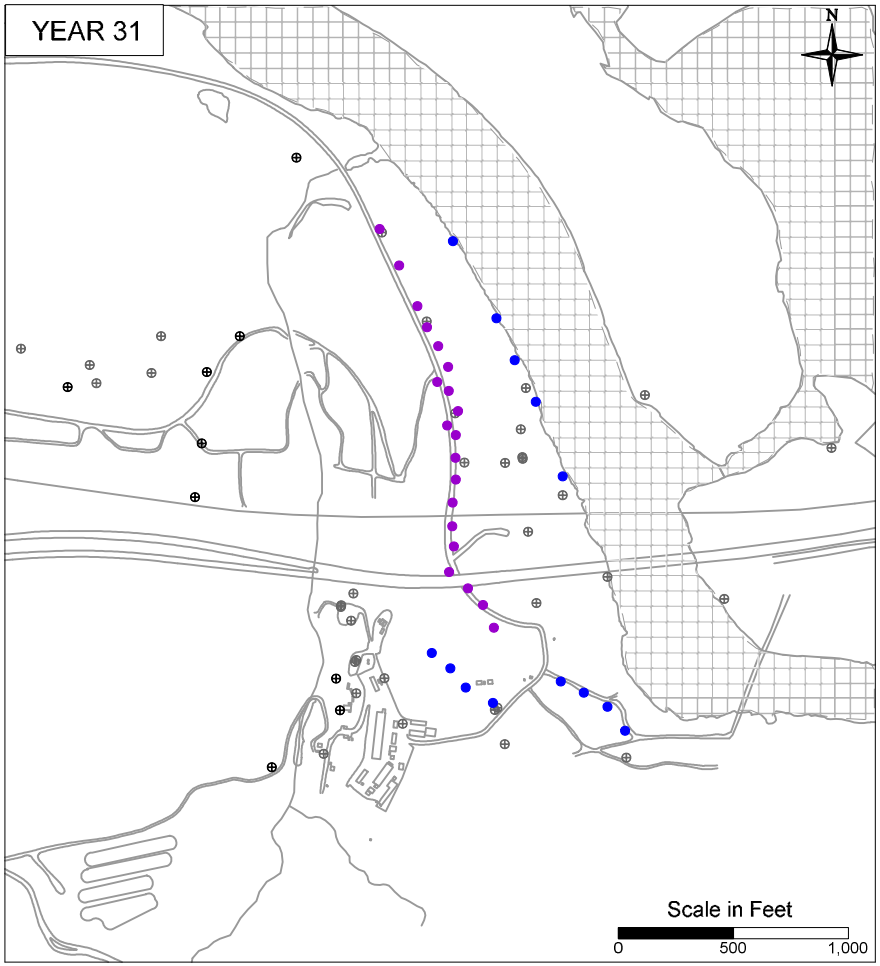
- IRZ WELLS
- UPGRADIENT INJECTION WELLS
- EXTRACTION WELLS
- MONITORING WELLS

PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
MODELING APPENDIX

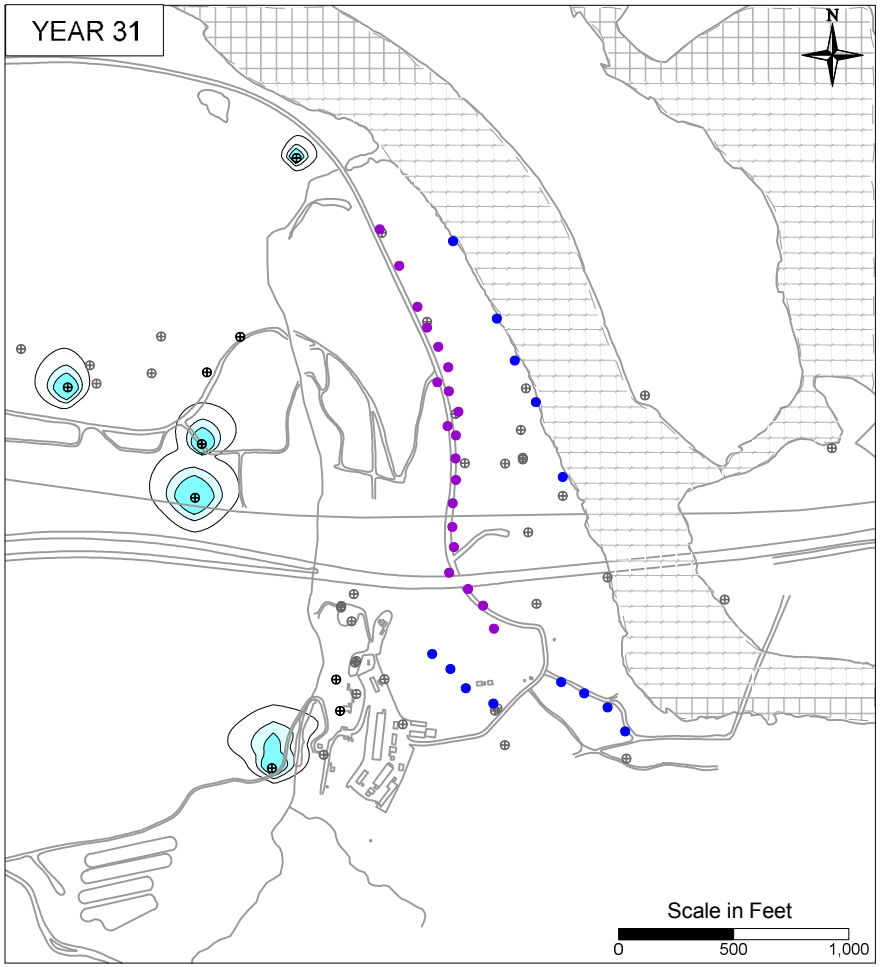
ARSENIC PARAMETER REFINEMENT:
31 YEAR SIMULATED ARSENIC RECOVERY
TRANSPORT RESULTS IN MODEL LAYER 1

ARCADIS

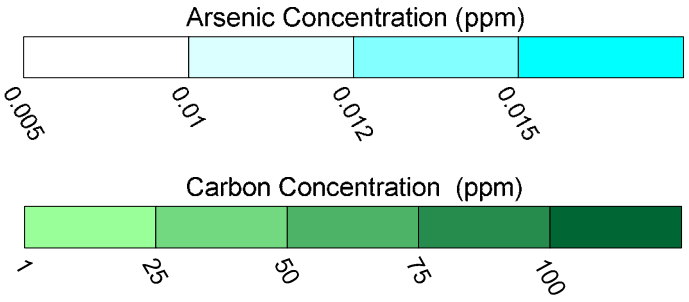
FIGURE
7



30% Design: Arsenic Precipitation Only



Update: Uplands Arsenic Sorption Only



LEGEND

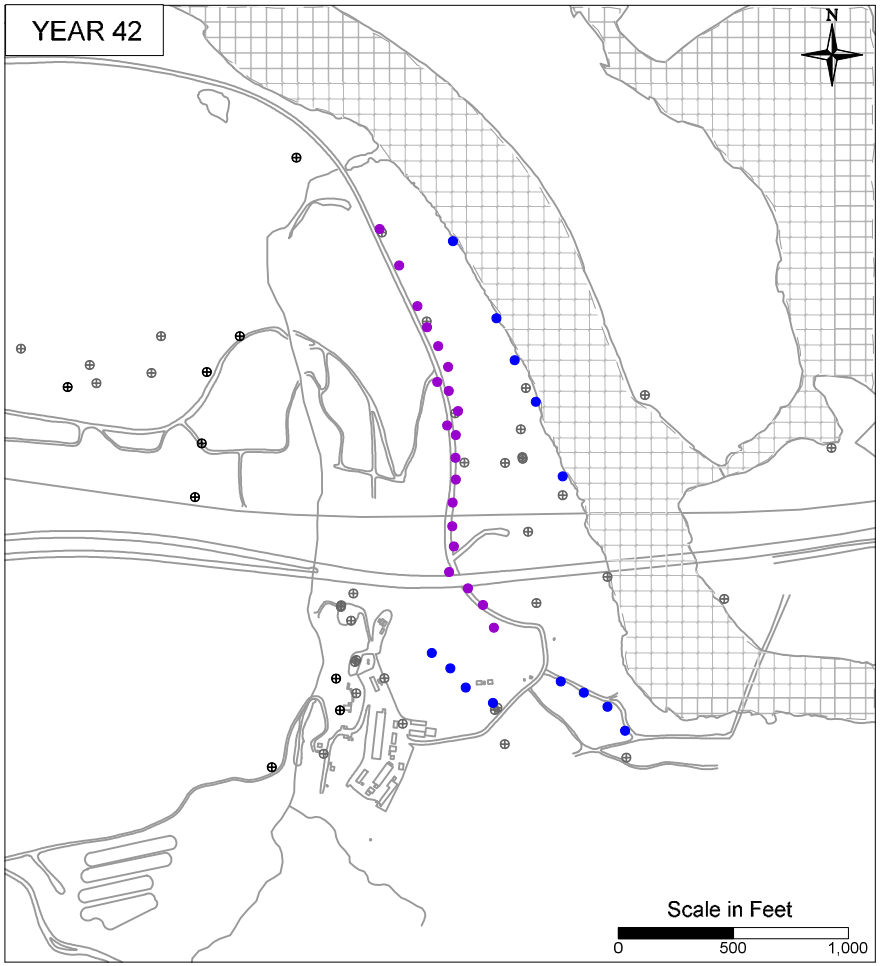
- IRZ WELLS
- UPGRADIENT INJECTION WELLS
- EXTRACTION WELLS
- MONITORING WELLS

PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
MODELING APPENDIX

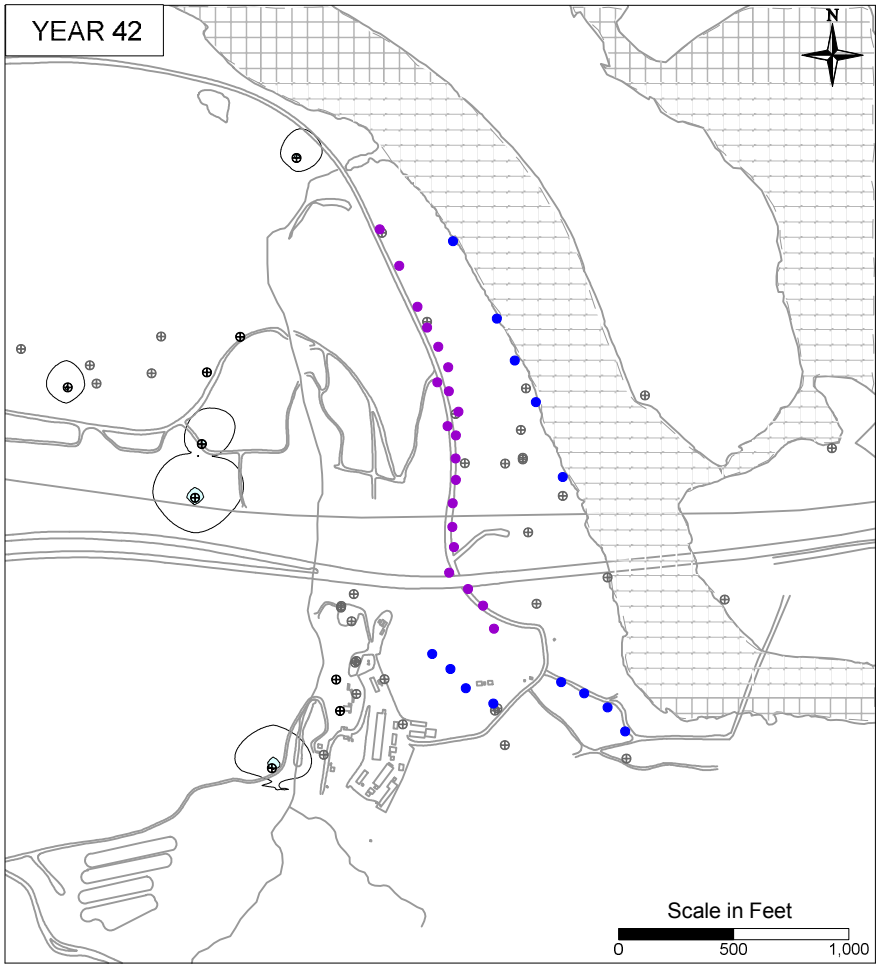
ARSENIC PARAMETER REFINEMENT:
31 YEAR SIMULATED ARSENIC RECOVERY
TRANSPORT RESULTS IN MODEL LAYER 3

ARCADIS

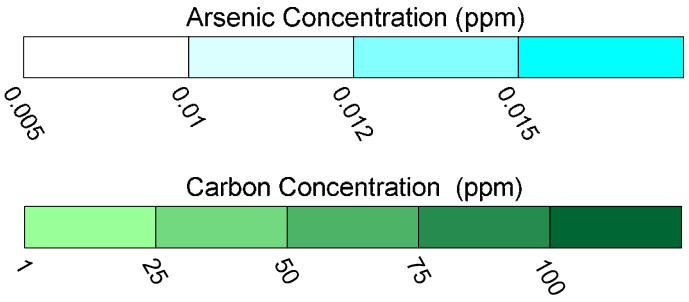
FIGURE
8



30% Design: Arsenic Precipitation Only



Update: Uplands Arsenic Sorption Only



LEGEND

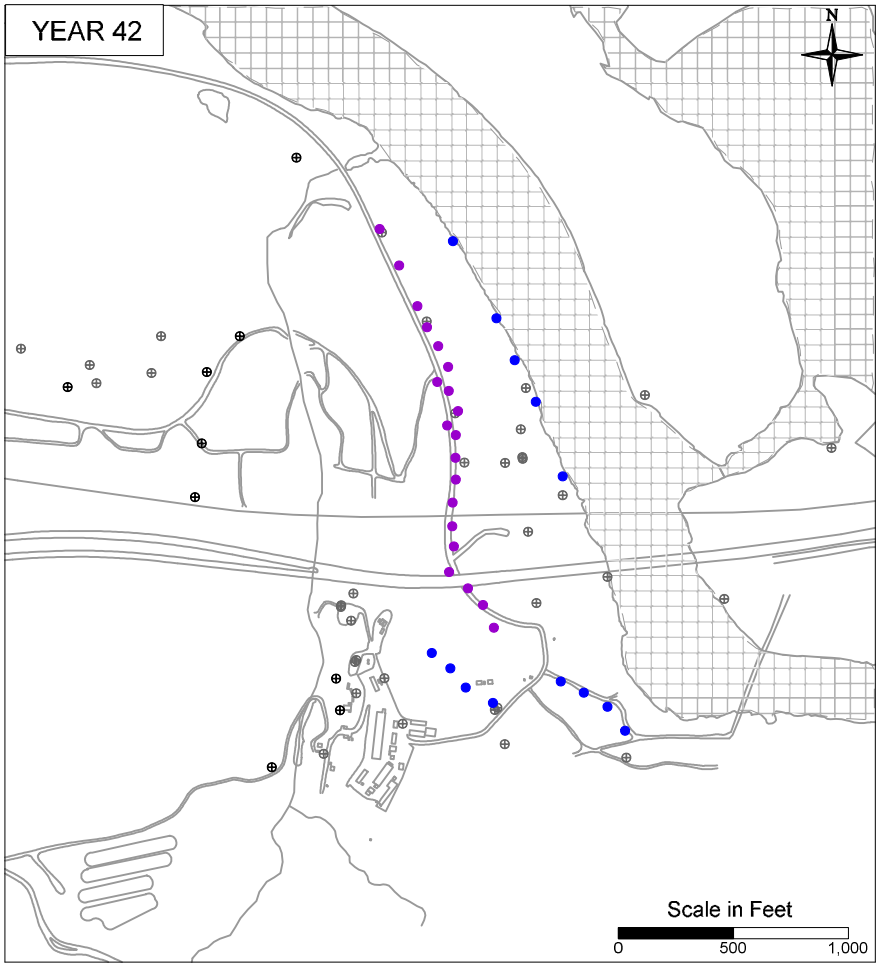
- IRZ WELLS
- UPGRADIENT INJECTION WELLS
- EXTRACTION WELLS
- MONITORING WELLS

PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
MODELING APPENDIX

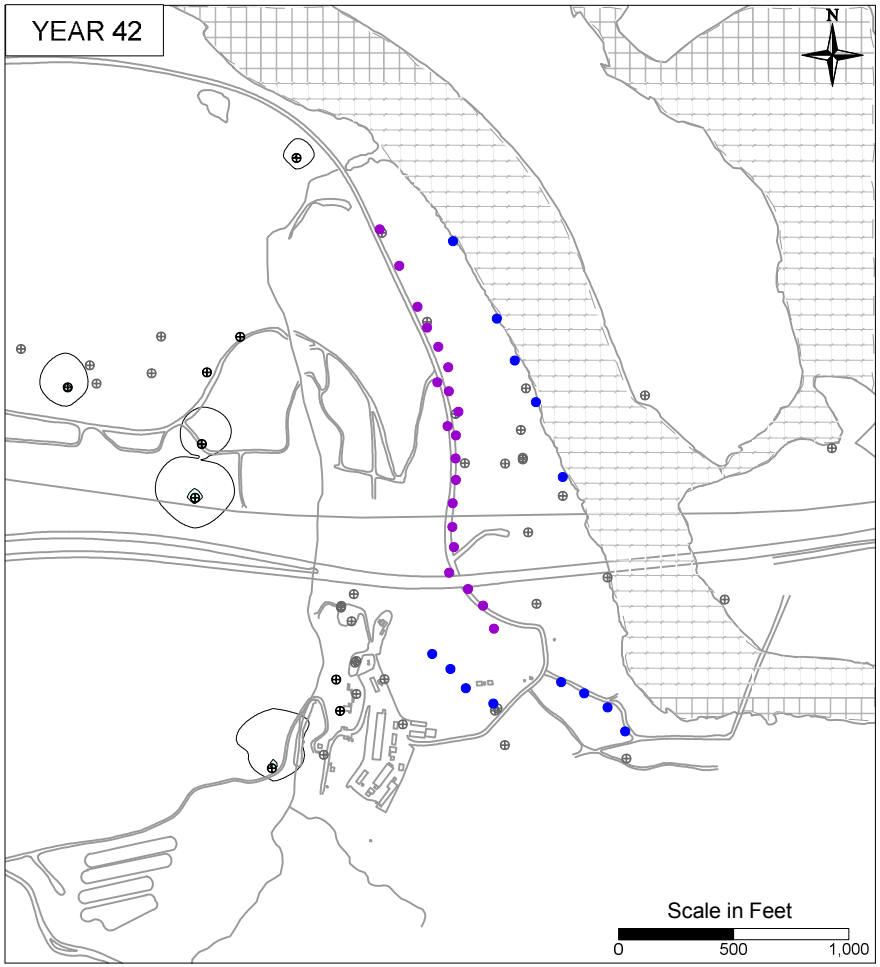
ARSENIC PARAMETER REFINEMENT:
42 YEAR SIMULATED ARSENIC RECOVERY
TRANSPORT RESULTS IN MODEL LAYER 1

ARCADIS

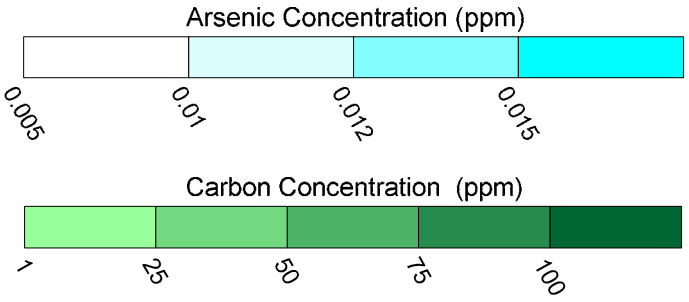
FIGURE
9



30% Design: Arsenic Precipitation Only



Update: Uplands Arsenic Sorption Only



LEGEND

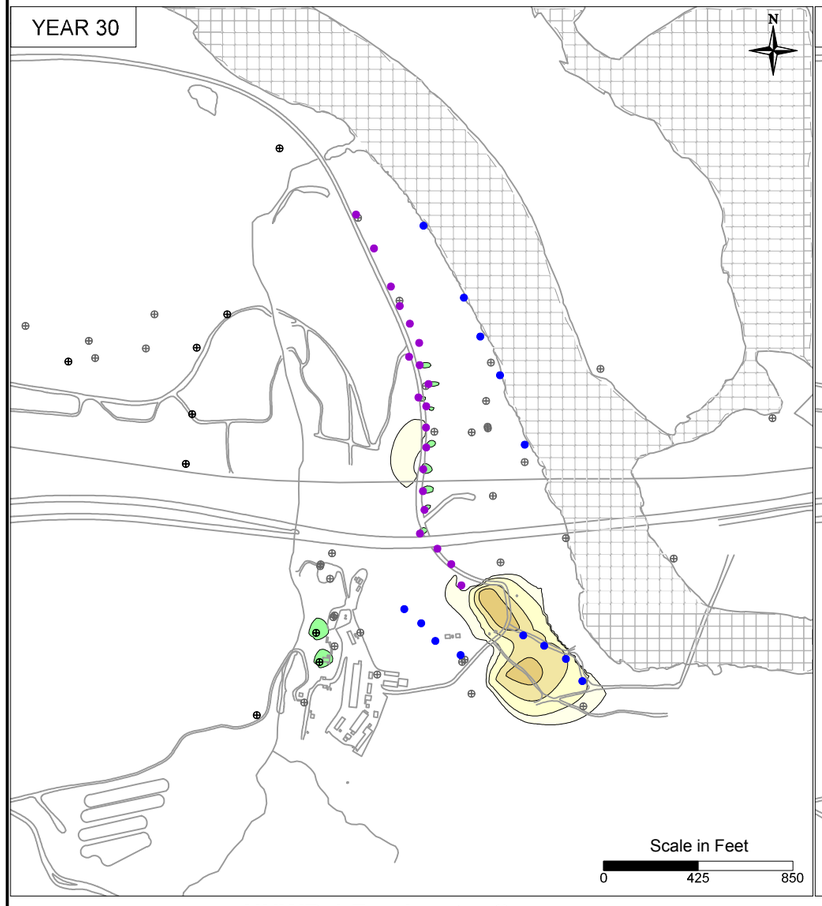
- IRZ WELLS
- UPGRADIENT INJECTION WELLS
- EXTRACTION WELLS
- MONITORING WELLS

PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
MODELING APPENDIX

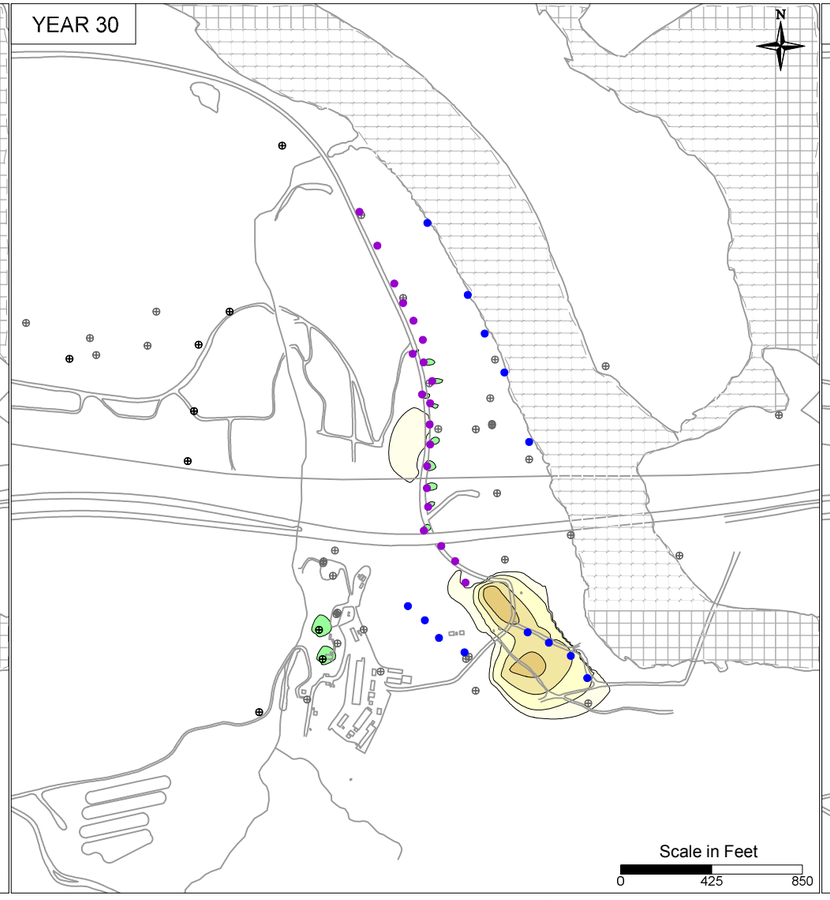
ARSENIC PARAMETER REFINEMENT:
42 YEAR SIMULATED ARSENIC RECOVERY
TRANSPORT RESULTS IN MODEL LAYER 3

ARCADIS

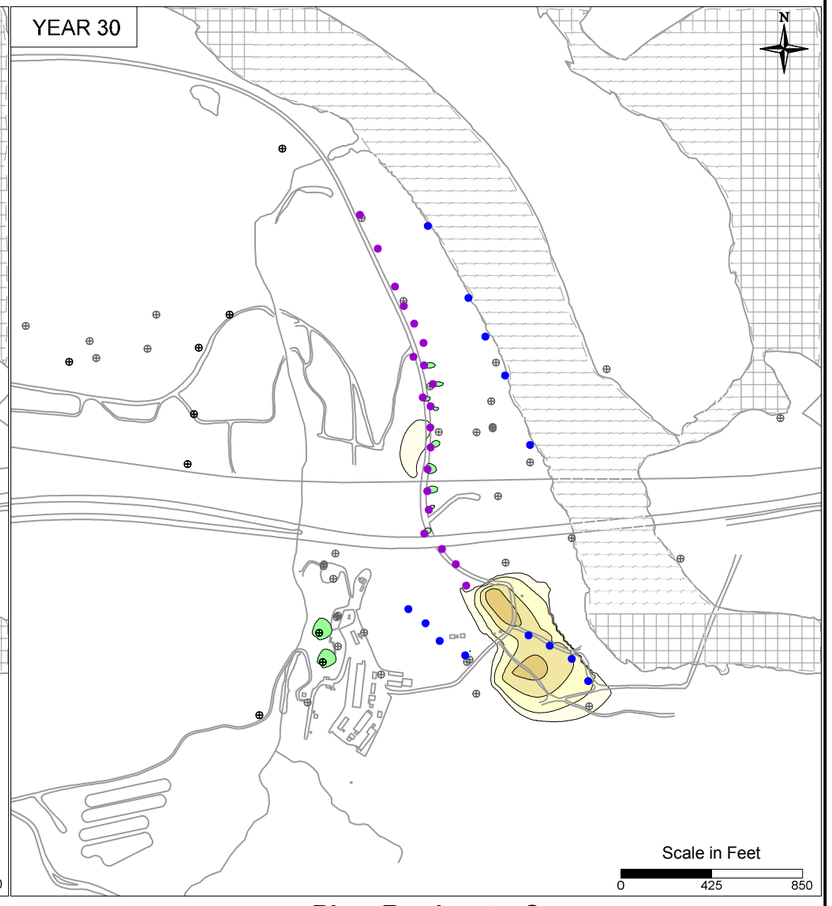
FIGURE
10



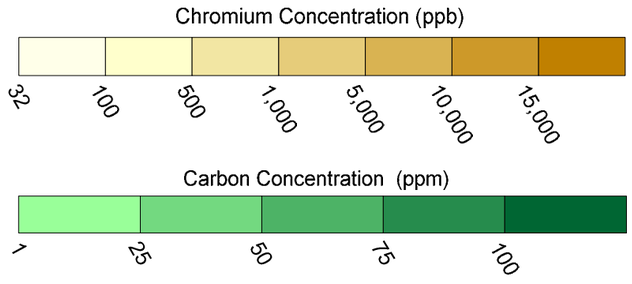
HNWR-1 Freshwater Source



Park Moabi Freshwater Source



River Freshwater Source



LEGEND

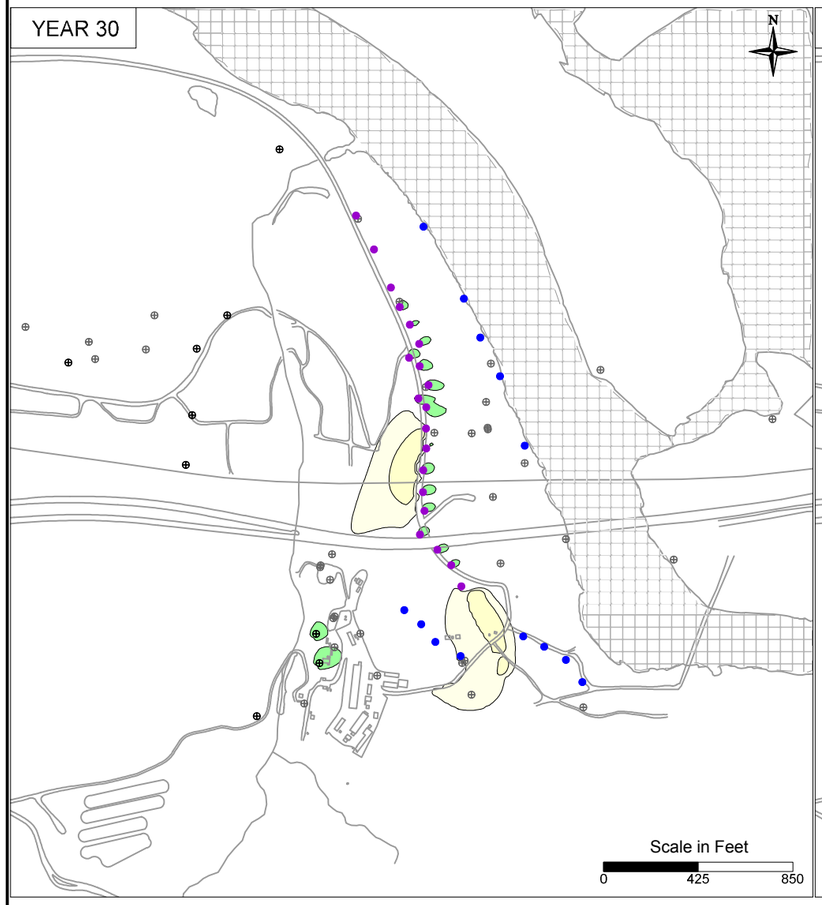
- IRZ WELLS
- UPGRADIENT INJECTION WELLS
- EXTRACTION WELLS
- MONITORING WELLS

PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
MODELING APPENDIX

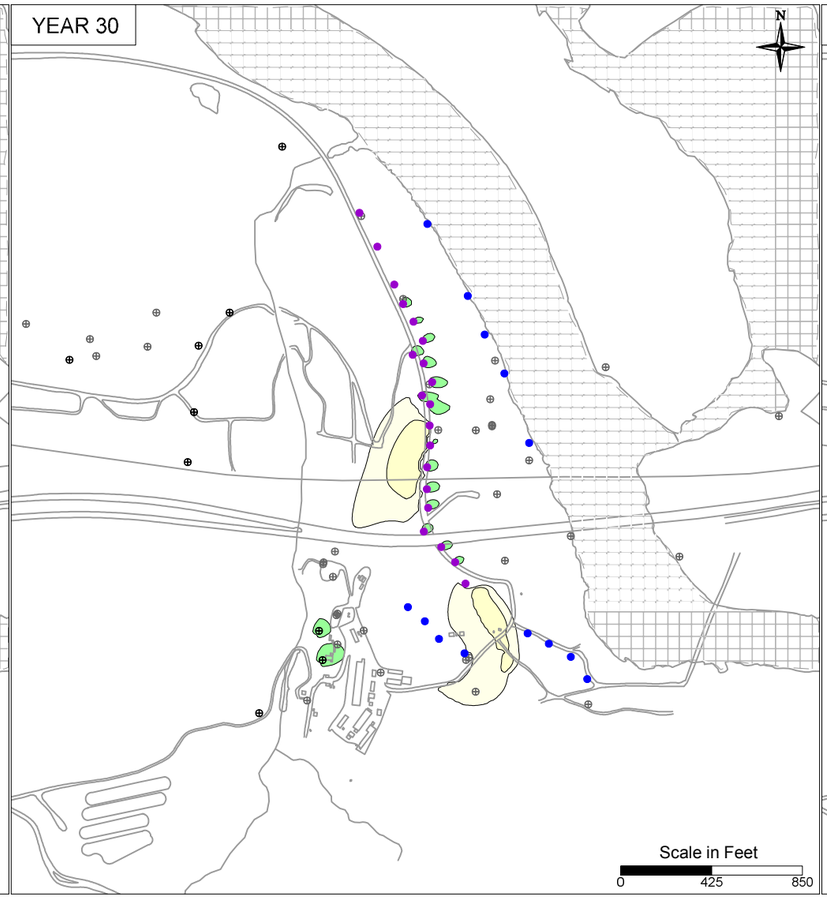
FRESHWATER SOURCE EVALUATION:
30 YEAR SIMULATED HEXAVALENT CHROMIUM TRANSPORT RESULTS IN MODEL LAYER 1

ARCADIS

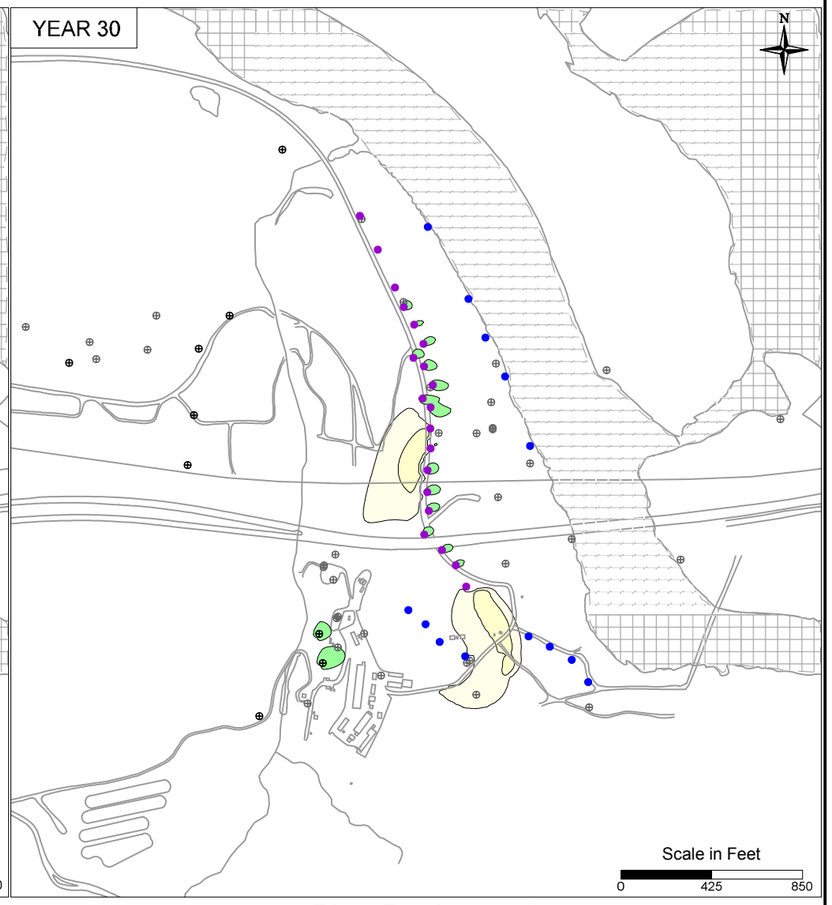
FIGURE
11



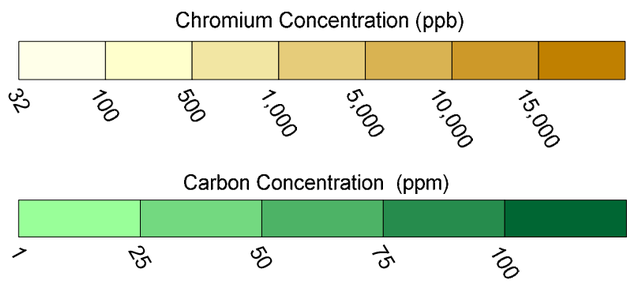
HNWR-1 Freshwater Source



Park Moabi Freshwater Source



River Freshwater Source



LEGEND

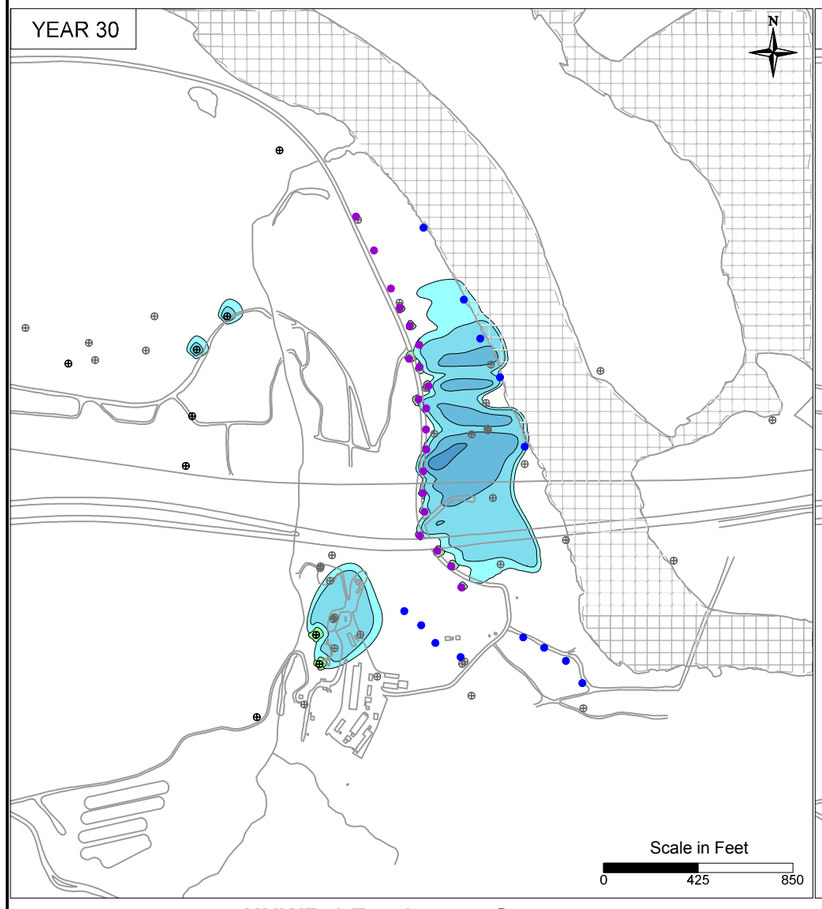
- IRZ WELLS
- UPGRADIENT INJECTION WELLS
- EXTRACTION WELLS
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PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
MODELING APPENDIX

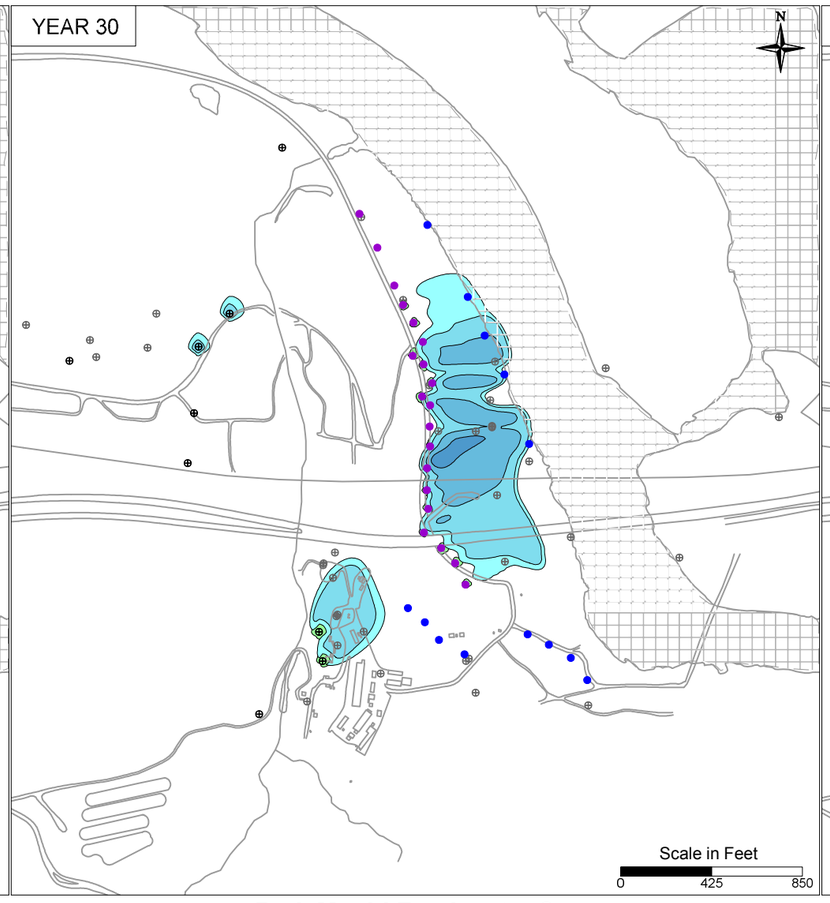
FRESHWATER SOURCE EVALUATION:
30 YEAR SIMULATED HEXAVALENT CHROMIUM TRANSPORT RESULTS IN MODEL LAYER 3

ARCADIS

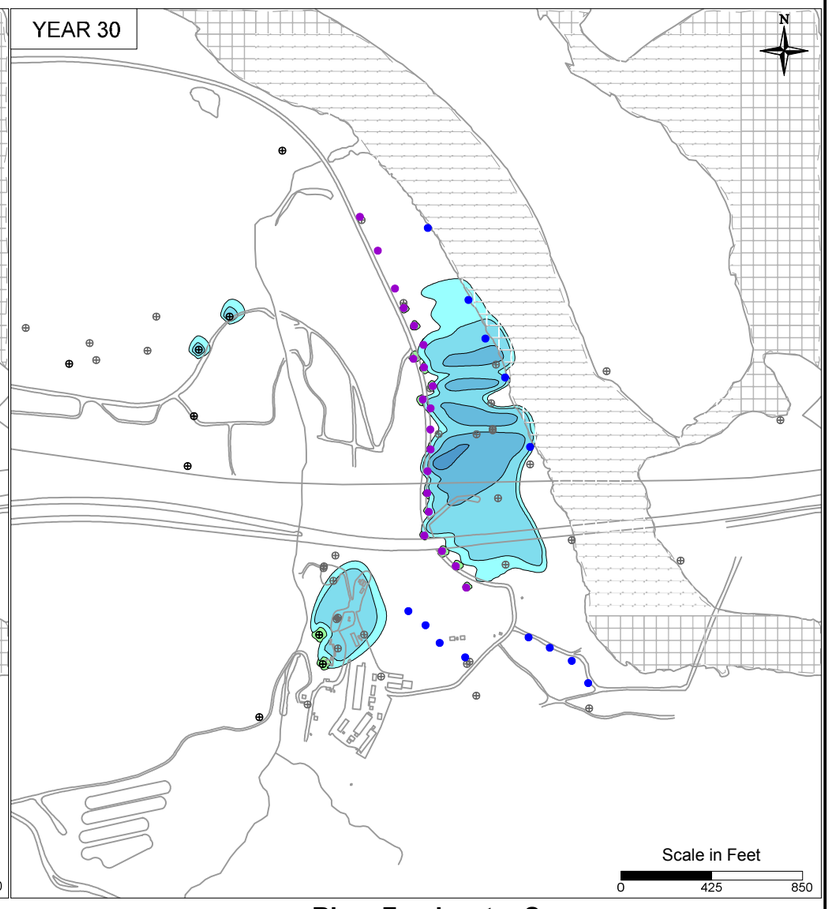
FIGURE
12



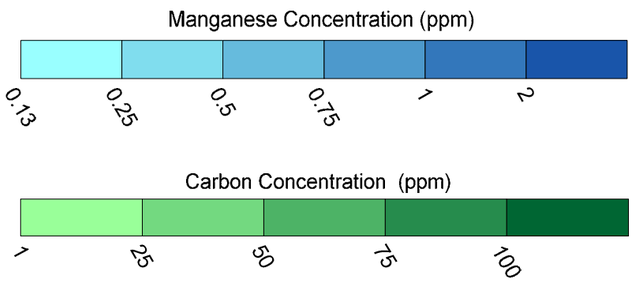
HNWR-1 Freshwater Source



Park Moabi Freshwater Source



River Freshwater Source



LEGEND

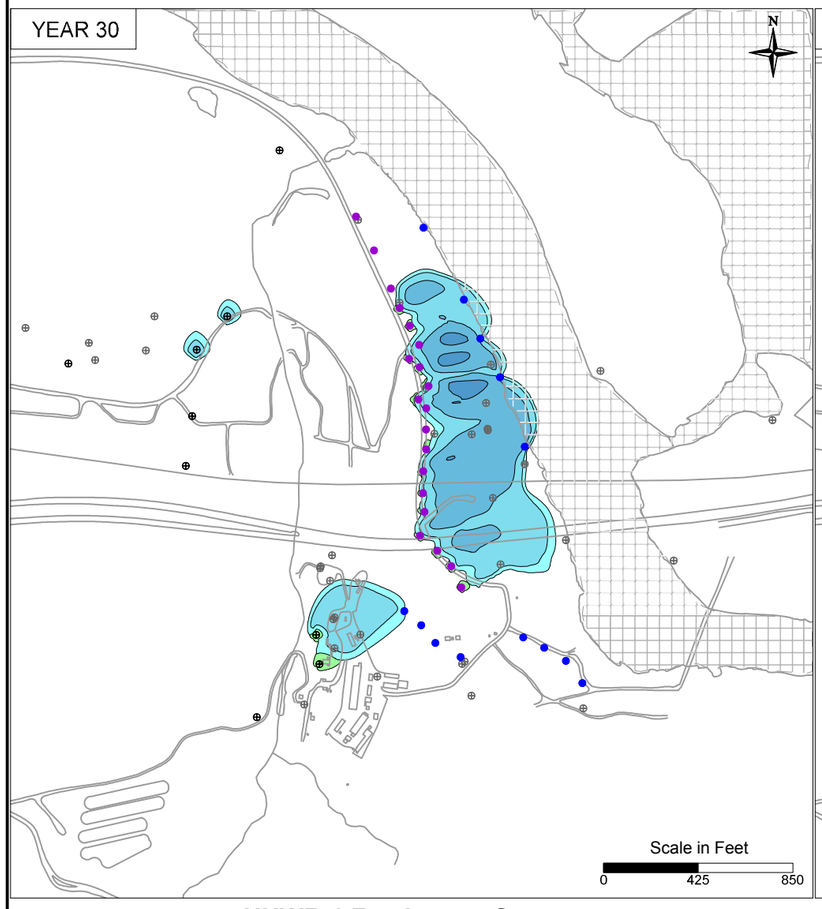
- IRZ WELLS
- UPGRADIENT INJECTION WELLS
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- MONITORING WELLS

PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
MODELING APPENDIX

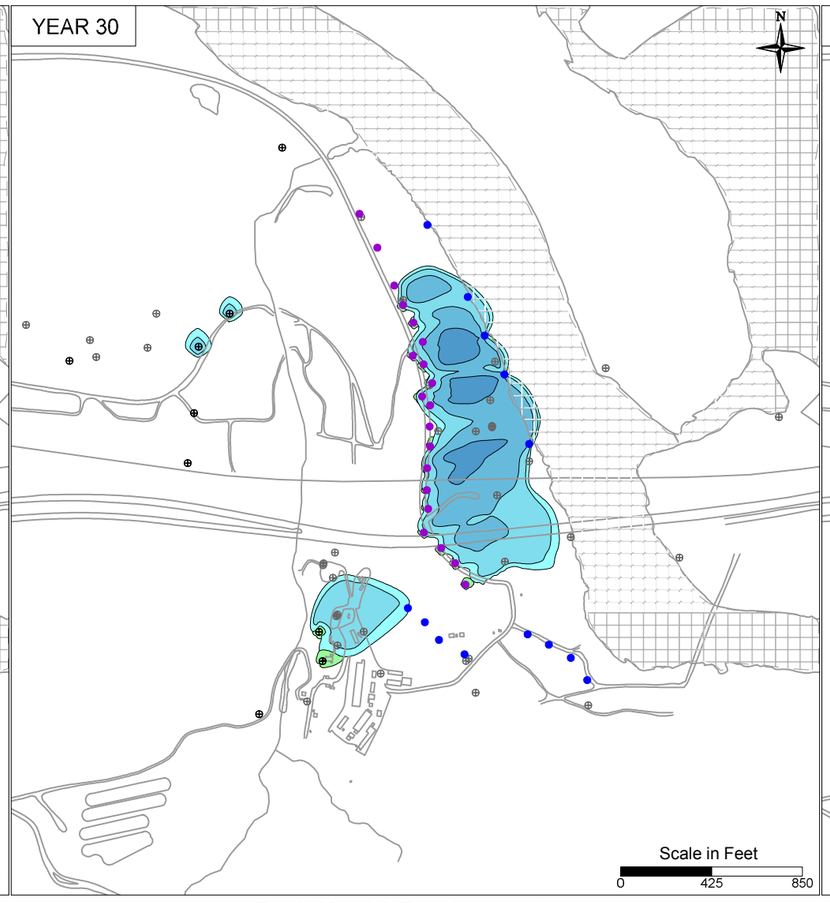
FRESHWATER SOURCE EVALUATION:
30 YEAR SIMULATED MANGANESE BYPRODUCT TRANSPORT RESULTS IN MODEL LAYER 1

ARCADIS

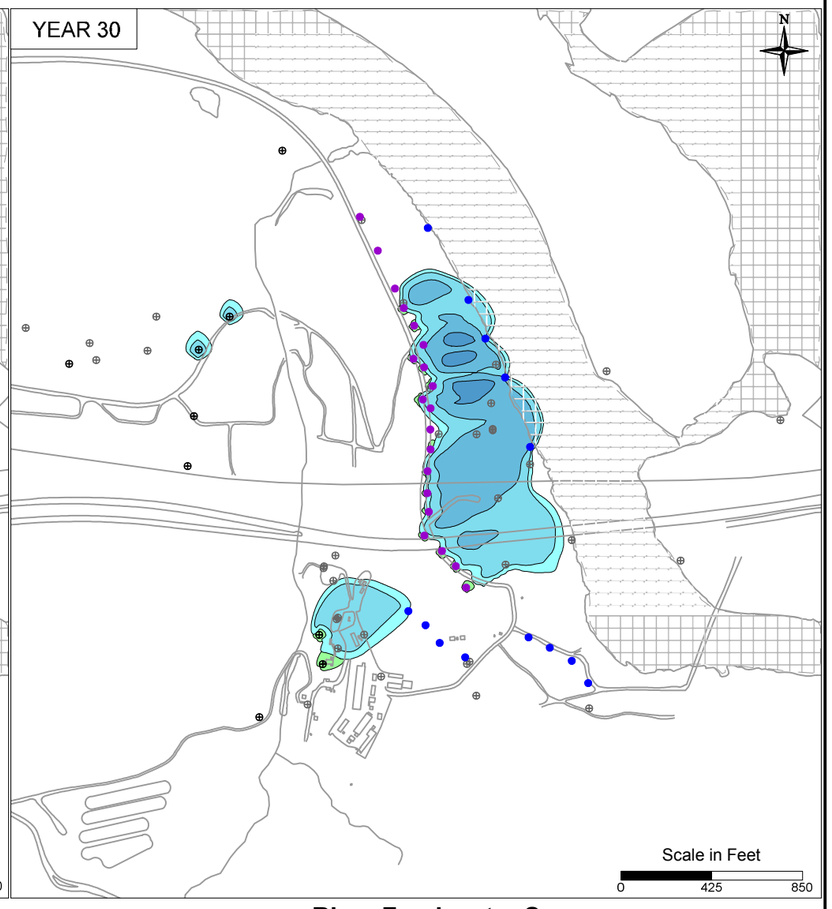
FIGURE
13



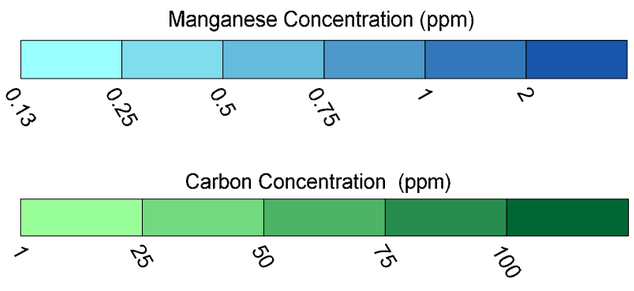
HNWR-1 Freshwater Source



Park Moabi Freshwater Source



River Freshwater Source



LEGEND

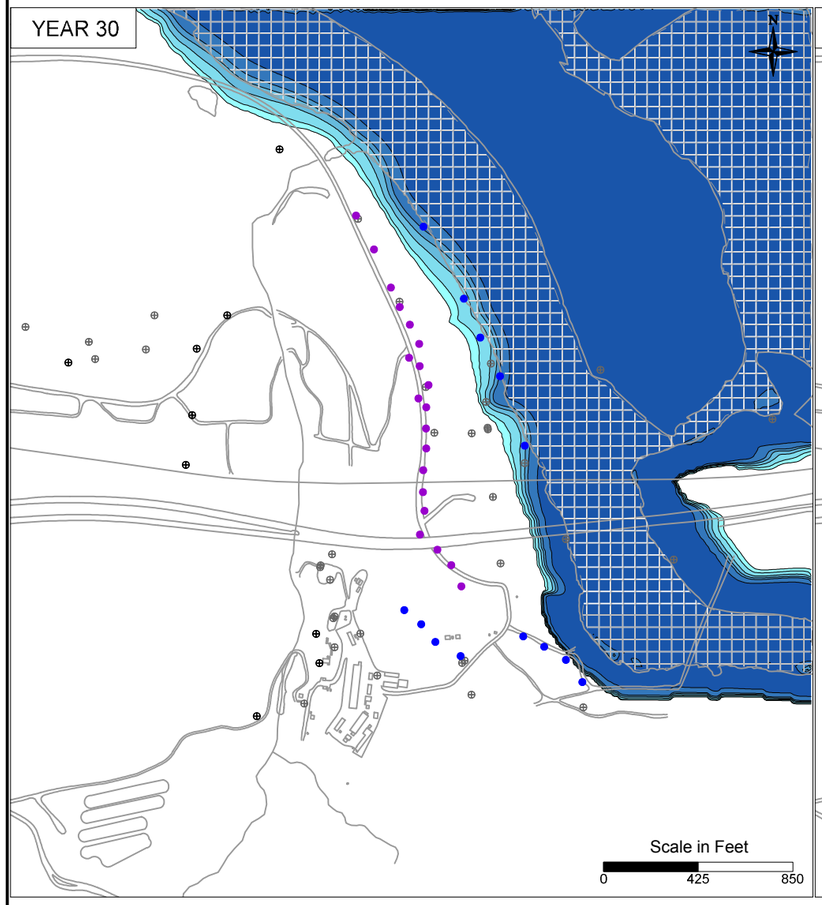
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- UPGRADIENT INJECTION WELLS
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PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
MODELING APPENDIX

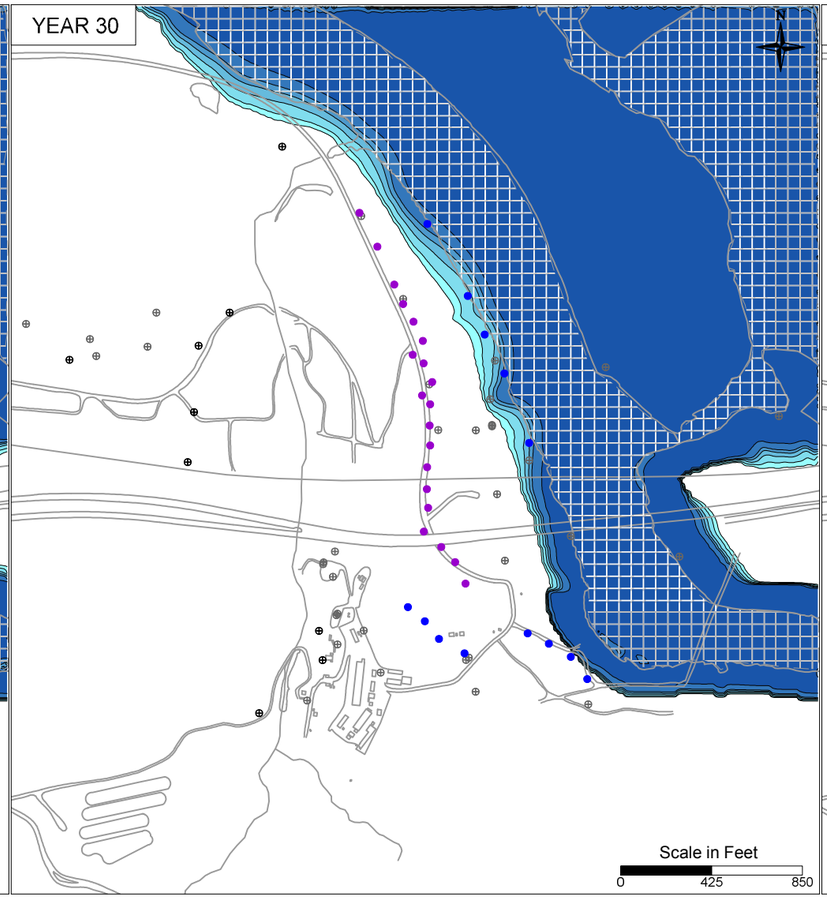
FRESHWATER SOURCE EVALUATION:
30 YEAR SIMULATED MANGANESE BYPRODUCT TRANSPORT RESULTS IN MODEL LAYER 3

ARCADIS

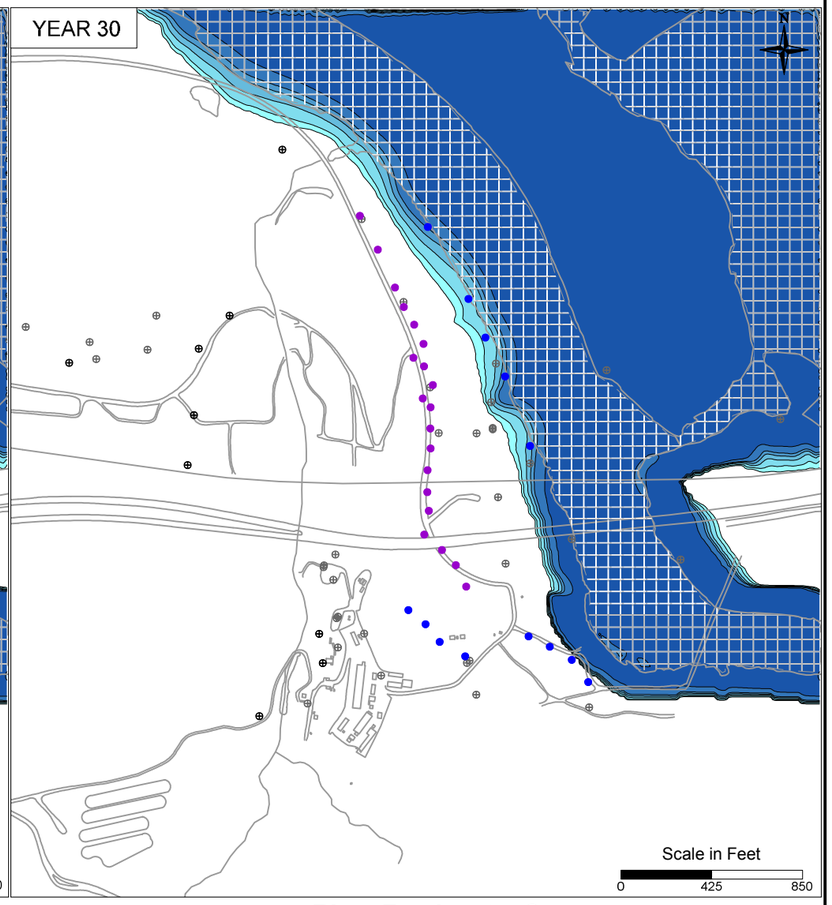
FIGURE
14



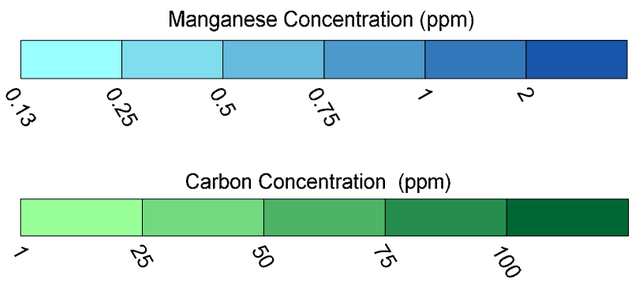
HNWR-1 Freshwater Source



Park Moabi Freshwater Source



River Freshwater Source



LEGEND

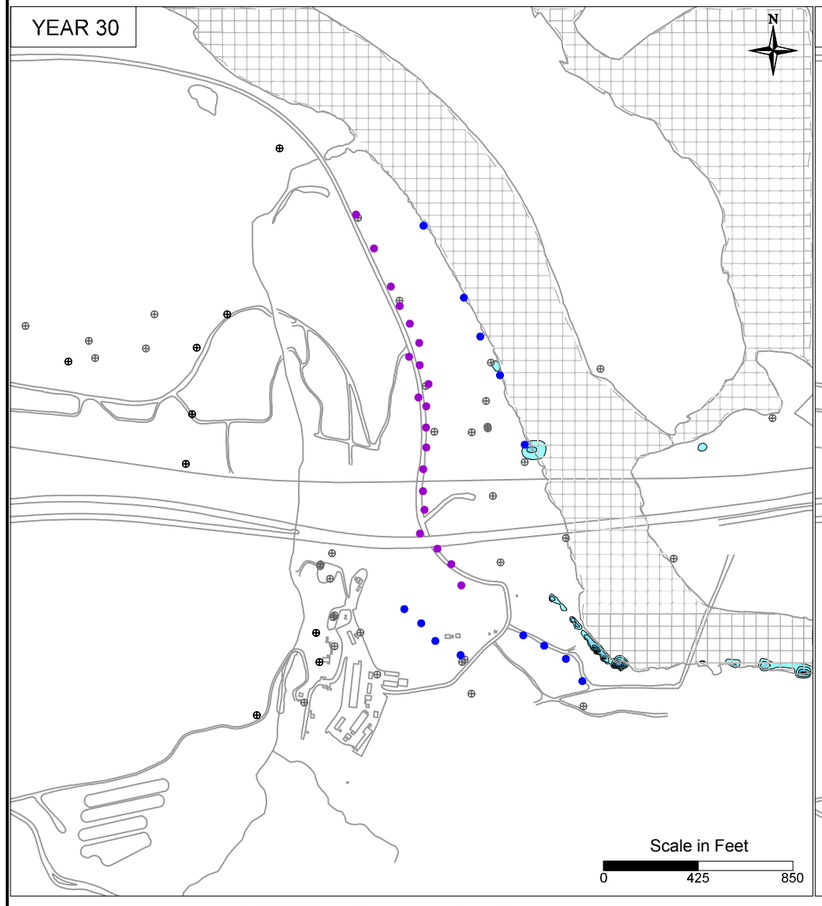
- IRZ WELLS
- UPGRADIENT INJECTION WELLS
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- MONITORING WELLS

PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
MODELING APPENDIX

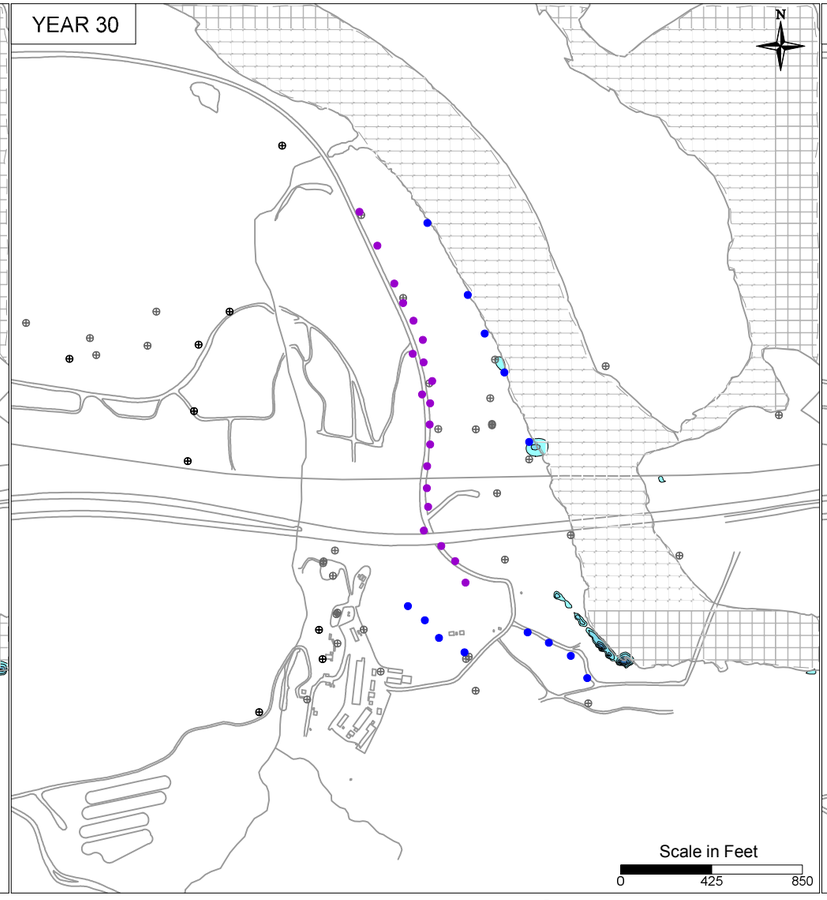
FRESHWATER SOURCE EVALUATION:
30 YEAR SIMULATED MANGANESE RIND
TRANSPORT RESULTS IN MODEL LAYER 1

ARCADIS

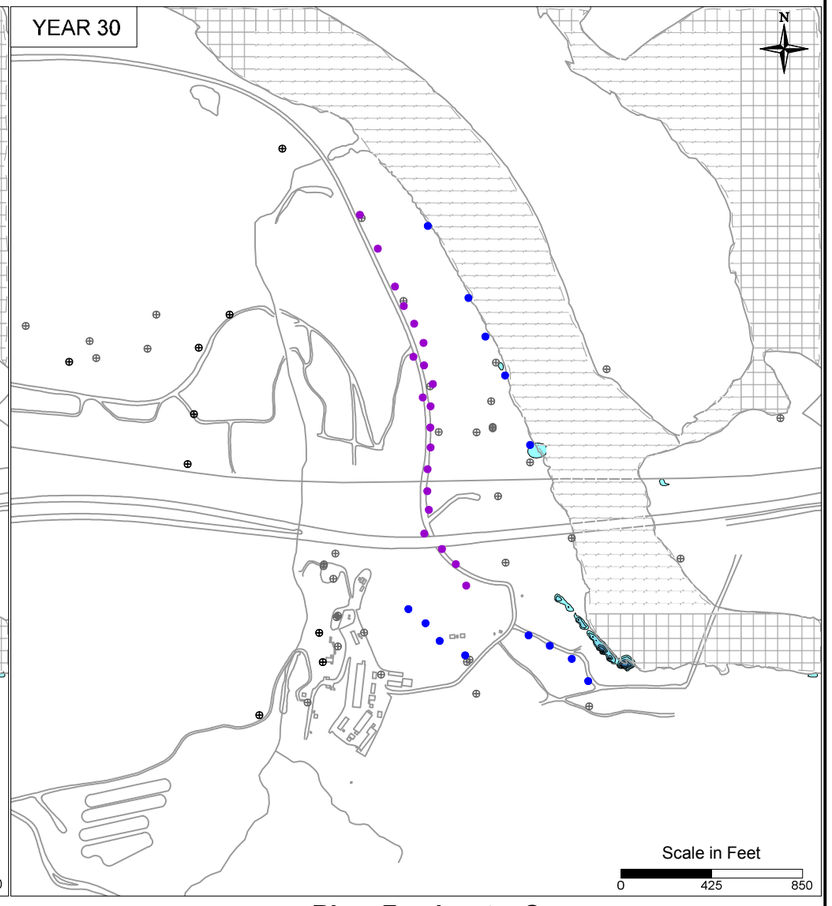
FIGURE
15



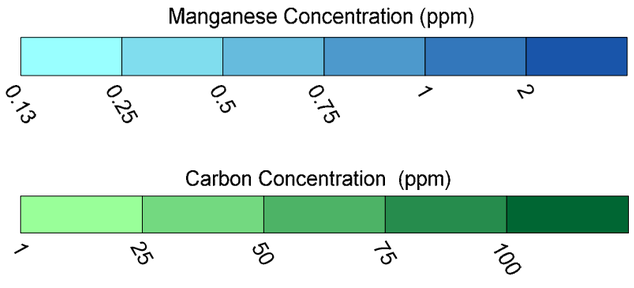
HNWR-1 Freshwater Source



Park Moabi Freshwater Source



River Freshwater Source



LEGEND

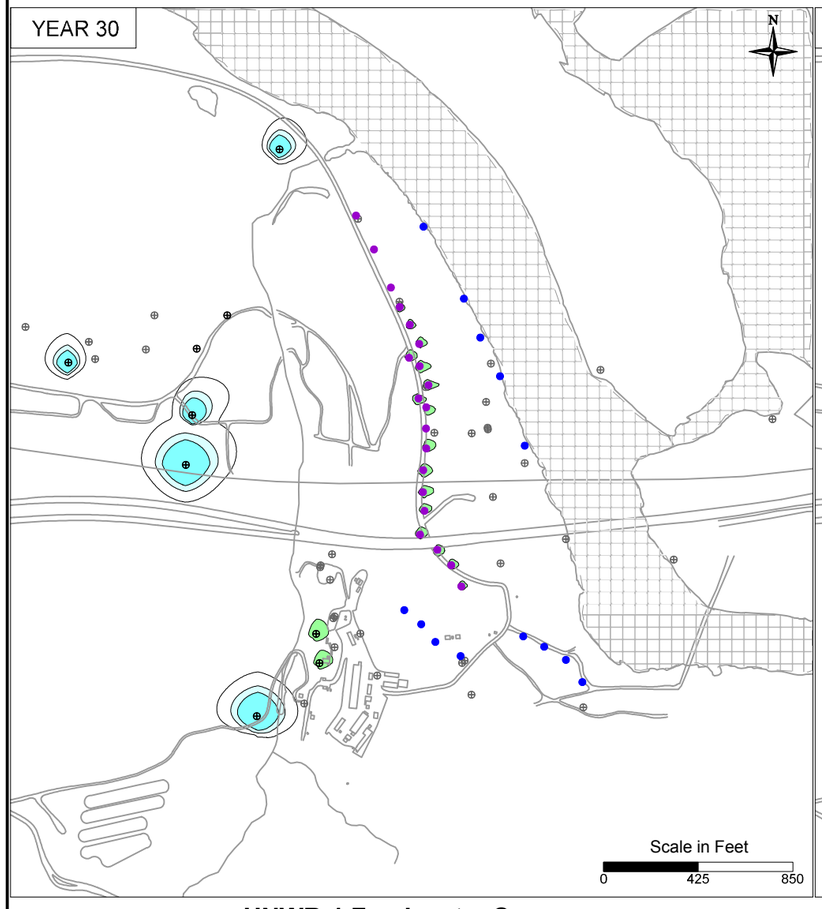
- IRZ WELLS
- UPGRADIENT INJECTION WELLS
- EXTRACTION WELLS
- MONITORING WELLS

PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
MODELING APPENDIX

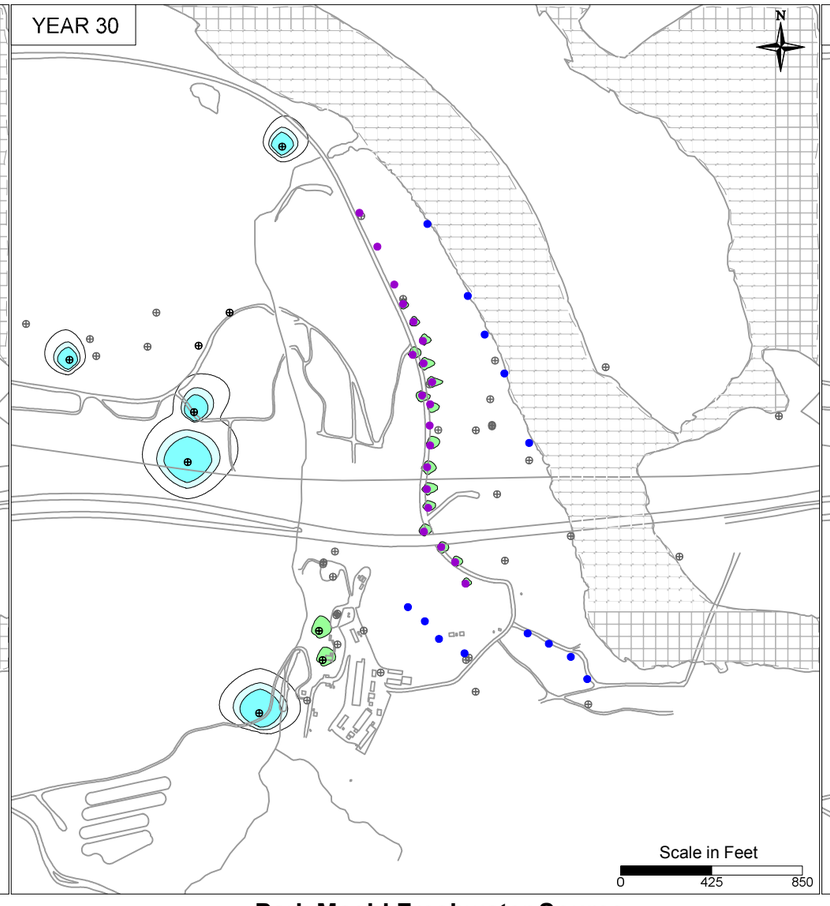
FRESHWATER SOURCE EVALUATION:
30 YEAR SIMULATED MANGANESE RIND
TRANSPORT RESULTS IN MODEL LAYER 3

ARCADIS

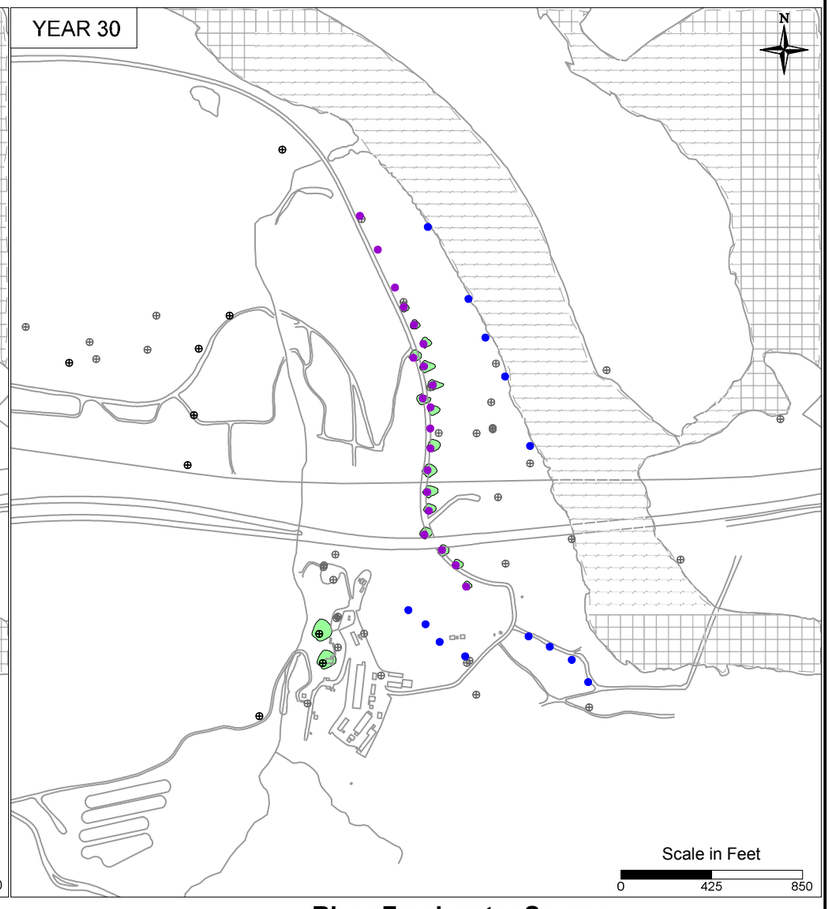
FIGURE
16



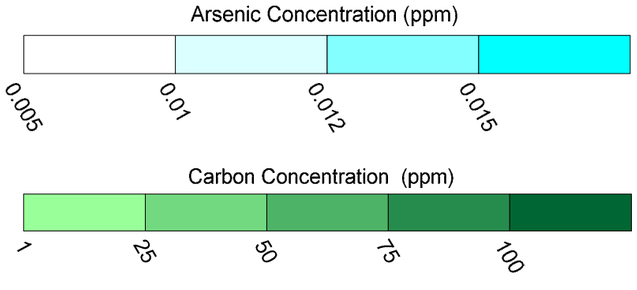
HNWR-1 Freshwater Source



Park Moabi Freshwater Source



River Freshwater Source



LEGEND

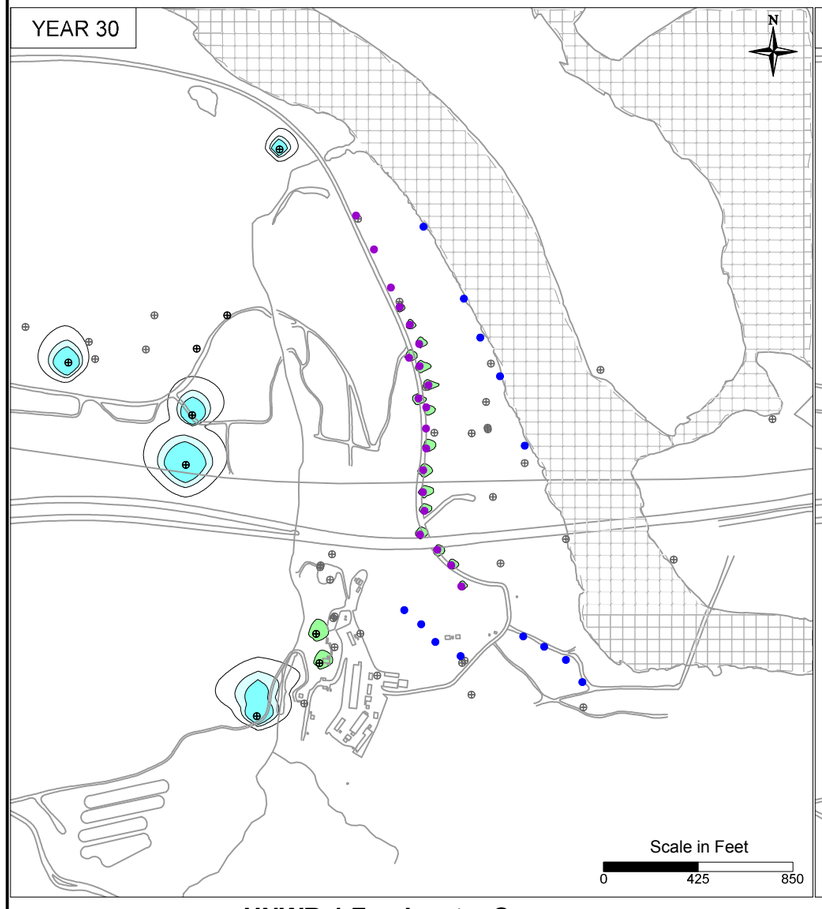
- IRZ WELLS
- UPGRADIENT INJECTION WELLS
- EXTRACTION WELLS
- MONITORING WELLS

PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
MODELING APPENDIX

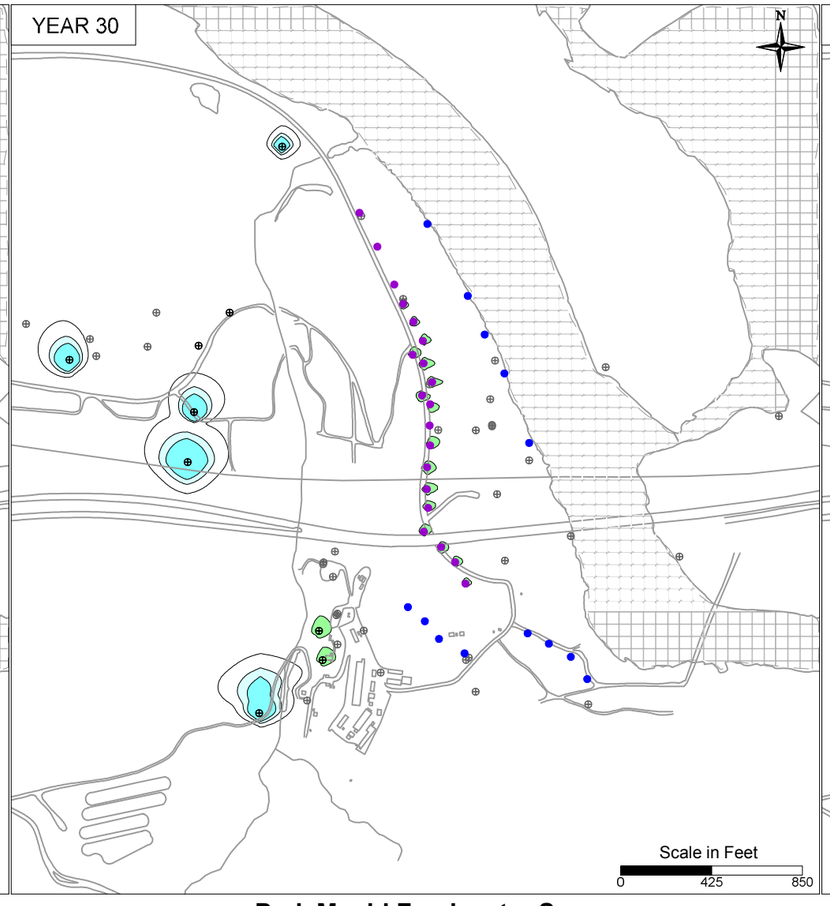
FRESHWATER SOURCE EVALUATION:
30 YEAR SIMULATED ARSENIC
TRANSPORT RESULTS IN MODEL LAYER 1

ARCADIS

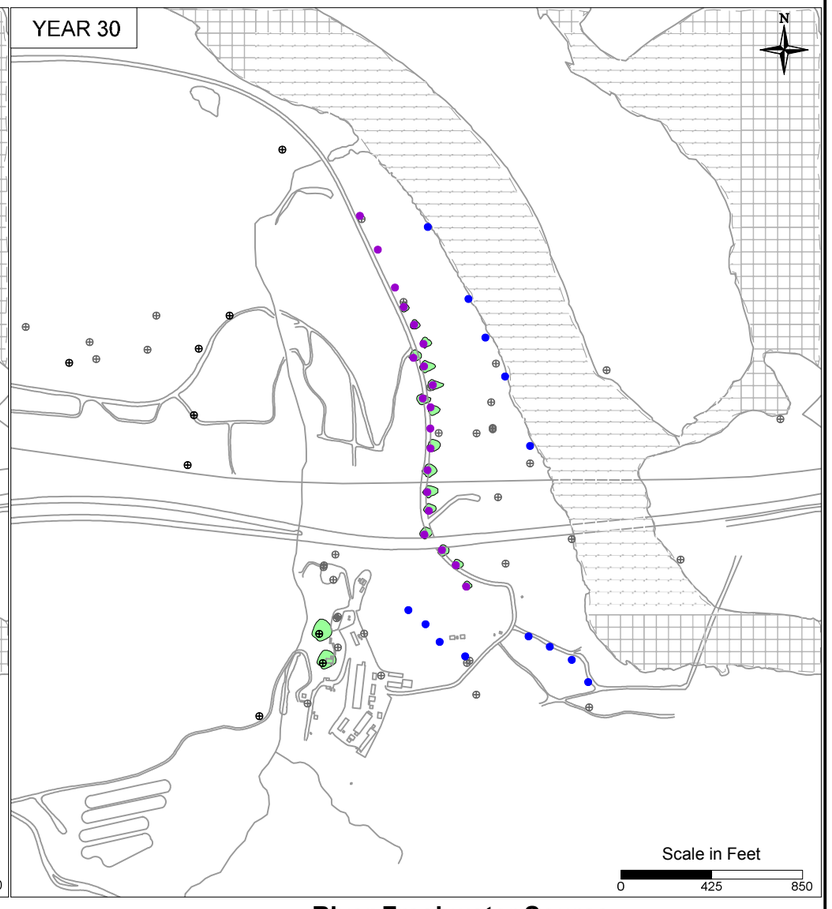
FIGURE
17



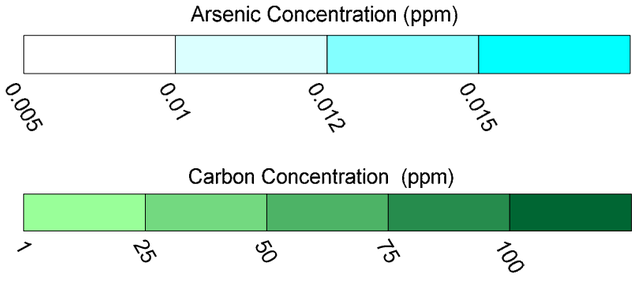
HNWR-1 Freshwater Source



Park Moabi Freshwater Source



River Freshwater Source



LEGEND

- IRZ WELLS
- UPGRADIENT INJECTION WELLS
- EXTRACTION WELLS
- MONITORING WELLS

PG&E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA
MODELING APPENDIX

FRESHWATER SOURCE EVALUATION:
30 YEAR SIMULATED ARSENIC
TRANSPORT RESULTS IN MODEL LAYER 3

ARCADIS

FIGURE
18

Responses to Comments

U.S. Department of the Interior Review Comments on the Freshwater Source Evaluation Technical Memorandum

DOI Review Comments and PG&E Responses

Comment Number	Comment Location (Section/Page/ Paragraph/Sentence)	DOI Comment	PG&E Response
1	General	The Freshwater Source Evaluation Technical Memorandum (FWTM) is responsive to comments #142 DTSC-55 through #153 DTSC-66. It represents considerable additional technical evaluation of the three principal sources for freshwater, and provides a sound basis for PG&E's selection the HNRW-1 well as the source for freshwater for use in the groundwater remedy when considering water quality and quantity, implementability and sustainability, and the influence of freshwater pumping on remedy performance. Additionally, based on the technical review of the modeling, DOI supports the premise that the arsenic in the water from the HNWR-1 well will result in minimal contamination of the aquifer and that the aquifer will return to background concentrations post-remedy.	Comment noted.
2	Section 2.2.1, Page 3, Total Dissolved Solids - 2nd para.	Can PG&E provide the geochemical model simulation performed using the U.S. Geological Survey's (USGS's) PHAST code that shows that less than one percent of the available porosity was blocked by reprecipitation? Also, this information is provided in Section 3.3.1 and is not directly applicable to Section 2.2.1 where the purpose is to only discuss the significance of TDS on aquifer plugging, not the specific analysis for HNRW-1.	The PHAST simulations were performed on a simplified model grid using average site hydraulic parameters, ambient water quality in the vicinity of the proposed injection area, and HNWR-1 water quality for injected water. These simulations are attached to this RTC table.
3	Section 2.2.2, Page 4, Total Dissolved Solids, 1st para.	Within this paragraph, there is discussion about groundwater in the lower portion of the aquifer reaching TDS of 10,000 mg/L. It also discusses low TDS in the upper portion. If the injection wells (UPGRAD-INJ-1 thru 4) are to receive both fresh water injection and carbon-amended floodplain water for reinjection, is it true that these wells can then only be screened in layers 3 and 4?	The injection wells need to be screened in all layers in order to effectively flush the plume through the IRZ. Water from the floodplain is currently planned to be delivered only to IRL-1 and IRL-2 (formerly UPGRAD-INJ-1 and 2); however, the design of all the injection wells will include screen throughout the saturated thickness of the aquifer.
4	Section 2.2.2, Page 5, Constituents Introduced Above Site Background …, 1st para.	There are no examples of the constituents that do not attenuate after the end of remediation. Does this pertain to emerging contaminants as covered in the next section?	Correct, this pertains to the emerging contaminants covered in the tech memo.

DOI Review Comments and PG&E Responses

Comment Number	Comment Location (Section/Page/ Paragraph/Sentence)	DOI Comment	PG&E Response
5	Section 3.1.1	As stated in the Technical Memo, groundwater extracted from HNWR-1 could be recharged from a number of different sources including the Colorado River. There is the potential that dissolved organic carbon (DOC) could be drawn into the aquifer supplying groundwater to HNWR-1. One scenario is that reactive DOC in groundwater causes reductive dissolution of iron and manganese oxides on aquifer sediment, resulting in an increase in the concentrations of Fe(II) and Mn(II). As(V) associated with these oxides could be released to solution and possibly reduced to As(III). If such a scenario occurs, groundwater from HNWR-1 injected into the upland aquifer could have greater concentrations of Fe(II), Mn(II), and As(III) or As(V) than were modeled for the Technical Memo. In addition, any DOC that has not reacted with aquifer sediment could be introduced into the upland aquifer. Because of the oxidizing nature of the upland aquifer, reoxidation of Fe(II) and precipitation iron oxides should provide additional sorption sites for any potential increase in As concentrations. The potential consequences of increased DOC in groundwater in the vicinity of HNWR-1 need to be discussed.	Although river water has been being pulled into the floodplain since 2005 in response to IM-3 pumping, the effects postulated in this comment have not yet been observed. It is possible that this could occur at HNWR-1 due to the higher pumping rate and likely different hydrogeologic conditions on the Arizona side of the river. Iron and manganese cause plugging in injection wells, even in relatively small concentrations. Any significant concentrations of iron and manganese in water from HNWR-1 would likely result in increased maintenance to the injection wells. Dissolved organic carbon (DOC) could also contribute directly to well plugging if it is in a form that can be readily metabolized by microbes. Frequent automatic backwashing of injection wells (included in 60% design) may be effective in preventing well plugging. However, depending on the concentrations of DOC and its form, additional treatment would likely be necessary to remove DOC prior to injection.
6	Section 3.1.1, Page 7, 1st para.	The conclusion should also mention that injected water withdrawn from wells at Park Moabi will likely be drawn back to Park Moabi by the end of the active remedial action.	This discussion was included in the discussion of freshwater supply in Exhibit 3.3-1 (Evaluation Criteria #1) of the 60% design document.

DOI Review Comments and PG&E Responses

Comment Number	Comment Location (Section/Page/ Paragraph/Sentence)	DOI Comment	PG&E Response
7	Section 3.3.1, and Attachment C, Page 3	Phreeqc simulations of arsenic mobility in the upland aquifer were conducted by adding As(V), at concentrations measured in groundwater from HNWR-1, to groundwater of the composition measured in the upland aquifer. The rationale for ignoring HNWR-1 groundwater chemistry should be explained. For example, is the volume of groundwater from HNWR-1 injected into the upland aquifer small enough so as not to alter the chemistry of the upland groundwater? Are the chemistries of both groundwaters similar?	Comment noted. The groundwater chemistry within the freshwater injection zone was used in the PHREEQC model because it was assumed that this chemistry will be most important in determining the long-term stability of adsorbed arsenate. After injection, and after the freshwater flows away from the injection point, the arsenic concentration in solution will be governed by equilibrium between sorbed arsenate and the native groundwater. Further, the average alkalinity and pH, two of the most important controlling factors for arsenate adsorption, are not substantially different between HNWR-1 and background alluvial groundwater. Although the TDS of HNWR-1 water is lower than in the native groundwater, the TDS of the injected water may increase slightly due to ion exchange and mineral dissolution. In addition, the effects of TDS on arsenate adsorption can be subtle and tend to partially cancel out (e.g., whereas ions may compete for arsenic sorption sites, adsorbed positively-charged ions can enhance the attraction of arsenate). PHREEQC tests using HNWR-1 chemistry and native groundwater chemistry suggest that differences in sorption are minimal. Note that as directed by DTSC on December 31, 2012, PG&E included a pre-injection treatment system in this 60% design. The decision by the State Water Resources Control Board (SWRCB) is anticipated to guide further direction from DTSC regarding the ultimate use of the freshwater source and what level of treatment if any will be required for various constituents. As such guidance is still forthcoming, in this 60% design BOD PG&E has made the conservative assumption for freshwater pre-injection treatment goals, specifically that the arsenic treatment goal is to reduce concentrations to below the federal/state Maximum Contaminant Level (MCL) of 10 micrograms per liter (µg/L) and that the fluoride treatment goal is concentrations below the state MCL of 2 milligrams per liter (mg/L). Therefore, as the freshwater source will be treated for arsenic, the fate and transport of naturally occurring arsenic associated with freshwater injection is no longer applicable and has been removed from the 60% design.

DOI Review Comments and PG&E Responses

Comment Number	Comment Location (Section/Page/ Paragraph/Sentence)	DOI Comment	PG&E Response
8	Section 3.3.1, Page 12, 2nd full para.	The Technical Memo states that amorphous iron oxide having sorption properties measured by Dzombak and Morel (1990) where used to define the concentration of sorption sites in the upland aquifer. Amorphous iron oxide is usually associated with iron oxides that have precipitated more recently. Over time, amorphous iron oxides tend to recrystallize forming iron oxide minerals such as goethite which can have different sorption characteristics than amorphous iron oxides. The evidence for using amorphous iron oxides as the adsorbent for arsenic needs to be discussed.	The concentration of sorption sites was estimated using measured amorphous iron oxide concentrations in aerobic core study samples (CH2M HILL 2005a, as referenced in this TM), along with published properties of adsorption sites per unit mass of amorphous iron oxides. The method of measurement referenced from the Aerobic Core Study was Dithionite-Citrate-Bicarbonate, which selectively measures amorphous iron (as opposed to crystalline forms such as goethite).
9	Section 3.3.1, Page 12, 2nd full para.	State the thermodynamic database used in the Phreeqc modeling (Wateq4f).	Wateq4f was not the database used in the PHREEQC modeling. The default PHREEQC thermodynamic database was used in geochemical calculations (Parkhurst and Appelo 1999 as cited in the TM), supplemented with parameters for arsenate adsorption on iron oxides obtained from Dzombak and Morel (1990). Note that as directed by DTSC on December 31, 2012, PG&E included a pre-injection treatment system in this 60% design. The decision by the SWRCB is anticipated to guide further direction from DTSC regarding the ultimate use of the fresh water source and what level of treatment if any will be required for various constituents. As such guidance is still forthcoming, in this 60% design BOD PG&E has made the conservative assumption for freshwater pre-injection treatment goals, specifically that the arsenic treatment goal is to reduce concentrations below the federal/state MCL of 10 µg/L and that the fluoride treatment goal is concentrations below the state MCL of 2 mg/L. Therefore, as the freshwater source will be treated for arsenic, the fate and transport of naturally occurring arsenic associated with freshwater injection is no longer applicable and has been removed from the 60% design.
10	Section 3.3.1, Page 12, last full para.	The oxidation state of arsenic used in the Phreeqc modeling needs to be stated. Under oxidizing conditions, arsenic +5 [As(V)] is stable; under reducing conditions, arsenic +3 [As(III)] is stable. Each oxidation state of arsenic has different sorption characteristics. A brief explanation of the HNWR-1 modeling results would be useful. For example, 'groundwater from HNWR-1 is oxidizing as indicated by the presence of dissolved oxygen. Phreeqc modeling of groundwater chemistry from HNWR-1 indicates that As(V) is the stable oxidation state of arsenic.'	The oxidation state of arsenic was not specified for the input to PHREEQC. The program uses the specified redox characteristics of the system to calculate the proportions of As(V) and As(III). In the environment surrounding the injection wells (and in HNWR-1), the As is predominantly As(V). The PHREEQC database contains separate adsorption criteria for each oxidation state of arsenic.

DOI Review Comments and PG&E Responses

Comment Number	Comment Location (Section/Page/ Paragraph/Sentence)	DOI Comment	PG&E Response
11	Section 3.3.1, Page 12, last full para.	The explanation regarding the stability of dissolved arsenic is adequate but it is not apparent that a simple model of a complex hydrogeologic system could explain difference in arsenic concentrations that only range approximately a factor of 2 or 3 and are at very low levels. As stated in discussions, groundwater monitoring is needed to determine the fate of As in the uplands and to determine the appropriate corrective action as deemed necessary.	As directed by DTSC on December 31, 2012, PG&E included a pre-injection treatment system in this 60% design. A monitoring plan is also included in Volume 2 of the Draft O&M Manual. As previously mentioned, the decision by the SWRCB is anticipated to guide further direction from DTSC regarding the ultimate use of the fresh water source and what level of treatment if any will be required for various constituents. The freshwater source details will be included in an addendum to this 60% design, after such requirements are determined and completion of planned source water studies.
12	Section 3.3.1, Page 13, 2nd complete para.	Arsenic in well TLMP-2 is relatively low and it is in the geothermal groundwater. Simply based on the distribution of arsenic concentrations, it appears that something in the hydrogeologic environment from HNWR-1 to PGE-95 is causing arsenic concentrations to be higher than elsewhere on the Arizona or California side of the river. It may be related to geothermal water, but it seems apparent that some other factor(s) is causing the high arsenic concentrations.	Agreed. It is not clear exactly what factors contribute to the elevated arsenic concentrations in the area near HNWR-1 and PGE-9S.
13	Section 3.3.1, Page 14, 3rd complete para.	This new assessment of the limited amount of water sourced from the Sacramento Wash is a significant finding of this TM and implies likely changes to the TDS of the water being withdrawn overtime, particularly since there are shallow high TDS environments nearby (MW-54-85). A backup plan (as suggested) for additional wells to the north should be developed. One of the potential considerations regarding the long term pumping of the HNWR-1 well is that arsenic concentrations could be reduced over time as drawdown pulls from areas of less geothermal activity. If an addition pump test is planned, it is recommended that As be sampled both before and after pumping.	A contingency well site has been identified north of HNWR-1 and is shown and discussed in Section 3.3.2 of the 60% design. A long-term pump test is being planned for HNWR-1 (as part of the Alternative Freshwater Source Evaluation Implementation Plan, currently under review by DTSC and DOI) that will include sampling for As and other constituents prior to and throughout the pumping period to look for any trends in arsenic and other constituents.
14	Section 3.3.1, Page 17, 1st bullet	Manganese dioxide implies a greensand filter which is used to oxidize iron and arsenic causing precipitation and removal. However, iron and arsenic has been oxidized already. It appears it is being used for its adsorption capacity.	Manganese dioxide media has higher adsorptive capacity and is a very durable media.

DOI Review Comments and PG&E Responses

Comment Number	Comment Location (Section/Page/ Paragraph/Sentence)	DOI Comment	PG&E Response
15	Section 3.3.1, Page 19	It is assumed that the treatment of all the HNWR-1 water was considered in the estimate of the facility size. If blending of HNWR-1 treated water and untreated water were considered, couldn't the facility size be reduced?	Correct, the size of the arsenic treatment system depicted in the Tech Memo was based on assumptions regarding influent arsenic concentration (15 µg/L), treatment process (capable of achieving 5 µg/L), and effluent arsenic concentration (5 µg/L to provide a factor of safety below the MCL). There would be no size reduction since blending water with 15 µg/L arsenic with treated water with 5 µg/L arsenic to achieve effluent of 5 µg/L arsenic, would require treatment of all water. A bench-scale test is currently being conducted to optimize system processes/design which might result in a smaller overall footprint. Results from the bench-scale were incorporated into the 60% design (see the Freshwater Pre-Injection Treatment System Design Basis Technical Memorandum included in Appendix M of this 60% BOD). Additional information from the ongoing testing will be included in the addendum of the 60% design.
16	Section 3.3.2, Pages 20-21	No data is included for arsenic for the California well(s). Data, if available, should be provided for the California well(s) for comparison.	Arsenic data for California wells PM-03 and PM-04 were included in Tables 3-4 and 3-5 of the Freshwater Source Evaluation Technical Memorandum, respectively.
17	Section 3.4.1, Page 27, Initial Design	Management of Quagga Muscles should be included as a consideration for river water intake structures.	Approaches to prevent quagga mussel attachment or growth fall into two categories, non-chemical and chemical control. Typically, several control approaches are implemented together as part of an overall control strategy based on a host of design criteria. Example control approaches are: • Removal/cleaning/replacement of screen • Physical removal • Filtration • Chemical treatment • Application of either an anti-fouling or biocide coating In summary, quagga mussel management will have additional impacts to the infrastructure required (e.g., footprint size, pre-treatment, and intake structure design) as well as O&M of the fish screen (e.g., recoating, chemical delivery and storage, and additional process piping and pumping). A more detailed analysis would be required to find the optimum control strategy.

DOI Review Comments and PG&E Responses

Comment Number	Comment Location (Section/Page/ Paragraph/Sentence)	DOI Comment	PG&E Response
18	Exhibit 3-11, Contingency Matrix, Page 37, Item 4.	If arsenic is more mobile than expected in the upland aquifer, another possible contingency measure would be *in situ* treatment of arsenic. Iron could be added to the injected groundwater, thereby increasing the number of sorption sites in the aquifer. Fe(II) added to the aquifer would be oxidized by dissolved oxygen in groundwater resulting in precipitation of amorphous iron oxide. Fe(II) would likely disperse into the aquifer before oxidation and precipitation minimizing any change in permeability. Fe(III) could also be added; however, there is the potential problem of more rapid precipitation near the well screen causing decreased permeability.	As reported in the Freshwater Tech Memo, PG&E reviewed a pilot test of in-situ arsenic treatment involving ferric iron. The process required considerable above-ground treatment infrastructure and the wells in this pilot test plugged in a matter of hours. It is possible that an in-situ arsenic treatment scheme could be made to work, but it would likely require a pilot scale test to develop the technology prior to full scale application. As directed by DTSC on December 31, 2012, PG&E included a pre-injection treatment system in this 60% design. The decision by the SWRCB is anticipated to guide further direction from DTSC regarding the ultimate use of the fresh water source and what level of treatment if any will be required for various constituents. The freshwater source details will be included in an addendum to this 60% design, after such requirements are determined and completion of planned source water studies.

California Department of Toxic Substances Control Review Comments on the Freshwater Source Evaluation Technical Memorandum

DTSC Comments and PG&E Responses

Comment Number	Comment Location (Section/Paragraph/ Page)	DTSC Comment	PG&E Response
1	General Comment regarding arsenic in HNWR-1	Based on California State Water Resources Control Board's anti-degradation policy, discharge of arsenic from Arizona above the background for the receiving water body will require a Waste Discharge Requirement. Currently this issue is being discussed by the agencies and PG&E. DTSC understands that PG&E can consider in-situ or ex-situ arsenic pre-treatment prior to injection with technologies discussed in the Tech Memo. However, PG&E should recognize such action to be a disadvantage in the use of the HNWR-1. Currently, PG&E concludes that pre-treatment is not necessary; therefore, it is an advantage for the use of HNWR-1. Another disadvantage to the use of the HNWR-1 is that modeling indicates, at a minimum, an additional 12 years would be necessary for the injected arsenic concentration to significantly attenuate. This adds time to the remedy to be completed. Additional monitoring infrastructure would also be required and for a longer period of time to adequately monitor for arsenic. Finally, if arsenic does not behave as modeled, a potential exists for a separate action to cleanup arsenic around the injection areas. Impacts associated with importing arsenic bearing water from HNWR-1 have been modeled based on preliminary assumptions. It might become necessary to increase HNWR-1 injection rates into the upland areas to contain the plume. If so, would there be additional impact associated with the imported arsenic? Similarly, it may be necessary to install additional injections wells to ensure contaminated groundwater does not improperly migrate to the west or north. This would also result in a larger arsenic contaminant footprint. Finally, it may be advantages to increase flow HNWR-1 flow rates to increase cleanup time. While HNWR-1 contains arsenic above regulatory criteria, it will continuously burden remedy decisions now and in the future.	The well network being designed for monitoring water quality near the injection wells during the active phase of the remedy will be adequate for monitoring arsenic following cessation of injection. If the arsenic behaves as expected and does not migrate more than a few hundred feet from the injection wells during the active phase of the remedy, there is no reason to think it would migrate further after the injection stops. Therefore, the post injection monitoring would likely consist of sampling the inactive injection wells and possibly a few nearby monitor wells to confirm that arsenic is not moving and concentrations are declining. It will not require any additional infrastructure and will likely only require a minimal amount of monitoring. As directed by DTSC on December 31, 2012, PG&E included a pre-injection treatment system in this 60% design. The decision by the SWRCB is anticipated to guide further direction from DTSC regarding the ultimate use of the fresh water source and what level of treatment if any will be required for various constituents. The freshwater source details will be included in an addendum to this 60% design, after such requirements are determined and completion of planned source water studies.
2	2.1 Water Quantity, Page 2	The section states, "*If the aquifer is more transmissive than anticipated in these areas, additional fresh water would be needed to create the gradient necessary for remedy operation. On the other hand, if the aquifer is less transmissive than anticipated, less water would be needed."* The process for changing the injection rate should be include in the Operations and Maintenance Plan and must allow for communication with agencies and approval.	The injection wells will be tested after installation and if hydraulic properties are different than anticipated, additional model simulations will be conducted to evaluate the effect on the design. This process is described in Section 3.3.3.4 of the 60% BOD.

DTSC Comments and PG&E Responses

Comment Number	Comment Location (Section/Paragraph/ Page)	DTSC Comment	PG&E Response
3	2.2.1 Prevention of Well and Aquifer Plugging, Total Dissolved Solids, Page 3	Aquifer plugging occurring at the IM-3 injection well(s) must be discussed as it is a site specific example of aquifer plugging that occurs within the exact area of the remedy. Such site specific knowledge cannot be overlooked. The mechanism(s) for clogging in IM-3 wells should be discussed and compared to model runs. Does the model perform adequately when compared to plugging/reduced well efficiency at IM-3 injection wells?	Reduced performance of IM-3 injection wells has been observed periodically over the last several years. The incrustation on the well screens has been identified as a thin layer of manganese oxide, and thermodynamic calculations using PHREEQC have identified manganese mineral phases that are at or above saturation in the injection water. The precipitation kinetics for these compounds are varied, making it difficult to precisely predict how quickly and how much manganese will precipitate, but observations indicate that production drops when manganese is above 10 µg/L in the injection water. A manganese impurity in the ferrous chloride used by the treatment plant is suspected to be the source of manganese causing the precipitation. Due to uncertainty in the kinetics of manganese precipitation and lack of sufficient data on the concentrations of manganese in the effluent during much of the IM-3 operational history, modeling of the IM-3 well plugging due to manganese would not provide any additional confidence in the geochemical model. The desired water quality goal for manganese included in the freshwater tech memo (<10 µg/L) is based on recent experience with well plugging during operation of the IM-3 wells. It has been observed that the IM-3 wells perform much better when Mn concentrations in the injected water are <10 µg/L. Thus, the site specific IM-3 experience has been incorporated into the Freshwater Tech Memo.
4	2.2.1 Prevention of Well and Aquifer Plugging, Dissolved Organic Carbon Solids, Page 3/4	PG&E states that "*the average dissolved organic carbon content in the Colorado River near* *Topock is 9 mg/L. While this is considered low for a surface water source, it is considerably higher than the groundwater sources being considered and might be enough carbon to contribute to injection well fouling*." Can river water be tested now to determine if treatment to prevent well fouling is needed? Does data already exist in MWD databases for a proper assessment?	There are no existing data to support an evaluation of the plugging potential the dissolved carbon in the river water. Laboratory microcosm tests could be conducted at any time to evaluate the bio-availability of the dissolved carbon in the river. A microcosm test would provide a basis from which to estimate plugging potential, but might not provide definitive results about the need for a treatment plant. A pilot test using an injection well at the Topock site would be the best means of evaluating plugging potential of organic carbon in river water.

DTSC Comments and PG&E Responses

Comment Number	Comment Location (Section/Paragraph/ Page)	DTSC Comment	PG&E Response
5	2.2.2 Protection of Aquifer Water Quality, Page 4	According to the RWQCB anti-degradation policy (State Water Resources Control Board Resolution No. 68-16), injection of arsenic above MCL outside of the current plume into a receiving body that has lower concentration would not meet ARAR for anti-degradation. Although PG&E is still evaluating this matter, a potential for schedule delay exists if a pre-treatment system would prove to be necessary. To avoid a potential significant schedule delay, it is recommended that PG&E include the location and design of this hypothetical arsenic pre-treatment system in the 60% Design as it may be required to comply with RWQCB requirements. The section states, "During the Topock Background Study, arsenic concentrations above the MCL were found in water supply wells in the vicinity of the Topock Marina, Arizona." Figure 3-6 of the Tech Memo includes an arsenic concentration map developed from the background study. It unfortunately indicates that the Arizona well is located in an area of some of the highest arsenic concentrations in the entire region.	As directed by DTSC on December 31, 2012, PG&E included a pre-injection treatment system in this 60% design. The decision by the SWRCB is anticipated to guide further direction from DTSC regarding the ultimate use of the fresh water source and what level of treatment if any will be required for various constituents. The freshwater source details will be included in an addendum to this 60% design, after such requirements are determined and completion of planned source water studies.

DTSC Comments and PG&E Responses

Comment Number	Comment Location (Section/Paragraph/ Page)	DTSC Comment	PG&E Response
6	2.2.2 Protection of Aquifer Water Quality, Constituents Introduced Above Site Background or Above Water Quality Standards that Do Not Attenuate After the End of Remediation, Page 5,	The section states, "*As discussed above, modeling indicates that arsenic concentrations that may temporarily be elevated by injection of HNWR-1 well water (with naturally occurring arsenic level of 15µg/L, which is below site background of 24.3µg/L but above the MCL of 10µg/L) will attenuate under site conditions and return to pre-remedy baseline levels after the end of remediation (see Figures 3-9 through 3-12). Monitoring will be performed during remedy implementation to verify the above modeling results, and appropriate adjustments will be made to remedy operations as needed.*" This paragraph does not portray arsenic issues in an appropriate light. Arsenic modeling results pictured in Figure 3-12 yields, upon close examination, that elevated arsenic concentrations, including values above the MCL, will still persist at least 12 years after the outboard injection of water ceases. Therefore, it must take even longer for arsenic levels to revert to pre-remedy, baseline conditions. See other arsenic comments regarding RWQCB's anti-degradation policy; long term arsenic persistence and, therefore, long term monitoring requirements. Furthermore, the 24.3 µg/L arsenic value cited in the paragraph is a regional value and not site specific. DTSC commented on this very issue during development of the background study report. PG&E needs to site language from the 2009 background study report acknowledging limitations with the regional values. The next paragraph states, "*It should be noted that naturally occurring chromium (VI) in the fresh water used for injection will be at concentrations at or below the site background of 32µg/L. Any residual Cr(VI) introduced with the fresh water is expected to be persistent in the aerobic portions of the aquifer, but would continue to be attenuated in the natural reducing conditions in fluvial sediments adjacent to and beneath the river after the remedial action is complete."* Again, PG&E should acknowledge that the 32µg/L chromium value is a regional value. Chromium concentrations in the freshwater injection areas decrease to non-detects with depth. Therefore, any chromium introduced into the lower portions of the aquifer is providing an additional flux of hexavalent chromium above baseline conditions. Again, PG&E needs to site language from the 2009 background study report acknowledging limitations with the regional values (i.e., depth).	As stated in the technical memorandum, monitoring for arsenic will be performed during remedy implementation to verify the fate and transport modeling results, and appropriate adjustments will be made to remedy operations as needed. The Topock groundwater background study commenced in 2004 with an approved work plan and ended in 2009. This step-wise (Steps 1 through 4), multi-year study was conducted with interaction and approvals from DTSC (early years), and DTSC/DOI (later years) at every step. In January 2008, at the direction of DTSC, PG&E presented discussions of the following three topics (see attached cover letter to the January 2008 revised background study report): • Future Uses of the Groundwater Background Study Results • Potential Limitations for Use of the Groundwater Background Study • Rationale for a Single (rather than Multiple) Background Concentrations for the Topock Groundwater Study In this 2008 letter, PG&E presented the basis for its belief that the groundwater background study is not overly conservative, and may actually underestimate the natural range in background values due to the number of upper end data points eliminated during Step 2 and Step 3. As required by DTSC in the November 30, 2007 letter, a total of 30 analyses were deleted from the background study data set (including arsenic data from three background study wells in Arizona). This deletion of 30 data points has resulted in changes in the UTLs for lead and arsenic. Furthermore, PG&E presented the case that having multiple (rather than a single) background concentrations at the Topock site would result in significant scientific uncertainty, is not practical from a regulatory standpoint, and would hinder rather than advance the progress toward selection and implementation of a final groundwater remedy.

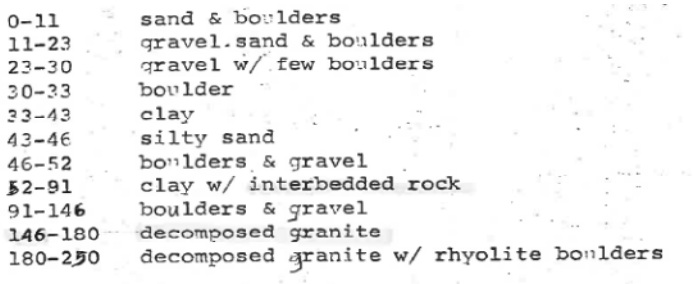
DTSC Comments and PG&E Responses

Comment Number	Comment Location (Section/Paragraph/ Page)	DTSC Comment	PG&E Response
7	2.2.2 Protection of Aquifer Water Quality, Emerging Contaminants, Page 5	The section states, "*Examples of this include the Tucson Airport Area Superfund site, where it was discovered in 2002 that 1,4-dioxane had been passing undetected through the air strippers since 1987 and was injected into a previously uncontaminated portion of the aquifer. A similar problem occurred at the Aerojet site in Rancho Cordova, CA, where perchlorate passed undetected through air strippers and was injected into a clean portion of an aquifer*." The examples cited are isolated incidences and are not the norm. It is unlikely that significant concentrations of emerging chemicals would be detected within the Topock site area due to the absence of known source areas upstream and dilution effects. Issues associated with emerging contaminants must be supported with site specific data. While emergent contaminants have been detected away from the Topock site, DTSC is unaware of any detections of perchlorate or 1,4-dioxane in any Topock site river or water well samples. PG&E tested for perchlorate as part of the interim measures activities to ensure that the contaminant would not be injected into the uplands area. DTSC assumes similar testing precautions would be taken for river water. River water could be periodically monitored for large suites of constituents. Discussion of hypothetical emergent contaminant scenarios in the future will need to be supported with site specific data or at least data in the vicinity of the site. Absent of site specific data, emergent contaminants do not appear to be a significant disadvantage to the use of river water. Please note that emerging contaminants are issues only if they exceed regulatory water quality standards. Regulatory criteria for emergent contaminants may take decades to develop and will allow for reasonable assessment and planning in the future. The section states, *"Some of these emerging contaminant compounds are not mobile in the subsurface and may never move far from the river."* If they are not mobile in the subsurface, it would seem they would also not travel much after injection.	Fortunately, examples of emerging contaminants being present in injection wells have been rare, but the consequences are severe, resulting in contamination of large areas of previously pristine groundwater. Thus, while the risk of injecting an unrecognized trace contaminant may be low, the consequences are high. The following quote is excerpted from the website of the Colorado River Regional Sewer Coalition (CRRSCo), a non-profit corporation of Arizona, California and Nevada river communities, local governments, Indian tribes, and regional water providers in the Lower Colorado River Basin. It highlights the several risks to water quality in the Colorado River, including risks from emerging contaminants: *"In April 2004, however, the environmental organization American Rivers and its partners designated the Colorado River as the nation's "most endangered river," citing mounting problems with radioactive, human and toxic waste that are contaminating groundwater levels to unsafe conditions. The situation has been compounded by rapid population growth, with the result being that areas already being served by outdated wastewater technology and septic tanks that can no longer function to treat wastewater without creating further contamination problems.* *Contamination increasingly threatens the livelihoods of those millions of Americans living in the Lower Basin states. It threatens their health. It threatens their lives. But people living in the Lower Basin are not alone in facing this water crisis. If the spread of contamination is not addressed sooner, rather than later, not only the quality of water in the Lower Basin but the quantity of water along the entire river will be in jeopardy.* *Three sources of pollution are at the heart of the contamination crisis confronting both the upper and lower basins: nitrates, uranium and chromium. In addition, there are a number of emerging pollution and biological issues further contributing to the problem, such as pesticide residues, pharmaceuticals, industrial contaminants and other endocrine disrupting compounds, salinity and quagga mussels."* DTSC is correct that regulatory standards for emerging contaminants may take decades to develop. That is precisely the concern that PG&E has. If presently unregulated contaminants are injected into the aquifer and regulations are later put in place, PG&E could be held responsible for cleanup of a newly regulated contaminant over an area much larger than the original chromium plume.

DTSC Comments and PG&E Responses

Comment Number	Comment Location (Section/Paragraph/ Page)	DTSC Comment	PG&E Response
8	3.1 Evaluation Criterion #1 -- Influence of Freshwater Pumping on Remedy Performance, Page 6	Model simulations are based on using a 600 gpm freshwater pumping rate. Would the simulations change if the pumping rate increases to the maximum of 1200 gpm as stated by PG&E? The 60% Design should also evaluate by modeling the potential issues associated with pumping at 1200 gpm as pumping may range up to this threshold.	The maximum freshwater pumping rate in the 60% design is 1,010 gpm (900 gpm for the groundwater remedy injections plus 110 gpm for TCS operations), which corresponds to injecting a maximum combined rate of 1,200 gpm into the Inner Recirculation Loop/Freshwater injection wells (900 gpm freshwater plus 300 gpm from the River Bank extraction wells). Additional model runs to examine this condition were not completed for the 60% design but are expected to show further nominal reductions in the remedial timeframe.
9	3.1.1 Conclusion, Page 7	The section states, *"Based on the solute transport model simulations, there are negligible differences between the three freshwater sources from a hydraulic perspective."* Would the conclusion be different if injection rate is ramped up to 1200 gpm?	See responses to DTSC Comment #9 as it relates to the maximum freshwater injection rate condition for the 60% design. No, within the area of concern the hydraulics are similar under elevated freshwater injection rates for the three potential freshwater sources.
10	3.2.1 Well or Wells in Arizona, Topock-2 and Topock-3 Wells, Page 7	Please provide any and all information regarding old wells Topock 1 and 2 in the 60% Design. PG&E must have information on these wells as they supplied the compressor station for years. Identify these wells on Figure 3-1 or equivalent. Indicate what maintenance/rehabbing was done to all Topock wells. The history of these older wells may help in understanding the potential future behavior of well HNWR-1. The geology/log of Topock 2 and 3 (1 & the "old" 2 also) is missing. Please provide and discuss. Topock 3 is stated to produce "poor quality water". Please elaborate on what poor quality water is. Include analytical data of poor water quality. Indicate current and historical pumping rates at all Topock wells.	PG&E purchased water from the owners of the Topock 2 and 3 wells but had no involvement in the operation of maintenance of the wells. PG&E therefore has no data on historical maintenance activities or pumping rates from these wells. The ADEQ Arizona Groundwater Study reports that the Topock 2 and 3 wells pump about 74 acre feet per year. Logs of Topock 2 and 3 are provided in Appendix B2 of the RFI/RI Volume 2 Report (CH2M HILL 2009a) but will also be included herein as requested, at the end of this RTC table. PG&E is not aware of any log for the original (old) Topock 2 well. This well was reportedly drilled in 1959 and abandoned in 1974. PG&E did locate some laboratory reports of samples from the Topock 3 well in 1978 and 1979. This is believed to be prior to the plugging of the bottom 100 feet of this well. These reports (attached at the end of this RTC table) show sodium and TDS at concentrations above recommended drinking water standards. PG&E also located some information on the former Topock 1 well, which is also attached. The data show that this well was about 34 feet deep but there is no well log. There are laboratory results of water samples from 1957, 1968, and 1980.

DTSC Comments and PG&E Responses

Comment Number	Comment Location (Section/Paragraph/ Page)	DTSC Comment	PG&E Response
11	3.2.1 Well or Wells in Arizona, Conclusion for Arizona Groundwater Option, Page 9	The section should discuss the geology and hydrology of the area – detailed preferably. Knowing the geologic units in the area might help to locate areas with higher yields. Ancestral Colorado River deposits might contain more sands and gravels. Please provide a basic hydrogeologic description of the area before making hydrogeologic conclusions. Place the requested information in the 60% Design.	Unfortunately, there is no good information on the geologic units in this area. The driller's logs from existing wells are sparse and inconsistent in their descriptions. The only existing well that is installed in the Sacramento wash bottom in the vicinity of the Project Area is the HNWR-1 well. The log for this well was provided on page 7 of the Freshwater Tech Memo. This clean sand and gravel material between 83' and 156.5' is likely the desired Holocene sand and gravel that is the target for the new production well. The next nearest wells are the Topock 2 and 3 wells. These wells are located outside the channel of Sacramento Wash, so they would not have penetrated the desired Holocene gravels. The driller's log of Topock 3, the more detailed of the two logs, is provided below:  0-11 sand & boulders 11-23 gravel.sand & boulders 23-30 gravel w/ few boulders 30-33 boulder 33-43 clay 43-46 silty sand 46-52 boulders & gravel 52-91 clay w/ interbedded rock 91-146 boulders & gravel 146-180 decomposed granite 180-250 decomposed granite w/ rhyolite boulders After completion, Topock 3 well produced poor quality water. It was cemented back to a depth of 150 feet and the water quality improved. The present Topock 3 well is screened from 85 to 130 feet. It is unlikely that any of the units encountered in Topock 3 correlate with those in HNWR-1. The next nearest wells are at the Kinder Morgan compressor station and at the ADOT yard, but these wells produce water from the older alluvial fan deposits and/or bedrock, so they are not considered relevant to the target geologic units for new production wells. The next nearest well that is located near the river and might considered relevant is the RPGS (aka GSRV-2) well, located about 1.6 miles north of HNWR-1. The driller's log of the RPGS Well contains very little detail. It notes sand down to 18 feet, clay from 18 to 25 feet, and a mixture of sand and gravel down to 245 feet. Large gravel was noted between 120 and 124 feet. No bedrock was encountered. The well is not located in the bottom of a large wash where Quaternary gravels would be expected to be found, so it is likely the gravel encountered in RPGS are older than we are targeting with the new wells. About one-half mile further north from RPGS is the Serrano Landscaping well. The drillers log for this well also contains very little

DTSC Comments and PG&E Responses

Comment Number	Comment Location (Section/Paragraph/ Page)	DTSC Comment	PG&E Response
			detail. It indicates a mixture of sand, sand and gravel, and some gravelly sand to a depth of 260 feet. Boulders are noted in the uppermost 25 feet. In summary, the data from existing wells is not adequate to define any specific hydrogeologic in this area. It is encouraging that, with the exception of Topock 3, sediments encountered in all of the wells drilled along the river on the Arizona side were predominantly sand and gravel. In general, the sediments along the Arizona shore appear to be coarser grained than those typically encountered on the California side of the river.
12	3.3.1 Well or Wells in Arizona, Arsenic, Page 12	It is clear that arsenic in Arizona is elevated above the MCL of 10. Nevertheless, the receiving body of water in California is below the MCL and the proposed action will cross state jurisdiction. Currently, California Regional Water Quality Control Board is requiring PG&E to conduct additional study and possible WDR for the proposed injection.	Comment noted. As previously mentioned, the RWQCB, subject to its invitation for PG&E to seek review by the State Water Resources Control Board, indicated that the HNWR-1 water would likely need treatment to remove naturally occurring arsenic prior to injection. With the RWQCB's consent, PG&E has opened discussions with the SWRCB regarding the need to treat naturally occurring arsenic. As the SWRCB has not yet made a decision on this matter, PG&E continued to evaluate options for freshwater supply by seeking location(s) for new well(s) that could supply an adequate quantity of water of sufficient quality to not require treatment prior to use for remedy operation, and on November 20, 2012, submitted an Implementation Plan for Alternative Fresh Water Sources Evaluation (Implementation Plan) (CH2M HILL 2012g). Comments from Tribes, Agencies, and Stakeholders were received, and a Revised Implementation Plan was submitted on January 28, 2013 (CH2M HILL 2013a). The Revised Implementation Plan is currently under review by DTSC and DOI. As directed by DTSC on December 31, 2012, PG&E included a pre-injection treatment system in this 60% design. The decision by the SWRCB is anticipated to guide further direction from DTSC regarding the ultimate use of the fresh water source and what level of treatment if any will be required for various constituents. The freshwater source details will be included in an addendum to this 60% design, after such requirements are determined and completion of planned source water studies.

DTSC Comments and PG&E Responses

Comment Number	Comment Location (Section/Paragraph/ Page)	DTSC Comment	PG&E Response
13	3.3.1 Well or Wells in Arizona, Arsenic, Page 12	The section states, "*The most likely explanation is that iron oxide minerals, effective adsorbers of arsenic, are undoubtedly present in the aquifer matrix in Arizona, however, long-term exposure to the groundwater with naturally occurring arsenic has saturated all the adsorption sites on these minerals. There are a finite number of adsorption sites for matrix minerals, and if the groundwater has excess concentration of an adsorbing constituent (such as arsenic), then the matrix minerals and groundwater will form an equilibrium state, with the adsorption sites at capacity (Schindler 1991, Stumm 1992).*" If this is true, shouldn't PG&E conduct a bench test to determine the capacity of the adsorption sites to test this theory in California? If the continued loading of arsenic can potentially overwhelm the localized adsorption site causing equilibrium to be formed with arsenic, this can be a significant data gap. Wouldn't PG&E test this theory prior to actually injecting a known toxin into a beneficial aquifer? DTSC believes it to be PG&E's responsibility to ensure the protection of the State's water in every way possible.	The concentration of amorphous iron oxide that provides adsorption sites has been measured in core samples during the Aerobic Core testing study (CH2M HILL 2005a, see response to Comment 8 above). Amorphous iron oxides have been studied for their adsorption capacities and adsorption site densities (i.e. number of adsorption sites per unit mass of oxide) have been published and used in the current site model (Dzombak and Morel 1990). The combination of the measured site data and the published adsorption site densities provides a reasonable model of fate and transport of arsenic at the site. Additional sample collection and testing would add time and scope to the project. PG&E believes that groundwater monitoring would be a more effective evaluation of the modeled fate and transport. As directed by DTSC on December 31, 2012, PG&E included a pre-injection treatment system in this 60% design. The decision by the SWRCB is anticipated to guide further direction from DTSC regarding the ultimate use of the fresh water source and what level of treatment if any will be required for various constituents. The freshwater source details will be included in an addendum to this 60% design, after such requirements are determined and completion of planned source water studies.
14	3.3.1 Well or Wells in Arizona, Arsenic, Page 13	Although we do not anticipate a drastic change in geochemistry at the injection sites, what could cause desorption of the arsenic from the iron oxide in the aquifer? Would well rehabilitation measures adversely impact arsenic concentrations around injection sites?	Desorption of arsenic would require a drastic change in water chemistry surrounding the aquifer matrix. This would be in the form of a large concentration of an ion that is geochemically similar to the adsorbed arsenate, such as phosphate. Positively-charged metal ions would not have an effect, since arsenate is negatively charged, nor would anions with different properties such as sulfate and bicarbonate. Well rehabilitation rinses would only effect several feet around the well, and these fluids are not likely to contain ions that would cause significant desorption. Also, the rinses are pumped back out of the well, limiting if not eliminating their effect on the aquifer matrix near the well.

DTSC Comments and PG&E Responses

Comment Number	Comment Location (Section/Paragraph/ Page)	DTSC Comment	PG&E Response
15	3.3.1 Evaluation of water from areas with lower arsenic outside the influence of hydrothermal activities, Page 13	It is stated that "*If it becomes necessary to develop a water supply from a well in Arizona other than HNWR-1, it would likely be from a well outside the APE to the north. There are two wells north of HNWR-1 for which some information exists. Well GSRV-2 is located along Highway 95 just south of Warm Springs Wash, approximately 1.6 miles north of HNWR-1.*" Although the concentration of arsenic is below MCL at GSRV-2 area, the higher than established regional background concentration for hexavalent chromium is a concern. That Cr6 may confound the clean-up effort of the anthropogenic contamination of the same chemical. This is also not desirable for the Topock remediation.	The average Cr(VI) concentration in GSRV-2 during the background study was 25 µg/L, which is higher than in HNWR-1 but below the regional background of 32 µg/L. PG&E is proposing a contingency well much closer to HNWR-1 than to GSRV-2, where Cr(VI) is anticipated to be lower than GSRV-2 . In fact, the proposed contingency well location in this 60% design is in the vicinity of the proposed Site B in the Revised Implementation Plan for Alternative Fresh Water Sources Evaluation Tech Memo (CH2M HILL 2013a). If allowed to proceed with the Implementation Plan, water quality data will be collected at Site B.
16	3.3.1 Total Dissolved Solids (TDS), Page 14	This section discusses modeling to *"assess whether the volume of this mass would block a significant portion of the aquifer porosity. The simulation showed that less than one percent of the available porosity was blocked by re-precipitation."* However, the Tech Memo never evaluated the current IM-3 injection wells or discusses what the root causes were for the degradation of injection efficiencies at existing injection wells. Since IM-3 injection wells have been in operation for approximately six years, and well rehabilitations have taken place, the experience from those wells may be more beneficial than model simulations.	The desired concentration of manganese (<10 µg/L) specified in the tech memo is based directly on experience operating the IM-3 injection wells. When manganese concentrations are greater than 10 µg/L, plugging of the IM-3 injection wells occurs much more rapidly. Because manganese is the only constituent known to be associated with plugging at the IM-3 wells, there is no data from the IM-3 operations to evaluate plugging potential from iron or arsenic.

DTSC Comments and PG&E Responses

Comment Number	Comment Location (Section/Paragraph/ Page)	DTSC Comment	PG&E Response
17	3.3.1 Total Dissolved Solids (TDS), Page 14	This section states "*There are no wells between HNWR-1 and the marsh, so the groundwater quality in this area is unknown. Similarly, it is not known how far below the bottom of HNWR-1 the high TDS water lies. It is therefore not possible to predict what changes might occur in water quality at HNWR-1 over time with any degree of certainty. It is likely that the TDS will increase as more river water is pulled in.*" PG&E regards potential water quality issues of the Colorado River, including emerging chemicals, as a major disadvantage of using that water. Contrarily, PG&E anticipates the water quality of HNWR-1 to decrease over time, but PG&E has not identified any potential testing or further evaluation of the water in that area for sustainability. Shouldn't PG&E evaluate or test the current water quality at the marsh as an indicator of possible outcome prior to selection of HNWR-1 as the preferred option? DTSC expects this level of evaluation to support the design.	The water in the marsh comes from the river and there are no sources of emerging contaminants or other pollutants in the Topock Marsh. The primary factor that would cause a difference in water quality between the marsh and the river is evaporative concentration of minerals in the marsh. In his Ph.D. dissertation, Bradley Guay estimates about 46% of the water entering the marsh is lost to evaporation. The data show a 5- to 6-fold increase in specific conductance between the marsh inlet and the downstream sampling point which was somewhere above the south dike. HNWR-1 is located in a portion of the marsh below the south dike. There is an exchange of water in this section of the marsh as the river level fluctuates. The TDS is likely somewhat lower in this part of the marsh due to dilution with river water. There are likely seasonal changes in water quality associated with differences in evaporation rate and river levels. Establishing baseline water quality in the marsh near HNWR-1 would likely require multiple sampling events at different times of the day and different seasons. However, even if the water quality in the marsh is known, there is no way to accurately predict how this would affect the water quality in HNWR-1 because one does not know how much river water will be drawn in and what the character of that water will be after it passes through the reducing rind and reaches HNWR-1. There are adequate data available from the MWD database to assess the quality of water in the river. There is no reason to suspect any exotic contaminants would be introduced as water flows through the marsh. It can therefore be assumed that the concentrations of whatever is in the river would be increased by about a factor of 5 or 6 in the marsh. Not all the constituents present in river water would be mobile in groundwater. For those constituents that are mobile, there would be considerable attenuation through dilution and dispersion prior to reaching HNWR-1. Therefore, obtaining water from HNWR-1 provides a significant buffer against inadvertent injection of anything harmful that might be present in river water. Unfortunately, without detailed hydrogeologic studies involving installation of multiple monitor wells and long term pumping tests at HNWR-1, it is not possible to predict how the water quality in the marsh may affect the water quality in HNWR-1 over the decades long operational period of the remedial action.

DTSC Comments and PG&E Responses

Comment Number	Comment Location (Section/Paragraph/ Page)	DTSC Comment	PG&E Response
18	3.3.1 Conclusion for Arizona Groundwater Option, Page 15	PG&E concluded that treatment of arsenic is not needed. However, as stated in prior comments, this conclusion may not be supported by California agencies and may not meet ARAR for the California Water Resources Control Board's resolution 68-16. PG&E is currently evaluating this issue.	Comment noted.
19	3.3.1 Blending with water sources with lower arsenic, Page 16	PG&E has neglected, in this tech memo, to evaluate the possibility of blending water from Park Moabi area with existing Topock 2 and 3 water. PG&E is currently acquiring water from Topock 2 and 3 for compressor station use, therefore no additional infrastructure is needed. Importing additional water from Topock 2 and 3 seems possible based on combined yield. By installing only well(s) from Park Moabi for blending, the additional infrastructure would be minimal while possibly meeting the water quality and quantities needed for the remedy.	As described in the Freshwater Source Evaluation tech memo, a careful review of the available data indicates that a well producing from the high quality water zone at Park Moabi would produce less than 100 gpm and the pumping would likely produce adverse impacts on existing Park Moabi wells. The Topock 2 well could likely produce about 400 gpm, but there is a risk of upconing of more saline water from depth. In addition, the arsenic concentration of Topock 2 is similar to that of HNWR-1 (about 15 µg/L). In order to have arsenic below the MCL of 10 µg/L, assuming that the new Park Moabi well contained no arsenic, it would be necessary to blend water at a ratio of approximately 1/3 from Park Moabi and 2/3 from Topock 2. With the maximum modeled fresh water flow rate of 900 gpm, the new well at Park Moabi would need to produce about 300 gpm. If it contained any arsenic, the amount of water needed from Park Moabi would be even greater. Based on the available data, PG&E does not believe that a well at Park Moabi would provide a sufficient volume of water to blend with Topock 2/3 water and result in an arsenic concentration below the MCL. The existing pipeline from Topock 2/3 would also need to be replaced or a second pipeline installed in order to accommodate the balance of the maximum modeled flow rate. In addition, another well in Arizona would need to be installed to ensure adequate quantity from Arizona, and this well would need to somewhere far enough from Topock 2/3 to avoid interference. Therefore, the amount of infrastructure needed to blend water from two sources could be greater than for the HNWR-1 well alone because it would require new piping to be installed from both Park Moabi and from Arizona and a new well in Arizona. In PG&E's opinion, the concept of blending water from Park Moabi and Topock 2/3 does not appear to offer any advantages over obtaining water from HNWR-1.

DTSC Comments and PG&E Responses

Comment Number	Comment Location (Section/Paragraph/ Page)	DTSC Comment	PG&E Response
20	3.3.3 Colorado River, Total Dissolved Solids, Page 22	The average TDS of the river is stated, but the source of the data set in not identified. DTSC assumes that the TDS exhibited by the river, while ranging, would exhibit consistent values over the years that it has been monitored, and, therefore, would be consistent over the life of the remedy. This would be in contrast to HNWR-1 where the TDS values from the well as it is pumped continuously over the life of the remedy could change significantly. Projecting TDS variability during the life of the remedy for both the river and HNWR-1 should be evaluated and addressed in the 60% Design. This is important as low TDS is a major desirable quality of the HNWR-1 source.	The TDS data are from the PG&E river monitoring program. As noted previously, there are no data to support a projection of the possible trends in water quality in HNWR-1 over the life of the remedy. Neither are there data to support a projection of TDS in the river. This is stated in Section 3.3.2 of the 60% design.
21	3.3.3 Colorado River, Coliform Bacteria, Page 22 & 23	The section cites coliform bacteria levels measured from Lake Havasu located at least 15 miles downstream of Topock and Whitsett Intake located at least 35 miles downstream. Citing data so far away and near a major city seems inappropriate for this evaluation and casts doubt on the utility of the data and statements in the section. Is this an issue at the Topock area?	There are no data on coliform bacteria in the river at Topock, however it should be noted that Topock is downstream from Needles and Laughlin so there is the potential for bacterial contamination to be present at Topock due to discharges from septic systems or sewage treatment plants.
22	3.3.3 Colorado River, Perchlorate and Nitrate, Page 23	The section states that perchlorate was not analyzed in samples collected near the Topock site. This is an incorrect statement. PG&E should review its data set and note the couple of perchlorate nondetects from locations CON and I-3 in 2003. Mention of the perchlorate analyses in groundwater (all nondetects), especially in wells located adjacent to the river, should also be mentioned.	DTSC is correct. There are two perchlorate sample results in the PG&E river monitoring database, both non-detect with a detection limit of 4 ppb. Prior to the IM-3 pumping there was a net discharge of groundwater in the floodplain to the river. Therefore, perchlorate might not be detected in wells near the river even if it were present in the river.
23	3.3.3 Colorado River, Contaminants with Secondary MCLs, Page 23	The section notes a maximum elevated aluminum concentration of 540 µg/L in river water. As this value appears anomalous compared to the other data, PG&E should evaluate why it might be elevated. Are the data presented in Tables 3-7 and 3-8 samples that were filtered or unfiltered or a mixture of both?	According to MWD, the only filtered water is the water for Cr(VI) analysis.
24	3.3.3 Coliform Bacteria, Page 23	What are the physical methods that can be used to remove biological growth from well screens? If disinfection is required, will the disinfectant process also adversely impact microbes necessarily to establish the reduction zone?	Biological fouling doesn't generally respond well to strictly physical methods of removal. In IRZ wells, citric acid is sometimes used to help break down slime forming microbial growth prior to surging and bailing or pumping. Disinfectants are not typically used in IRZ well rehab because of the potential for damage to the microbial community needed to maintain reducing conditions. Disinfectants could be used in freshwater injection wells where there is no need to maintain a microbial community.

DTSC Comments and PG&E Responses

Comment Number	Comment Location (Section/Paragraph/ Page)	DTSC Comment	PG&E Response
25	3.3.3 Compounds Associated with Pharmaceuticals and Personal Care Products, Page 23	PG&E concludes that "*As areas become more or less populated over the next few decades, it is expected that the presence of PPCP compounds in river water to vary accordingly. In addition, as new and more advanced/exotic personal care products and pharmaceuticals are brought to the market as society advances over the next few decades, it is likely that new trace contaminants could be found in river water.*" While this may be true, this same argument can be applied to additional population that could impact the quality of water from the Sacramento wash on which the HNWR-1 depends.	The potential for significant population increases in existing communities along the Colorado River seems much greater than for sparsely inhabited and somewhat austere Sacramento Valley.
26	3.3.3 Colorado River, Compounds Associated with Pharmaceuticals and Personal Care Products (PPCP)/Emerging Contaminants, Page 23 & 24	PG&E's concerns with PPCP and emerging contaminants appears speculative at this point as a data gap exists regarding river water quality in the immediate vicinity of the site. The site is located away from more populated areas where these contaminants are stated to be more of a concern. There may simply be no problem with the river water in the Topock area. Data should be collected at the site to determine if there is any concern. Continued monitoring during the remedy would ensure that river water quality was always acceptable. The section states, "*Some of these emerging contaminant compounds are not mobile in the subsurface and may never move far from the river. If fresh water were obtained from a well rather than from the river, this travel time from the river to a well provides a buffer that might allow for mitigation measures to be implemented prior to injecting an emerging contaminant and having it spread across the site.*" This is not a concern as monitoring would always be conducted to provide a warning system against undesirable constituents. Non-mobile constituents would also not move far in groundwater away from an injection well.	See response to DTSC comment 7. Concentrations in the river could change rapidly due to upsets in sewage treatment plants or rainfall events. Monitoring for compounds for which there are currently no standards would not prevent injecting them at concentrations above a future standard. The safest course is to not inject raw river water, but rather seek a groundwater supply which is buffered from the potential short term fluctuations in concentrations in the river and not likely to become contaminated with river water for many years.
27	3.3.3 Potential Need for Conditioning of River Water Prior to Injection, Page 24	PG&E states that it plans to screen extraction wells in the lower, oxic portion of the aquifer. Please note, however, that many stakeholders are expecting these extractors to be a stop gap for any contaminants which may flow into the river. The current design will not meet that expectation and PG&E must consider a separate contingency plan for capturing contaminants that may move toward the river.	The 60% design document discusses possible contingency measures for the river bank wells. If it becomes necessary to pump from the reduce zone in the shallow aquifer, treatment will likely be required to remove iron and manganese prior to injection.

DTSC Comments and PG&E Responses

Comment Number	Comment Location (Section/Paragraph/ Page)	DTSC Comment	PG&E Response
28	3.3.3 Colorado River, Potential Need for Conditioning of River Water Prior to Injection, Page 24	• The section states that solids and bacteria/microorganisms will need to be removed prior to injection. The level at which conditioning is required should be stated. What concentrations of solids and bacteria/microorganisms are considered undesirable and would require conditioning? • Shallow infiltration galley: It is uncertain what different type of intake structures can be designed. The Tech Memo/30% should have discussed the range of alternatives. Can an intake screen be placed on the bottom of the river and then covered with permeable materials and armor to allow freshwater infiltration? • The section discusses PGE-8 and PGE-9 without discussing where these wells are located. DTSC believes they are misnamed and referring to wells PGE-9N and PGE-9S located on the Arizona shore under the arch bridge.	• Ideally, suspended solids and bacteria should be less than 2 mg/L. Less is better as any amount contributes to plugging and over the 50 year life of the remedy, even a small amount could significantly reduce the live of the injection wells. • Park Moabi attempted a shallow infiltration gallery and it produced very poor quality water. The pore water samples showed reduced conditions in all but one of 64 locations at shallow depths (~6feet) below the river bottom. If an intake were installed in the geochemically reduced bottom sediments, a treatment plant would likely be needed, at least initially, to remove iron and manganese prior to injection. • DTSC is correct, the memo should refer to PG&E 9N and 9S.
29	3.3.3 Potential Need for Conditioning of River Water Prior to Injection, Page 26	PG&E estimated the conditioning facility to be 5,400 square feet. It is unclear how this estimate was developed. With the exception of the disinfection tank, the treatment system process appears very similar to the pre-treatment system for arsenic. What is changed so that the treatment system would be more than doubling the size?	The disinfection function and the phase separators (similar to IM-3) were the primary differences between the River Water Conditioning Facility and the arsenic treatment system. In addition, Additional space was allocated to incorporate elements such as electrical transformers, and other items needed to integrate this facility with the Remedy and TCS operations.
30	3.4.1 Initial Design, Page 28	DTSC understands that there are numerous intake and fish screen designs, why did PG&E selected the round pipe with circular continuously cleaning design as the preliminary choice? Non-continuously cleaning or flat screens?	The round, continuously cleaning (ISI) screen is a proven design in small-flow, river applications similar to Topock. The screen can be removed from the water for easy inspection and maintenance.
31	3.4.1 Initial Design, Page 29	PG&E states "*Preliminary discussion with CDFG indicated that approval of a fish screen and intake structure that would avoid incidental take of the razorback sucker may be difficult to obtain.*" Perhaps this is a good discussion to invite Fish and Game for CWG meeting to provide understanding and hurdles involved.	Comment noted.
32	3.4.1 Initial Design, Page 29	When will the fish habitat assessment report be available? Since that would dictate, in part, the viability of an intake structure.	The Instream Habitat Typing Survey Technical Memorandum was submitted to DTSC on May 25, 2012, and is included in Appendix A6 of this 60% BOD.
33	3.4.1 Initial Design, Page 29	Where are the representative visuals for Sites 1 and 2? Are they similar to Site 3? There is limited explanation for the photo provided.	The visuals for Sites 1 and 2 are included in the *Instream Habitat Typing Survey Technical Memorandum* (CH2M HILL 2012f). This memorandum was submitted to DTSC on May 25, 2012, and is included in Appendix A6 of this 60% BOD.

DTSC Comments and PG&E Responses

Comment Number	Comment Location (Section/Paragraph/ Page)	DTSC Comment	PG&E Response
34	3.4.1 Initial Design, Page 30	PG&E states that "Based on the preliminary engineering evaluation and fish habitat survey, Site 4 appears to be the most feasible location for a river intake structure and fish screen…" However, there is no supporting discussion on the criteria used for this determination or the rationale for this statement. More importantly, Site 4 is also the closest location to the visible manifestation of the maze. This area also has more recreational users and boaters traveling through the area. A more thorough evaluation and discussion should have been prepared.	Section 3.4.1 (Initial Design) of the Freshwater Source Evaluation Tech Memo is intended to present a summary of the preliminary engineering survey and initial design. Attachment B of the Tech Memo includes additional details and evaluation including a comparison table of the sites evaluated against the evaluation criteria that support the conclusion.
35	4.0 Selection of Preferred Freshwater Source, Page 39	PG&E concludes that the HNWR-1 well in Arizona is the preferred freshwater supply option for the remedial action because it *"…presents less uncertainty, less risk to project schedule, and less disturbance of the site."* PG&E may be correct in selecting HNWR-1 as the preferred option; however, based on the comments above, DTSC believes that there are still significant uncertainties associated with its use. Specifically, the arsenic above MCL and above the concentration of the receiving water body may be problematic. If pretreatment of the arsenic is necessary prior to injection, site disturbance would be significant as a water treatment plant and significant length of pipeline would be needed for this option. Furthermore, PG&E has not evaluated the long term water quality at HNWR-1. What would be PG&E's response if TDS increases sharply from sustained extraction?	Exhibit 3-11 of Freshwater Source Evaluation Tech Memo presents a contingency matrix for some of the more serious types of problems that might be associated with the freshwater sources or with the injection of fresh water at the Topock site. One of the contingencies described in the matrix is pumping that draws in saline water from below or geochemically reduced water from the river or the marsh. The possible contingency measures listed for this contingency include install treatment to remove harmful constituents or seek other source(s) of fresh water or other location for well(s). As directed by DTSC on December 31, 2012, PG&E included a pre-injection treatment system in this 60% design. The decision by the SWRCB is anticipated to guide further direction from DTSC regarding the ultimate use of the freshwater source and what level of treatment if any will be required for various constituents. The freshwater source details will be included in an addendum to this 60% design, after such requirements are determined and completion of planned source water studies.

Attachment 1
PHAST Simulations

(*On CD-ROM only*)

```
DATABASE C:\Program Files\USGS\phast-1.5.1\database\phreeqd.dat
TITLE       Simulated Injection of HNWR-1 water into upland alluvial aquifer at
Topock
SOLUTION 1  CW-03D  09/16/05 representative of upland alluvial aquifer deep zone
Temp    31.6
pH      7.72
pe      8   Manganite  0.0
redox   pe
units   mg/l
density 1
Na      3030
K       39.8
Ca      422
Mg      29.2
Cl      4930
Mn      0.259
S(+6)   672     as SO4
Alkalinity      33.1
N       0.304   as N
F       1.4
Si      23.5    as SiO2
EQUILIBRIUM_PHASES 1
   Calcite  0.0 10.0
   Gypsum  0.0  0.0
   Manganite 0.0 1.0
END
SOLUTION 2  HNWR-1 (CH2M)  11/11/10
Temp    35.9
pH      7.84
pe      10
redox   O(0)/O(-2)
units   mg/l
density 1
Na      130
K       5.1
Ca      23
Mg      4
Cl      150
S(+6)   47      as SO4
Alkalinity      100
N(+5)   2.5     as N
F       3.8
Si      28.6    as SiO2
O(0)    8.0
END
SELECTED_OUTPUT
        -file ex1.dummy.sel
        -reset false
#        -ph
#        -saturation_indices  anglesite otavite smithsonite
#        -molalities CdX2 PbX2 ZnX2
#        -molalities
USER_PUNCH
# Prints concentrations in ug/kgw to Injection(n).xyz.chem
-heading    pH  Calcite Manganite Ca+2 HCO3- Mn+2 SI_Calcite SI_Manganite SI_Gypsum
10 PUNCH LA("H+")*-1
20 PUNCH EQUI("Calcite")
30 PUNCH EQUI("Manganite")
40 PUNCH ACT("Ca+2")
50 PUNCH ACT("HCO3-")
60 PUNCH ACT("Mn+2")
70 PUNCH SI("Calcite")
80 PUNCH SI("Manganite")
```

```
90 PUNCH SI("Gypsum")
END
```

```
TITLE
        Simulated Injection of HNWR-1 into deep alluvial aquifer for Topock
UNITS
        -time                   day
        -horizontal_grid        ft
        -vertical_grid          ft
        -head                   ft
        -hydraulic_conductivity ft/day
        -specific_storage       1/ft
        -dispersivity           m
        -flux                   ft/day
        -well_diameter          in
        -well_flow_rate         ft3/day

STEADY_FLOW false
        -minimum_time_step      0.03  d
        -maximum_time_step      30000  d
        -head_change_target     25.

FREE_SURFACE_BC false

SOLUTE_TRANSPORT true

SOLUTION_METHOD
        -direct_solver          true
        -space_differencing     0.5
        -time_differencing      0.5

GRID
        -uniform        X     0.  2000000.   11
        -uniform        Y     0.  2000000.   11
        -uniform        Z     0.   100.   2
        -overlay_uniform  X   998000.   1002000.  41
        -overlay_uniform  Y   998000.   1002000.  41
        -chemistry_dimensions   XYZ
        -print_orientation      XY
MEDIA
        -zone   0 0 0 2000000 2000000 100
                -Kx                         20.
                -Ky                         20.
                -Kz                         2.
                -porosity                    0.12
                -storage                       0.000005
                -longitudinal_dispersivity    7.5
                -horizontal_dispersivity      7.5
                -vertical_dispersivity         0.75

SPECIFIED_HEAD_BC
        -zone   0.  0.  0.    2000000.   0.   100.

                -head                   0    10.0
                -associated_solution    0       1
        -zone   2000000.  0.  0.    2000000.   2000000.   100.

                -head                   0    10.0
                -associated_solution    0       1
        -zone   0.  2000000.  0.    2000000.   2000000.   100.

                -head                   0    10.0
                -associated_solution    0       1
        -zone   0.  0.  0.    0.   2000000.   100.

                -head                   0    10.0
```

```
                -associated_solution    0       1

HEAD_IC
        -zone   0. 0. 0.                2000000. 2000000. 100.
        -head   10.0

CHEMISTRY_IC
        -zone   0. 0. 0.                2000000. 2000000. 100.
                -solution               1
                -equilibrium_phases     1

WELL
        1000000.   1000000.
        -injection_rate
                0       0
                0.1     9626.
        -solution
                0.      1
                0.1     2
        -diameter       0.5
        -elevation      0.      100.

TIME_CONTROL
        -time_step      0.      30.0
        -time_end       0.      3600.0

PRINT_FREQUENCY
        0.
        -hdf_chemistry                          180 days
        -xyz_chemistry                          180 days

END
```

Attachment 2
Cover Letter to 2009 Background Study Report

(*On CD-ROM only*)

Pacific Gas and Electric Company

Yvonne Meeks
Manager

Environmental Remediation
Gas T&D Department

Mailing Address
4325 South Higuera Sreet
San Luis Obispo, CA 93401
Location
6588 Ontario Road
San Luis Obispo, CA 93405
Tel: (805) 234-2257
Email: yjm1@pge.com

January 14, 2008

Mr. Aaron Yue
Project Manager
Geology Permitting and Corrective Action Branch
California Department of Toxic Substances Control
5796 Corporate Avenue
Cypress, CA 90630

Subject: Revised Groundwater Background Study, Steps 3 and 4: Report of Results PG&E Topock Compressor Station, Needles, California

Dear Mr. Yue:

This letter transmits the *Revised Groundwater Background Study Step 3 and 4: Report of Results* for the Pacific Gas and Electric Company (PG&E) Topock Compressor Station site. This report incorporates changes to the *Groundwater Background Study Steps 3 and 4 Results* report dated January 26, 2007, in response to the California Department of Toxic Substances Control (DTSC's) letter dated November 30, 2007, and the U.S Department of Interior's (DOI's) letter dated December 20, 2007. As agreed with DTSC and DOI, this revised report does not address two comments:

1. The outlier evaluations documented in this *Revised Groundwater Background Study Step 3 and 4: Report of Results* were performed using the mean concentrations for each analyte and well, for the reasons described in Section 2.2. DTSC has requested an additional outlier evaluation for each constituent considering all the measured concentrations for that constituent, rather than each well's mean concentration for that constituent. This additional outlier evaluation will be performed and the results will be reported separately from this report at a future date.
2. The background study wells included in this *Revised Groundwater Background Study Step 3 and 4: Report of Results* were those selected and approved through Steps 1 and 2 of the groundwater background study. DOI's letter dated December 20, 2007 indicates that the inclusion of three of the selected wells should be conditional on the results of the planned groundwater investigation in Arizona. If chromium is found above regional background levels on the Arizona side of the River, the decision to include the three wells in the vicinity of the Arizona investigation in the background study would need to be re-evaluated.

The remaining comments in DTSC's November 30, 2007 letter and DOI's December 20 letter are addressed in the *Revised Groundwater Background Study Step 3 and 4: Report of Results.* As directed by DTSC in the November 30, 2007 letter, the following three discussion topics are presented in this letter:

Topic 1 - Future Uses of the Groundwater Background Study Results

As discussed in the approved work plan[1], the objective of the background study is to define an upper threshold background concentration for total chromium, hexavalent chromium and other inorganic constituents in groundwater at the Topock site. The upper threshold concentration represents the upper concentration of the constituent in natural groundwater not affected by contamination and is referred to as a background concentration. These concentrations are reported in the form of statistical upper tolerance limits (UTLs). The UTL is an EPA-recommended, and widely accepted, statistical method for determining a background value from a set of data. The UTL represents a value that 95 percent of the population will fall below with 95 percent confidence.

The background study will be used during the Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) processes to:

- Support the RCRA Facility Investigation/Remedial Investigation (RFI/RI) and risk assessment activities at the Topock site and to provide a basis by which the list of constituents of potential concern (COPCs) can be evaluated and, if necessary, revised. For site characterization, this would include using the background concentrations to help distinguish the nature and extent of site-related contamination vs. naturally occurring levels of inorganic constituents. For COPC evaluation, the background concentrations can be used as points of comparison so that assessment is focused on those constituents that are elevated above naturally occurring levels. For risk assessment, background concentrations can be used to help identify the site-related chemicals so that they can be evaluated in the risk assessment, and those that contribute most significantly to risk can be identified. Background concentrations can also be useful in communicating risk to the public, putting site-related risks in perspective by comparing those risks to risks associated with background conditions at the site.

- Assist with the Corrective Measures Study/Feasibility Study (CMS/FS) activities at the Topock site during the development of remedial action/corrective action goals. Consistent with the National Contingency Plan, remedial action goals are derived based on two threshold criteria: overall protection of human health and the environment, and compliance with Applicable, or Relevant and Appropriate, Requirements (ARARs). Background concentrations may be used during the risk assessment process to develop remedial goals, particularly if the risk assessment indicates that risk-based remedial goals are lower than naturally occurring background levels. Background concentrations are also cited in certain chemical-specific ARARs, such as California's groundwater and vadose zone protection standards that are applicable to RCRA hazardous waste interim status treatment, storage and disposal facilities[2].

[1] Work Plan for Assessing Background Metals Concentrations in Groundwater, PG&E Topock Compressor Station and Vicinity, Needles, California. June 2004.

[2] U.S. Department of the Interior Preliminary Determination of Applicable, or Relevant and Appropriate, Requirements for the Pacific Gas and Electric Company Topock CERCLA Site

Topic 2 - Potential Limitations for Use of the Groundwater Background Study

As has been discussed with DTSC and DOI and noted in DTSC's November 30 letter and DOI's December 20 letter, the data collected for this study may be interpreted to represent two or more populations based on geochemical or geological distinctions. During preparation of the RFI/RI, risk assessment, and CMS/FS, the use of the background groundwater concentrations determined through calculation of UTLs for the study area as a whole will be evaluated, noting that the calculated UTLs may not be appropriate for all constituents in all portions of the site or at all depths.

Examples of populations or subpopulations that could be separated out from the background data set are discussed below:

- Groundwater in fluvial material that is influenced by the Colorado River vs. groundwater in alluvial material away from the river's influence. The latter is typically geochemically oxidizing whereas the former is relatively reducing, and this difference is expressed by differences in concentrations of several chemical parameters, including nitrate, ammonia, and oxidation-reduction potential. Section 2.2 of the *Revised Groundwater Background Study Step 3 and 4: Report of Results* identifies which inorganic constituents are dominant in the fluvial and alluvial waters and which are detected at low frequency.

- Groundwater in the alluvial aquifer is stratified and shows distinct differences from shallow to deep zones. For example, shallow alluvial groundwater in the area around well MW-18 and the Interim Measure No. 3 injection field contain hexavalent chromium, Cr(VI), concentrations that are greater than concentrations found in deeper wells in the same area, coupled with relatively low dissolved solids and major ion concentrations. Although these relatively elevated Cr(VI) concentrations are naturally occurring, they may be interpreted as representing a distinct geochemical zone that is not found elsewhere. It is common to observe shallow alluvial wells in non-plume areas of the Topock Site with relatively lower dissolved solids concentrations and more oxidizing conditions than in deeper alluvial wells. Consistent with the geochemical environment of the shallow zone, Cr(VI) concentrations in shallow wells also tend to be greater than in deeper wells.

- Three background study wells located immediately across the Colorado River from the site contain relatively higher concentrations of arsenic and fluoride, and may represent another distinct geochemical environment. Slightly elevated groundwater temperature has been observed in samples from one of these wells. These observations suggest there may be localized geothermal influences in this area. At DTSC's request, arsenic concentrations from these three wells and fluoride concentrations from one of these wells were excluded from the data set.

These groupings are subject to interpretation, and are described in Section 2.2 of the *Revised Groundwater Background Study Step 3 and 4: Report of Results*.

As required by DTSC's November 30th letter, a total of 30 analyses have been removed from the background study database that had been used to calculate UTLs for the *Groundwater Background Study Steps 3 and 4 Results* report dated January 26, 2007. Using box-and-whisker and probability plots, these analyses were interpreted by DTSC as being non-representative of

the database as a whole. The deletion of these 30 analyses from the background study data set has resulted in changes in the UTLs for lead and arsenic.

Topic 3 - Rationale for a Single (rather than Multiple) Background Concentrations for the Topock Groundwater Study

The approach to and design of the groundwater background study was documented in the approved work plan and study results (Phase 1, Phase 2, Phase 3/4 results). The definition of the background groundwater study area is the unconsolidated alluvial aquifer of the Mohave Groundwater Basin stretching from the Topock site in the south to Needles in the north (approximately 15 miles north of the Topock Site) and from the edge of the alluvial aquifer along the mountain front in the west to several miles east of the site in Arizona. Over 150 wells in the study area were evaluated during Step 1 of the background study. During Step 2 of the background study, 36 wells were sampled and screened for inclusion in the final data set. Factors considered in including the final set of wells included whether the groundwater general chemistry is consistent with the southern Mohave Valley groundwater general chemistry; whether a potential anthropogenic source may affect the concentrations of metals in groundwater; and whether the well was located within a cluster of other background wells which could cause a geographic bias. And as documented in the *Revised Groundwater Background Study Step 3 and 4: Report of Results,* outlier and geochemical evaluations were performed during Step 3 to maximize the representativeness of the groundwater background study data to the Topock site. One of the defining goals of the DTSC-approved background study protocol was to consider a wide range of geologic and geochemical regimes in developing a background number that would truly be representative of the area as a whole. The Cr(VI) concentrations found in the background study are consistent with those reported in other published studies in the region.

PG&E believes that the results of the groundwater background study are appropriate for completion of the RFI/RI and CMS/FS, are not overly conservative, and may actually underestimate the natural range in background values due to the number of upper end data points eliminated during Step 2 and Step 3. Although there is scatter in the dataset, this is expected in natural geochemical environments.

The derivation of separate background concentrations for various portions of the site has been suggested by some DTSC and DOI reviewers. PG&E believes that the development of multiple background concentrations would be subject to significant scientific uncertainty in categorizing well populations (and accommodating ranges of and changes to well chemistry), is not practical from a regulatory standpoint, and would hinder rather than advance the progress toward selection and implementation of a final groundwater remedy at the site. Moreover, the dataset collected for this study based on the approved work plan is aimed at identifying one background number for the entire study area. More specifically:

- Under a multiple population approach, the dynamic nature of groundwater flowing under the influence of current or future extraction/injection remedies could result in wells being shifted from one population to the other over time – resulting in a complex and potentially conflicting regulatory framework with no commensurate benefits.
- The methodology for defining which wells are associated with which population would be arbitrary and would be difficult to apply in practice. The boundaries of the datasets

would be indistinct, with individual wells falling partly in several different populations, depending on which constituent was being considered.

- Developing multiple populations would significantly delay proceeding to the final remedy as various aspects of the approach are challenged by stakeholders and/or further background study data collection is necessary to address an issue that was not the objective of the approved Background Study workplan.

Do not hesitate to contact me at (805) 234-2257 with any questions or comments on this information or the enclosed report.

Sincerely,

Yvonne Meeks
Topock Project Manager

cc: Chris Guerre/DTSC
Karen Baker/DTSC
Kris Doebbler/DOI

Attachment 3
Topock-1 Well Information

(*On CD-ROM only*)

DEPARTMENT OF WATER RESOURCES
99 EAST VIRGINIA AVENUE
PHOENIX, ARIZONA 85004

SEP 1981 DEPARTMENT OF WATER RESOURCES

REGISTRATION OF EXISTING WELLS

READ INSTRUCTIONS ON BACK OF THIS FORM BEFORE COMPLETING
PRINT OR TYPE — FILE IN DUPLICATE

REGISTRATION FEE (CHECK ONE)	
EXEMPT WELL (NO CHARGE)	☐
NON-EXEMPT WELL — $10.00	☒

FOR OFFICE USE ONLY
REGISTRATION NO. 55- 600188
FILE NO. B(16-21) 35 cdd
FILED 9-18-81 (DATE) AT 8 am (TIME)
INA ✓
AMA ✓

1. Name of Registrant:
Southwest Gas of Arizona Well No. 1
Box 646, Bullhead City, AZ 86430
(Address) (City) (State) (Zip)

2. File and/or Control Number under previous groundwater law: (08-33)
B (16-21) 35- cdd
(File Number) (Control Number)
Topock-1

3. a. The well is located within the SE ¼ SE ¼ SW ¼, Section 35, of Township 16N N/S, Range 21W E/W, G & SRB & M, in the County of Mohave.

b. If in a subdivision: Name of subdivision _____, Lot No. _____, Address _____.

4. The principal use(s) of water (Examples: irrigation - stockwater - domestic - municipal - industrial)
PG&E Gas Compressor Station and 4 meters serving 30 people.

5. If for irrigation use, number of acres irrigated from well N/A.

6. Owner of land on which well is located. If same as Item 1, check this box ☐
Santa Fe Railroad
Winslow, AZ 86047
(Address) (City) (State) (Zip)

7. Well data (If data not available, write N/A)
a. Depth of Well 33'8" feet
b. Diameter of casing 12-1/2 inches
c. Depth of casing N/A feet
d. Type of casing Steel.
e. Maximum pump capacity N/A gallons per minute.
f. Depth to water N/A feet below land surface.
g. Date well completed _____ (Month) _____ (Day) 1962 (Year).

8. The place(s) of use of water. If same as Item 3, check this box ☐.
____¼ ____¼ ____¼, Section ____ Township 8T7N (?) Range 24E
____¼ ____¼ ____¼, Section ____ Township ____ Range ____
Attach additional sheet if necessary.

9. DATE 9/15/81 SIGNATURE OF REGISTRANT [signature]

DEPARTMENT OF WATER RESOURCES
GROUNDWATER MANAGEMENT SUPPORT SECTION
500 North Third Street
Phoenix, Arizona 85004-3903
Phone (602) 417-2470 Fax (602) 417-2422

RECEIVED
NOV 17 1995
GROUNDWATER MGT

REQUEST FORM TO CHANGE WELL INFORMATION OWNERSHIP * DRILLER

Please complete the appropriate section of this request form and return to the above address with applicable fee. NOTE: A.R.S. §45-593.C requires that the Department be notified of change of well ownership and that the new owner is required to keep the Department's Well Registration records current and accurate. Well data and ownership changes must be submitted within thirty days after changes take place.

SAVE THIS FORM TO REPORT FUTURE CHANGES IN OWNERSHIP, CHANGES IN ADDRESS, OR CHANGE IN WELL DATA SUCH AS PUMP CAPACITY, CORRECTION OF LEGAL DESCRIPTION, CHANGE OF WELL DRILLER AND AMENDING INFORMATION PREVIOUSLY FILED.

RECEIVED
JAN 3 1996
GROUNDWATER MGT

1. **CHANGE OF WELL INFORMATION: (NO FEE REQUIRED)**

NOTE: If the location of the proposed well changes after drilling authority has been issued, attach a $10.00 reissue fee for each well.

WELL REGISTRATION NO. 55- N/A FILE NO: _____

If known, I/We request the following well information be changed: _____

2. **STATEMENT OF CHANGE OF WELL OWNERSHIP: ($10.00 FEE REQUIRED)**

If this change consists of more than one well and the names are common: attach a $10.00 fee. Otherwise, each well requires a separate fee of $10.00.

I, The City of Needles, state that I am the Previous/New Owner of the well described below: WELL #1 (Topock)

SE ¼ SE ¼ SW ¼ Section 35 Township 16N N/S Range 21W E/W
10 Acre 40 Acre 160 Acre

Well Registration No. 55- 600188 File No. B(16-21) 35 cdd (if known)

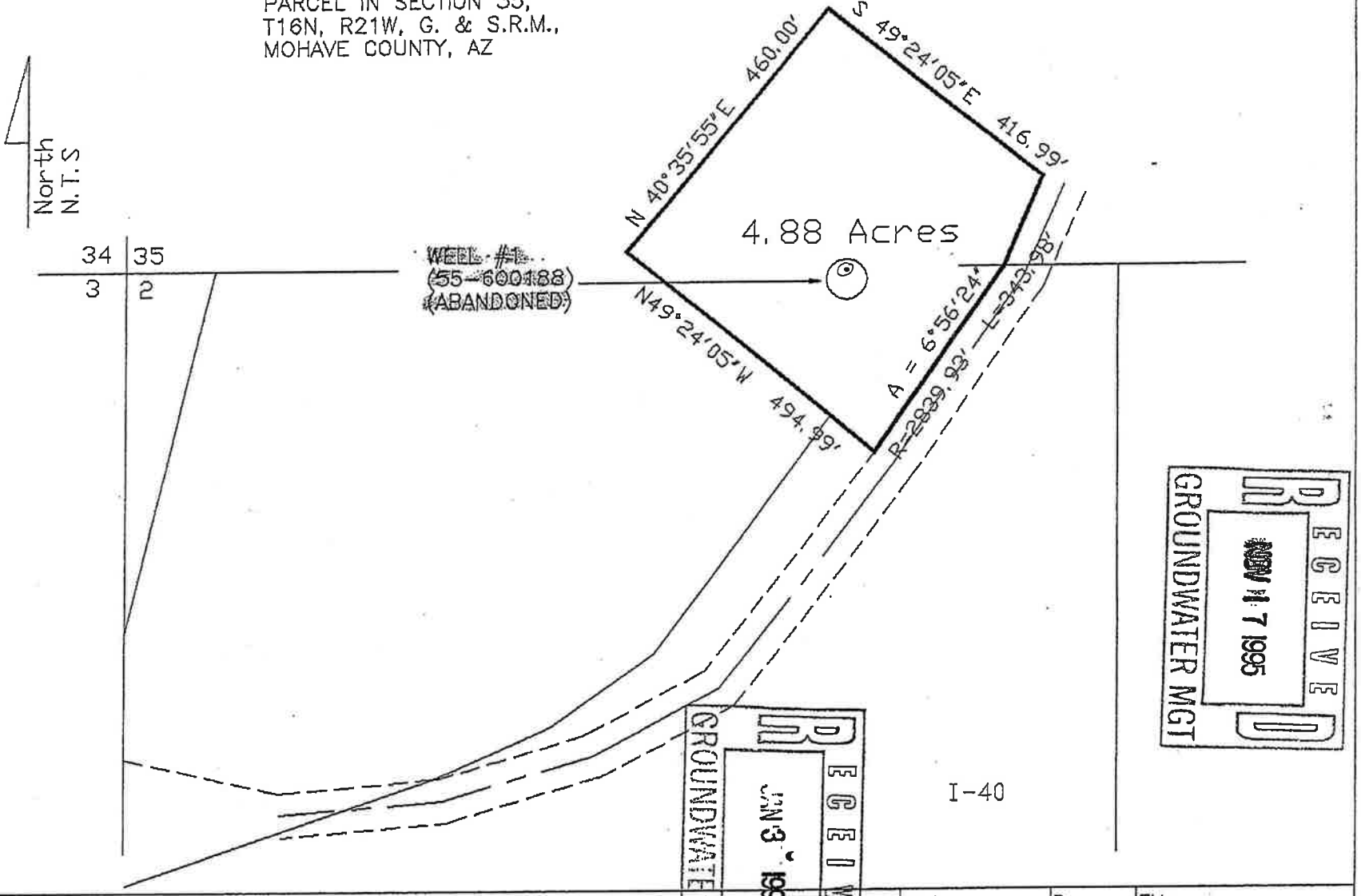
Southwest Gas of Arizona	City of Needles
PRINT Previous Owner's Name	PRINT New Owner's Name
P.O. Box 646	817 Third Street
Mailing Address	Mailing Address
Bullhead City, AZ 86430	Needles, CA 92363
City State Zip	City State Zip
(520) 754-2263	(619) 326-5700
Telephone	Telephone

Date November 7, 1995 Signature of Previous/New Well Owner _____

DWR 55-71 (Rev 10/95)

ENTERED JAN - 5 1996

CITY OF NEEDLES WELL No. 1
PARCEL IN SECTION 35,
T16N, R21W, G. & S.R.M.,
MOHAVE COUNTY, AZ



Title	Date	By	File
SITE PLAN FOR REGISTERED WELL No. 55-600188	11/07/95	J.W.	TOPOCK3.DWG

Mohave Engineering Associates, Inc.
Consulting Civil Engineers & Land Surveyors

John A. Proffit, P.E.
PRESIDENT

(602) 753-2627
FAX (602) 753-9118

Robert L. Schuetz, P.E.
Vice Pres., Office Mngr.
Thomas R. Christopher, R.L.S.
Vice Pres., Survey Mngr.

LEGAL DESCRIPTION: WELL SITE NO.1

A Parcel of land being situate in and parts of Lot 1, Section 2, Township 15 North, Range 21 West and Section 35, Township 16 North, Range 21 West of the Gila and Salt River Meridian, Mohave County, Arizona and being more particularly described by metes and bounds as follows;

Commencing at the 1/4 Section Corner common to said Section 2 and said Section 35, which point is marked by a 3" Aluminum Cap, set by the U.S. Fish and Wildlife Service, thence along the line common to said Section 2 and Section 35, S 89°44'18"W, 1504.30 feet to an intersection with and a point in the westerly right of way line of old U.S. Highway 66 and a point in the southerly line of herein described Parcel and the True Point Of Beginning;

Thence from said True Point Of Beginning and along the northwesterly right-of-way line of said old U.S. Highway 66, and the southeasterly line of herein described Parcel and along the arc of a true curve to the right, having a radius of 2839.93 feet and a back tangent of N 28°44'47"E, and through a central angle of 6°56'24" southwesterly 343.98 feet to a point and corner of herein described Parcel;

Thence leaving the northwesterly right-of-way line of old U.S. Highway 66, and along the southwesterly line of herein described Parcel, N 49°24'05"W, 494.99 feet to a point and corner of herein described Parcel;

Thence along the northwesterly line of herein described Parcel, N 40°35'55"E, 460.00 feet to a point and corner of herein described Parcel;

Thence along the northeasterly line of herein described Parcel, S 49°24'05"E, 416.99 feet to an intersection with and a point in the northwesterly right-of-way of said old U.S. Highway 66 and a corner of herein described Parcel;

Thence along the northwesterly right-of-way line of said old U.S. Highway 66, and the southeasterly line of herein described Parcel, and along the arc of a true curve to the right, having a radius of 2839.93 feet and a back tangent of N 26°15'45"E, and through a central angle of 2°29'02", southwesterly 123.11 feet to the True Point Of Beginning, said herein described Parcel containing 4.88 acres, more or less and is conveyed subject to any and all easements, reservations and rights-of-way of record or as may otherwise exist.

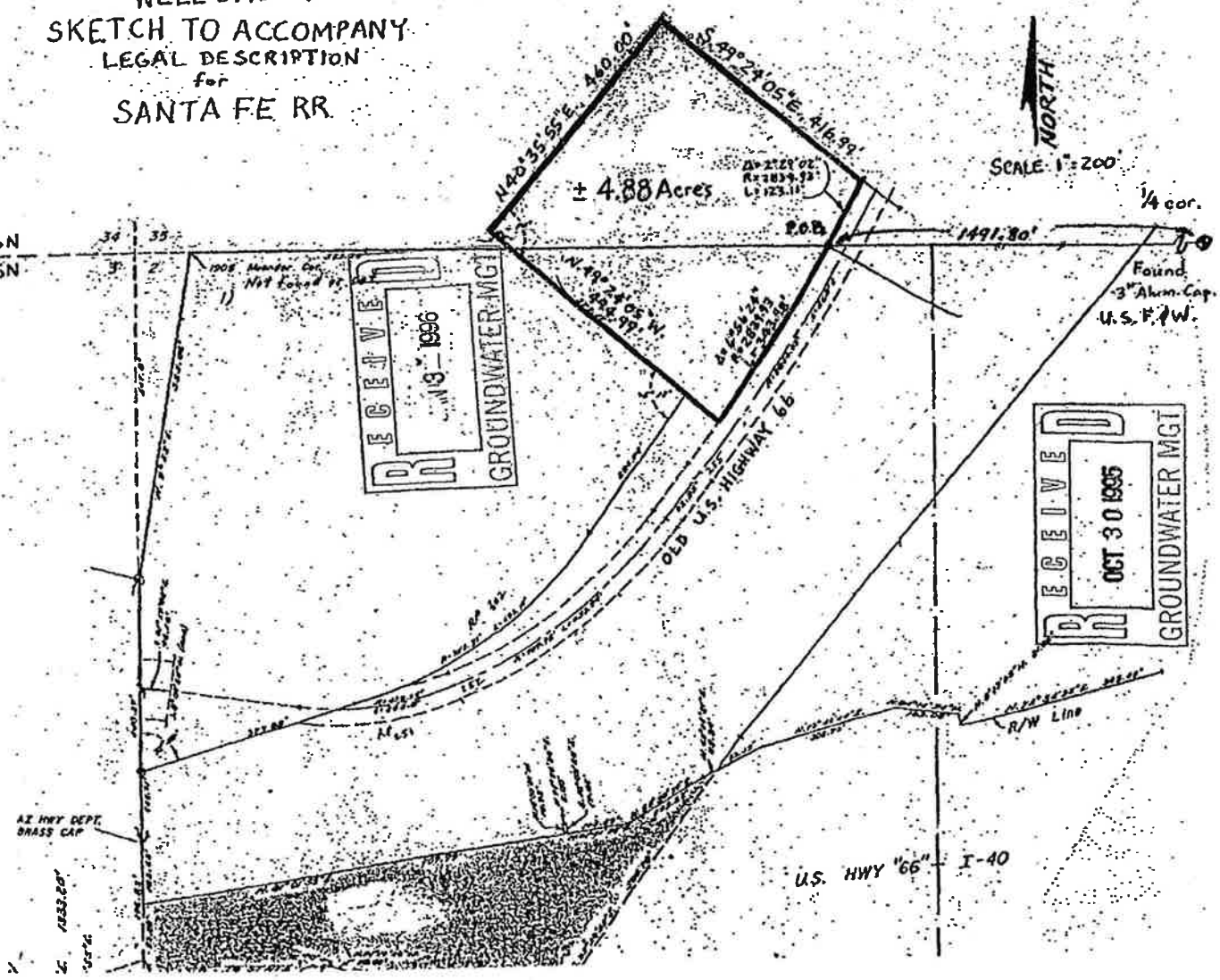
RECEIVED
NOV 3 1995
GROUNDWATER MGT

RECEIVED
OCT 30 1995
GROUNDWATER MGT

REGISTERED LAND SURVEYOR
CERTIFICATE NO.
25401
KENNETH W.
SHUMWAY
Date Signed 6-8-95
ARIZONA, U. S. A.

PAGE.006
11004510
Page 5 of 6
AUG 15 '95 9:29 FROM ASSET MANA :NT

"WELL SITE #1"
SKETCH TO ACCOMPANY
LEGAL DESCRIPTION
for
SANTA FE RR



(602) 268-1381

Topock #1

WATER QUALITY ANALYSIS - CHEMICAL

SPECIMEN NUMBER	SYSTEM NUMBER	CERTIFICATION NUMBER
	08-033	0010

NAME OF CLIENT: Southwest Gas Co.

ADDRESS: Box 646

CITY	STATE	ZIP CODE	COUNTY
Bullhead	Arizona	86430	Mohave

LAB USE ONLY
Lab Performing Test
Outside [4] 27
28 [1]

MAILING ADDRESS OF REPORT
ADDRESS: Box 646
CITY: Bullhead STATE: Arizona ZIP CODE: 86430

SYSTEM OR SOURCE NAME	CITY	WELL NUMBER
Well #1	Topock	08-033

LOCATION OF SAMPLING POINT	WELL NAME
Well Site	#1

COUNTY	TOWNSHIP	RANGE	SECTION	COLLECTED BY
Mohave	Topock			Dolan

LATITUDE	LONGITUDE	STATION NUMBER	DATE COLLECTED	HOUR
			5/16/80	1300

STORET NUMBER	CONTROL NUMBER	PRESERVATIVE ADDED?
		☐ YES ☑ NO

Lab No. 221-0505
Date Received 5-20-80
Time 1:pm S.C.

SPECIMEN UNSATISFACTORY
Reason: _____ CODE

SOURCE TYPE (check one)
☑ Well ☐ Surface ☐ Sewage ☐ Industrial ☐ Seepage

SOURCE DATA (check each applicable box)
☐ Public System ☐ Treated ☑ Routine Sample
☐ Individual System ☑ Untreated ☐ Re-Sample
☑ Semi Public System ☐ Special
☐ Grab Sample ☐ New Source
☐ Composite Sample ☑ Existing Source

SAMPLER'S COMMENTS: _____

		ME/L	Mg/L
10	☐ ROUTINE WATER CHEMISTRY		
11	☐ Electrical Conductivity, mmhos/cm 1.03		
12	☐ pH 7.9		
13	☐ CATIONS		
14	☐ Calcium		24
15	☐ Magnesium		6
16	☐ Sodium		131
17	☐ Iron		<.1
18	☐ Copper		<.02
19	☐ Manganese		<.02
20	☐ Zinc		.06
59	☐ Potassium		6
	TOTAL CATIONS		
21	☐ ANIONS		
22	☐ Alk P ($CaCO_3$)		<1.2
23	☐ Alk MO ($CaCO_3$)		119.6
24	☐ Chloride		186
25	☐ Nitrate (10.0)		3.3 ✓
26	☐ Sulfate		63.8
27	☐ Phosphate		
28	☐ Fluorides (1.4-2.4)		.5 ✓
38	☐ Nitrite		
60	☐ Sulfide		
61	☐ Silica		
	TOTAL ANIONS		

		Mg/L
29	☐ Solids	514
30	☐ Residue	
31	☐ Total Dissolved Solids (Calc.)	493
32	☐ Hardness ($CaCO_3$)	85
62	☐ Total Alkalinity as ($CaCO_3$)	98
33	☐ Total Soluble Salts (EC)	659
34	☐ V.S.S.	
35	☐ Foaming Agents (MBAS)	
36	☐ B.O.D.	
37	☐ C.O.D.	
39	☐ Kjeldahl Nitrogen Total	
40	☐ Other	
63	☐ Dissolved Oxygen (DO)	

		Mg/L
41	☐ TRACE METALS (Mg/l)	✓
42	☐ Arsenic (.05)	<.02
43	☐ Silver (.05)	<.02
44	☐ Chromium (0.05)	<.02
45	☐ Cadmium (0.01)	<.005
46	☐ Lead (0.05)	<.02
47	☐ Selenium (0.01)	<.01
48	☐ Mercury (.002)	<.001
57	☐ Barium (1.0)	<.5
58	☐ Chromium Hexavalent	
50	☐ SPECIAL	
49	☐ Boron	
51	☐ Radiological	
52	☐ Oil and Grease	
53	☐ C.C.E.	
54	☐ Phenols	
55	☐ Pesticides	
56	☐ PHYSICAL	
	☐ Color	
	☐ Taste	
	☐ Odor	
	☐ Turbidity	

☒ Acceptable for Public Usage
☐ Rejected for Public Usage
☐ Based on Parameters Run
Evaluated by M Nichols
Bureau of Water Quality Control
Date 6-11-80

PGS434588

Comments _____

Analyst _____ Date Reported 5-29-80

ARIZONA DEPARTMENT OF HEALTH SERVICES

#1 well

Division of Environmental Health Services

BRUCE BABBITT, Governor
SUZANNE DANDOY, M.D., M.P.H., Director

Date: 6-23-80

Southwest Gas Co
Box 646
Bullhead AZ 86430

Gentlemen:

RE: Chemical Analysis for addressee

Water System No. 08-033, Collected on 5-16-80

Sample type: Source X, System _____, Unknown _____

The interpretation of the chemical examination of the attached laboratory report No. 221-0505 shows that this sample does not exceed the maximum contaminant levels for inorganic chemicals and therefore is acceptable for use in a public water system in accordance with State regulation R9-8-221. This is not an approval of the referenced public water system, but merely an evaluation of the chemical quality of a sample of water which has been taken from that system.

BUREAU OF WATER QUALITY CONTROL
Safe Drinking Water Unit
by M Nelson

ff
cc: Northern Regional Office
Mohave County Health Department
Facility File

Enclosures

PGS434587

INTER-OFFICE MEMO

WRITE IT — DON'T SAY IT

To: Dennis Wood

Date 7-1-80

☐ Reply requested

☐ No reply necessary

Subject: Report # 221-0505

Here is a copy of the above report.
The water chemical analysis tested OK and
is acceptable for Public Usage.

From [signature]

FORM NO. 126

PGS434586

Topock #1

TEL. FAIRVIEW 7-8566

P. O. BOX 867

HORNKOHL LABORATORIES, Inc.

CHEMICAL AND TESTING ENGINEERS

714 TRUXTUN AVENUE

BAKERSFIELD, CALIFORNIA

January 15, 1968

LABORATORY NO. 188804

SAMPLE MARKED: Arizona Well #1, 1-5-68.

RECEIVED: January 11, 1968

SUBMITTED BY: Pacific Gas and Electric Company
P . O. Box 488
Barstow, California 92311
Attn: R.W. Horton

Purchase Order #LO-893141

DOMESTIC WATER ANALYSIS

CONSTITUENTS		PARTS PER MILLION		GRAINS PER GALLON		CLASSIFICATION
Carbonates (CO_3)	–	0.0	–	0.00	–	Good
Bicarbonates (HCO_3)	–	123.2	–	7.20	–	Good
Chlorides (Cl)	–	256.7	–	15.01	–	Fair
Sulfates (SO_4)	–	99.8	–	5.84	–	Good
Sulfides (S)	–	0.0	–	0.00	–	Good
Ammonia (NH_3)	–	Trrace	–	Trace	–	Good
Nitrites (NO_2)	–	0.0	–	0.00	–	Good
Nitrates (NO_3)	–	10.8	–	0.63	–	Good
Calcium (Ca)	–	36.4	–	2.13	–	Good
Magnesium (Mg)	–	7.8	–	0.46	–	Good
Sodium (Na)	–	204.2	–	11.94	–	Good
Iron (Fe)	–	0.1	–	0.01	–	Good
Silica, Si		27.5		1.61		Good
Hardness as $CaCO_3$	–	123.0	–	7.19	–	Fair
Total Solids @ 105°C.	–	708.9	–	41.46	–	Fair
pH	–	– –	7.8			Good
Conductivity Mhos/cm x10^5 @ 25°C.	–	– –	137.9			Good
Color	–	– –	Water White			
Odor	–	– –	None			
Turbidity	–	– –	Clear			
Fluorides, F	-	4.0		0.23		Should not exceed 1 ppm.
Manganese, Mn	-	0.00		---		Good

Thecretical Analysis

Calcium Bicarbonate	-	147.5	8.63
Magnesium Bicarbonate	-	14.6	0.85
Magnesium Sulfate	-	26.5	1.55
Sodium Sulfate	-	116.5	6.81
Sodium Chloride	-	423.3	24.75

PGS435942

Remarks: As noted by the classification column, the Chlorides, Fluorides, Hardness and Total Solids are above the recommendations of the State Department of Public Health.

Respectfully submitted,
HORNKOHL LABORATORIES, INC.

Heinz D. Pickel

Heinz D. Pickel, Chief Chemist

P:ap

STATE OF CALIFORNIA, DEPARTMENT OF PUBLIC HEALTH, APPROVED WATER LABORATORY

ALL REPORTS ARE SUBMITTED AS THE CONFIDENTIAL PROPERTY OF CLIENTS. AUTHORIZATION FOR PUBLICATION OF OUR REPORTS, CONCLUSIONS OR EXTRACTS FROM OR REGARDING THEM IS RESERVED PENDING OUR WRITTEN APPROVAL AS A MUTUAL PROTECTION TO CLIENTS, THE PUBLIC AND OURSELVES.

TEL. FAIRVIEW 7-8567 P.O. BOX 867

HORNKOHL LABORATORIES, Inc.

CHEMICAL AND TESTING ENGINEERS
714 TRUXTUN AVENUE
BAKERSFIELD, CALIFORNIA

January 15, 1168

Laboratory No. 188806
Sample Water
Received January 11, 1968
Submitted by Pacific Gas and Electric Company
P. O. Box 488
Barstow, California 92311
Attn: R. W. Horton

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC HEALTH
APPROVED WATER LABORATORY

Purchase Order #LO-893141

BACTERIOLOGICAL EXAMINATION

DATE AND HOUR COLLECTED: January 5, 1968
COLLECTED BY: R. P. Jacobs
ORIGINAL SOURCE: Well
POINT SAMPLE OBTAINED: Arizona Well #1

	LACTOSE BROTH 24 HOURS	LACTOSE BROTH 48 HOURS	BILE BROTH 24 HOURS	BILE BROTH 48 HOURS
10 CC. SAMPLES				
No. 1	—	Negative - Negative	—	
No. 2	—	Negative - Negative	—	
No. 3	—	Negative - Negative	—	
No. 4	—	Negative - Negative	—	
No. 5	—	Negative - Negative	—	
1 CC. SAMPLE				
No. 1	—		—	
0.1 CC. SAMPLE				
No. 1	—		—	

M.P.N.: Less than 2.2/100 ml.

TOTAL BACTERIA COUNT (PLATE COUNT/24 HOURS) 7900

COLOR Water White
ODOR None

TURBIDITY Clear

PGS435945

DP:ap

RESPECTFULLY SUBMITTED,
HORNKOHL LABORATORIES, INC.

Heinz D. Pickel

Heinz D. Pickel, Chief Chemist

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Topack #1

TEL. 8-3567 W. V. Calder

P. O. BOX 867

HORNKOHL LABORATORIES

CHEMICAL AND TESTING ENGINEERS
714 TRUXTUN AVENUE
BAKERSFIELD, CALIFORNIA

January 17, 1957

Laboratory No. 93355 *Marked* Santa Fe Well #1
Topack PG&E Comp Station

Sample Water

Received January 14, 1957

Submitted by The Pacific Gas and Electric Company
Box 3246
H Street Annex
Bakersfield, California

#1

* * * * * * * * * * *

COMPLETE INDUSTRIAL WATER ANALYSIS

Constituents	Parts Per Million	Grains Per Gallon
Carbonates	0.0	0.00
Bicarbonates	115.9	6.78
Chlorides	200.0	11.70
Sulfates	84.5	4.94
Sulfides	0.0	0.00
Calcium	31.2	1.82
Magnesium	4.9	0.29
Sodium	168.8	9.87
Iron	0.1	
Hardness as $CaCO_3$	98.0	5.73
Total Solids @ 105°C:	545.0	31.87
Total Solids @ Red Heat	505.0	29.53

pH: 7.3
Color: Water White
Odor: None
Turbidity: Clear
Conductivity: Mhos/cm^3x10^5@25°C: 87.2

THEORETICAL ANALYSIS

PGS435943

Calcium Bicarbonate	126.4	7.39
Magnesium Bicarbonate	24.9	1.46
Magnesium Sulfate	3.6	0.21
Sodium Sulfate	120.7	7.06
Sodium Chloride	329.7	19.28

Respectfully submitted,

HORNKOHL LABORATORIES

Frank Hornkohl

mk

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TRACTS FROM OR REGARDING THEM IS RESERVED PEND-

TEL. 8-8567 W. V. Adler

P. O. BOX

HORNKOHL LABORATORIES

CHEMICAL AND TESTING ENGINEERS

714 TRUXTUN AVENUE

BAKERSFIELD, CALIFORNIA

January 24, 1957

Laboratory No. 93854 - 93855 *Marked* See Below

Sample Water

Received January 14, 1957

Submitted by Pacific Gas and Electric Company
Box 3246
H Street Annex
Bakersfield, California

* * * * * * * * * * *

SILICA CONTENT

	Parts Per Million	Grains Per Gallon
Colorado River Water Topaz PG&E Comp. Station ----	59.2	3.46
Santa Fe Well #1 Topaz PG&E Comp. Station ----	29.6	1.73

Respectfully submitted,

HORNKOHL LABORATORIES

Chief Chemist

mk

PGS435944

ALL REPORTS ARE SUBMITTED AS THE CONFIDENTIAL PROPERTY OF CLIENTS. AUTHORIZATION FOR PUBLICATION OF STATEMENTS OR CONCLUSIONS OR EXTRACTS FROM OR REGARDING THEM IS RESERVED PENDING OUR WRITTEN APPROVAL AS A MUTUAL PROTECTION TO OURSELVES AND CLIENTS.
KERN PTG. CO.

Attachment 4
Topock-2 and -3 Wells Information

(*On CD-ROM only*)

DEPARTMENT OF WATER RESOURCES
99 EAST VIRGINIA AVENUE
PHOENIX, ARIZONA 85004

SEP 1981 DEPARTMENT OF WATER RESOURCES

REGISTRATION OF EXISTING WELLS

READ INSTRUCTIONS ON BACK OF THIS FORM BEFORE COMPLETING
PRINT OR TYPE — FILE IN DUPLICATE

02

REGISTRATION FEE (CHECK ONE)	
EXEMPT WELL (NO CHARGE)	☐
NON-EXEMPT WELL — $10.00	☒

FOR OFFICE USE ONLY
REGISTRATION NO. 55- 600187
FILE NO. B(16-21)35 cdd
FILED 9-18-81 (DATE) AT 8am (TIME)
INA ✓
AMA ✓

1. Name of Registrant:
Southwest Gas of Arizona Well No. 3
Box 646, (Address) Bullhead City, (City) AZ (State) 86430 (Zip)

2. File and/or Control Number under previous groundwater law: (08-33)
B (16-21) (File Number) 35- cdd (Control Number)

3. a. The well is located within the SE ¼ SE ¼ SW ¼, Section 35, of Township 16N N/S, Range 21W E/W, G & SRB & M, in the County of Mohave.
b. If in a subdivision: Name of subdivision _____, Lot No. _____, Address _____.

4. The principal use(s) of water (Examples: irrigation - stockwater - domestic - municipal - industrial)
PG&E Gas Compressor Station and 4 meters serving 30 people.

5. If for irrigation use, number of acres irrigated from well N/A.

6. Owner of land on which well is located. If same as Item 1, check this box ☐
Santa Fe Railroad
Winslow, (City) AZ (State) 86047 (Zip) (Address)

7. Well data (If data not available, write N/A)
a. Depth of Well 250 feet
b. Diameter of casing 12 inches
c. Depth of casing N/A feet
d. Type of casing Steel.
e. Maximum pump capacity 300 gallons per minute.
f. Depth to water N/A feet below land surface.
g. Date well completed 5 (Month) 17 (Day) 74 (Year).



8. The place(s) of use of water. If same as Item 3, check this box ☐.
____¼ ____¼ ____¼, Section ____ Township 8T 7N Range 24E
____¼ ____¼ ____¼, Section ____ Township ____ Range ____
Attach additional sheet if necessary.

9. DATE 9/15/81 SIGNATURE OF REGISTRANT Don Tutts

DEPARTMENT OF WATER RESOURCES
GROUNDWATER MANAGEMENT SUPPORT SECTION
500 North Third Street
Phoenix, Arizona 85004-3903
Phone (602) 417-2470 Fax (602) 417-2422

RECEIVED
NOV 17 1995
GROUNDWATER MGT

REQUEST FORM TO CHANGE WELL INFORMATION
OWNERSHIP * DRILLER

Please complete the appropriate section of this request form and return to the above address with applicable fee. NOTE: A.R.S. §45-593.C requires that the Department be notified of change of well ownership and that the new owner is required to keep the Department's Well Registration records current and accurate. Well data and ownership changes must be submitted within thirty days after changes take place.

SAVE THIS FORM TO REPORT FUTURE CHANGES IN OWNERSHIP, CHANGES IN ADDRESS, OR CHANGE IN WELL DATA SUCH AS PUMP CAPACITY, CORRECTION OF LEGAL DESCRIPTION, CHANGE OF WELL DRILLER AND AMENDING INFORMATION PREVIOUSLY FILED.

1. CHANGE OF WELL INFORMATION: (NO FEE REQUIRED)

NOTE: If the location of the proposed well changes after drilling authority has been issued, attach a $10.00 reissue fee for each well.

WELL REGISTRATION NO. 55- N/A FILE NO: _____

If known, I/We request the following well information be changed: _____

RECEIVED
JAN 3 1996
GROUNDWATER MGT

2. STATEMENT OF CHANGE OF WELL OWNERSHIP: ($10.00 FEE REQUIRED)

If this change consists of more than one well and the names are common: attach a $10.00 fee. Otherwise, each well requires a separate fee of $10.00.

I, The City of Needles, state that I am the Previous/~~New Owner~~ of the well described below:

WELL #3 (Topock) Topock-3

SE ¼ SE ¼ SW ¼ Section 35 Township 16N N/S Range 21W E/W
10 Acre 40 Acre 160 Acre

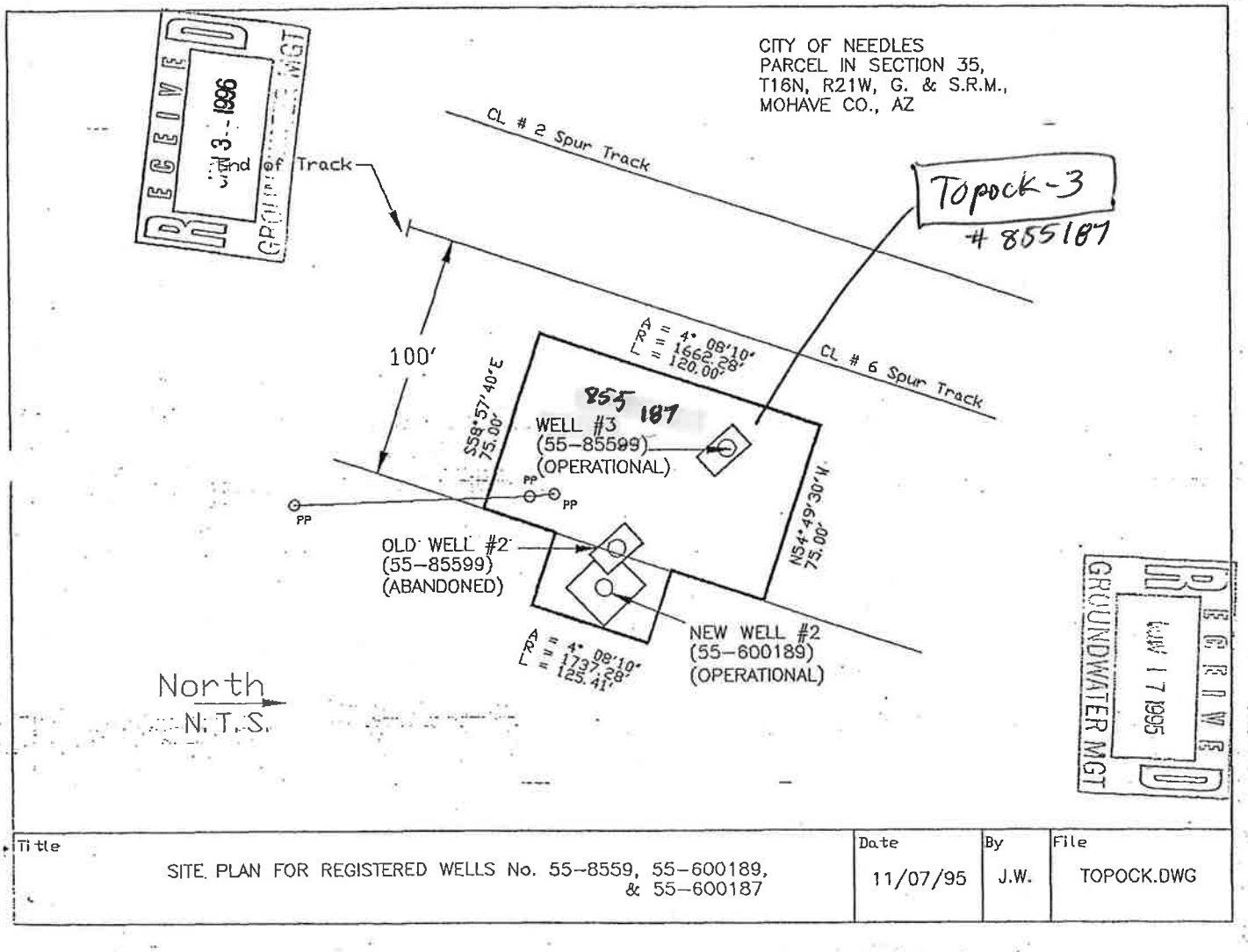
Well Registration No. 55- 600187 File No. B(16-21) 35 cdd (if known)

Southwest Gas of Arizona	City of Needles
PRINT Previous Owner's Name	PRINT New Owner's Name
P.O. BOX 646	817 Third Street
Mailing Address	Mailing Address
Bullhead City, AZ 86430	Needles, CA 92363
City State Zip	City State Zip
(520) 754-2263	(619) 326-5700
Telephone	Telephone

Date Nov. 7, 1995 Signature of Previous/~~New Well Owner~~ _____

DWR 55-71 (Rev 10/95)

ENTERED JAN - 5 1996



Title	Date	By	File
SITE PLAN FOR REGISTERED WELLS No. 55-8559, 55-600189, & 55-600187	11/07/95	J.W.	TOPOCK.DWG

Topock #3

Phone (702) 878-7757

DRILLING & PUMPS INC.
3521 SPRING MOUNTAIN ROAD
LAS VEGAS, NEV. 89102

Topock-3

June 5 1974

Southwest Gas Corporation
P O Box 246
Bullhead City Ariz

Well #3 at Topack Ariz

Drillers log of formations

0-11	sand & boulders
11-23	gravel.sand & boulders
23-30	gravel w/ few boulders
30-33	boulder
33-43	clay
43-46	silty sand
46-52	boulders & gravel
52-91	clay w/ interbedded rock
91-146	boulders & gravel
146-180	decomposed granite
180-250	decomposed granite w/ rhyolite boulders

DEPARTMENT OF WATER RESOURCES
99 EAST VIRGINIA AVENUE
PHOENIX, ARIZONA 85004



REGISTRATION OF EXISTING WELLS

READ INSTRUCTIONS ON BACK OF THIS FORM BEFORE COMPLETING
PRINT OR TYPE — FILE IN DUPLICATE

02

FOR OFFICE USE ONLY	
REGISTRATION NO. 55-	600189
FILE NO.	B(16-21)35cdd
FILED (DATE)	9-18-81
AT (TIME)	8am
INA	✓
AMA	✓

REGISTRATION FEE (CHECK ONE)	
EXEMPT WELL (NO CHARGE)	☐
NON-EXEMPT WELL — $10.00	☒

Topock-2

1. Name of Registrant:
   Southwest Gas of Arizona Well No. 2
   Box 646, Bullhead City, Arizona 86430
   (Address) (City) (State) (Zip)

2. File and/or Control Number under previous groundwater law: (08-33)
   B (16-21) 35- cdd
   (File Number) (Control Number)

3. a. The well is located within the SE ¼ SE ¼ SW ¼, Section 35, of Township 16N N/S, Range 21W E/W, G & SRB & M, in the County of Mohave.
   b. If in a subdivision: Name of subdivision _____, Lot No. _____, Address _____.

4. The principal use(s) of water (Examples: irrigation - stockwater - domestic - municipal - industrial)
   PG&E Gas Compressor Station and 4 meters serving 30 people.

5. If for irrigation use, number of acres irrigated from well N/A.

6. Owner of land on which well is located. If same as Item 1, check this box ☐
   Santa Fe Railroad
   Winslow, AZ 86047
   (Address) (City) (State) (Zip)

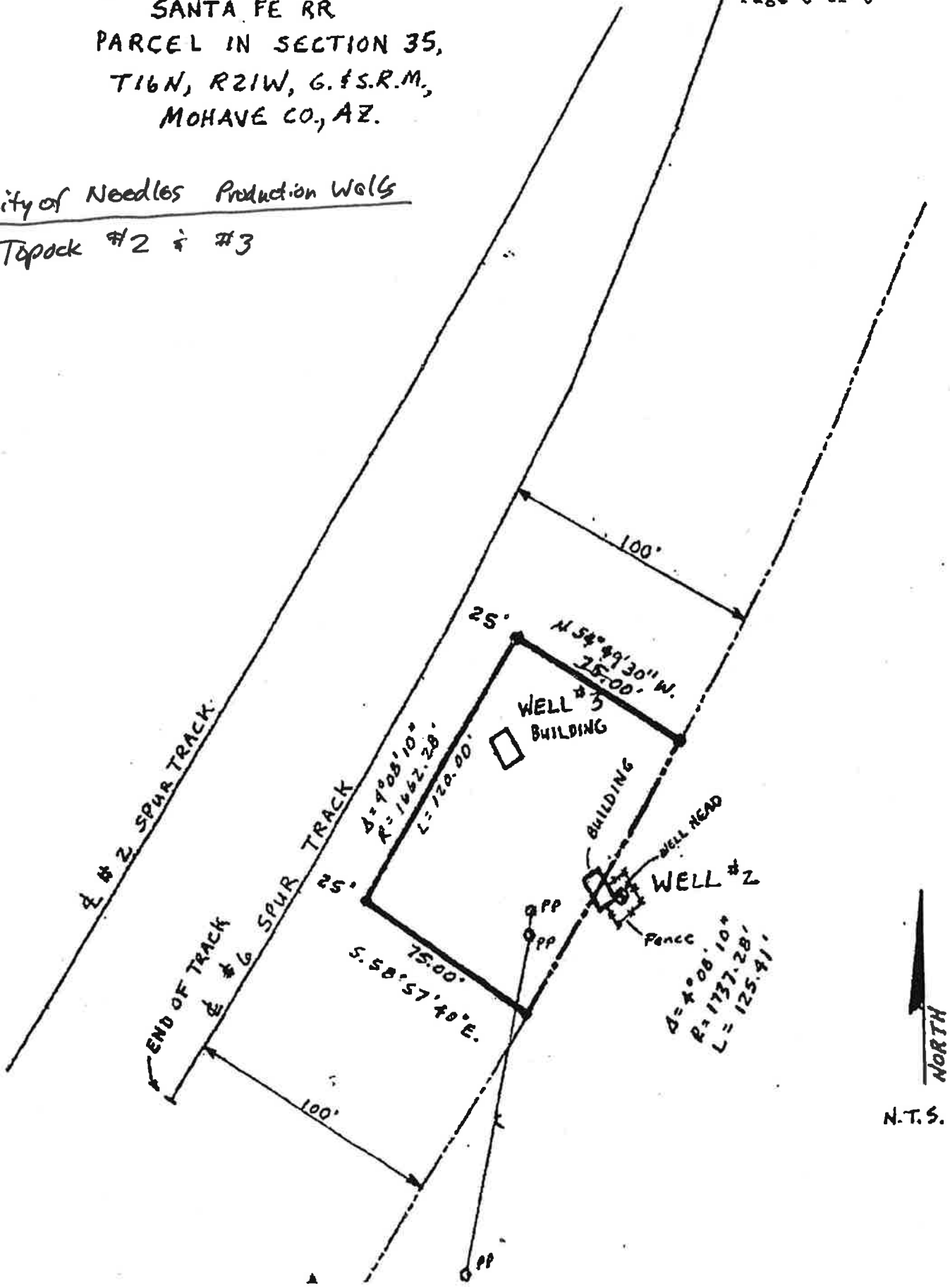
7. Well data (If data not available, write N/A)
   a. Depth of Well 150 feet
   b. Diameter of casing 12" inches
   c. Depth of casing N/A feet
   d. Type of casing Steel.
   e. Maximum pump capacity 400 gallons per minute.
   f. Depth to water N/A feet below land surface.
   g. Date well completed N/A (Month) (Day) (Year).

8. The place(s) of use of water. If same as Item 3, check this box ☐.
   ____¼ ____¼ ____¼, Section ____ Township 8T 7N Range 24E
   ____¼ ____¼ ____¼, Section ____ Township ____ Range ____
   Attach additional sheet if necessary.

9. DATE 9/15/81 SIGNATURE OF REGISTRANT [signature]

SKETCH WELL SITE No. 2 & 3
SANTA FE RR
PARCEL IN SECTION 35,
T16N, R21W, G. & S.R.M.,
MOHAVE CO., AZ.

City of Needles Production Wells
Topock #2 & #3



Mohave Engineering Associates, Inc.
Consulting Civil Engineers & Land Surveyors

John A. Proffit, P.E.
PRESIDENT

(602) 753-2627
FAX (602) 753-9118

Robert L. Schuetz, P.E.
Vice Pres., Office Mngr.
Thomas R. Christopher, R.L.S.
Vice Pres., Survey Mngr.

LEGAL DESCRIPTION: WELL SITE NO. 2 & 3

A Parcel of land situate in and being a part of Section 35, Township 16 North, Range 21 West of the Gila and Salt River Meridian, Mohave County, Arizona and being more particularly described as follows;

Commencing at the South one quarter (1/4) of said Section 35, thence along the southerly line of said Section 35, S 89°44'18"W, 1007.15 feet to an intersection with and a point in the easterly right-of-way line of The Atchison, Topeka and Santa Fe Railway;

Thence along the easterly right-of-way line of The Atchison, Topeka and Santa Fe Railway, N 38°39'33"E, 501.01 feet to a point of curve;

Thence along the arc of a true curve to the left having a radius of 1737.28 feet and through a central angle of 7°37'13", northeasterly an arc distance of 231.06 feet to the True Point Of Beginning and the corner of herein described Parcel;

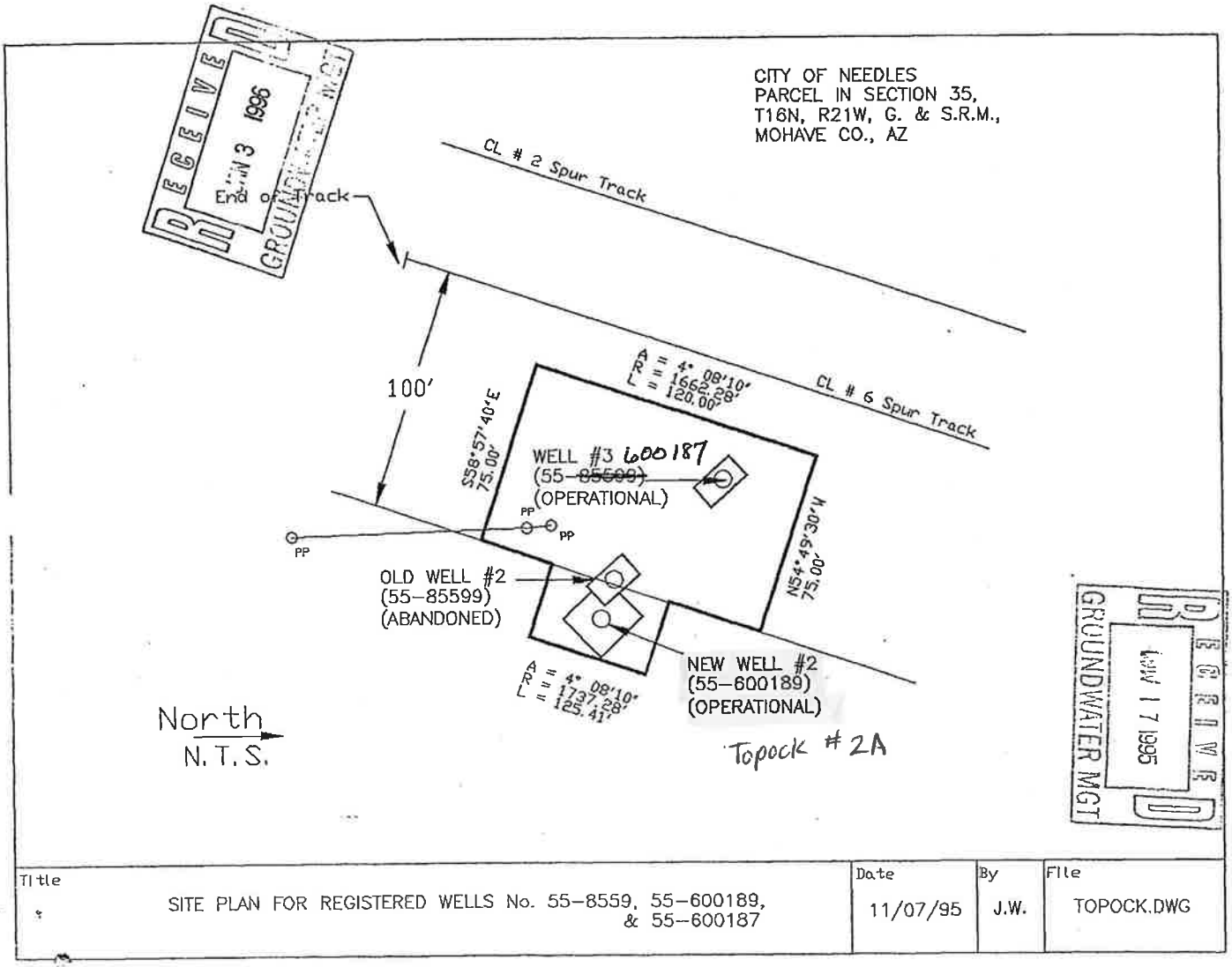
Thence from the True Point of Beginning and corner of herein described Parcel and continuing along the easterly right-of-way line of The Atchison, Topeka and Santa Fe Railway and the arc of a true curve to the left having a radius of 1737.28 feet and through a central angle of 4°08'10", northeasterly an arc distance of 125.41 feet to a point and corner of herein described Parcel;

Thence leaving the easterly right-of-way line of The Atchison, Topeka and Santa Fe Railway and along the northeasterly line of herein described Parcel, N 54°49'30"W, 75.00 feet to a point and corner of herein described Parcel;

Thence along the northwesterly line of herein described Parcel and along the arc of a true curve to the right, having a radius of 1662.28 feet and through a central angle of 4°08'10", southwesterly an arc distance of 120.00 feet to a point and corner of herein described Parcel;

Thence along the southwesterly line of herein described Parcel, S 58°57'40"E, 75.00 feet to the True Point Of Beginning, said herein described Parcel containing 0.21 acres, more or less, and is conveyed subject to any and all easements, reservations and rights-of-way of record or as may otherwise exist.





Title	Date	By	File
SITE PLAN FOR REGISTERED WELLS No. 55-8559, 55-600189, & 55-600187	11/07/95	J.W.	TOPOCK.DWG

15

STATE OF ARIZONA

DEPARTMENT OF
WATER RESOURCES

WELL DRILLER'S REPORT

This report should be prepared by the driller in all detail and filed with the Department within 30 days following completion of the well.

1. Owner Southwest Gas of Arizona
Name
Box 646, Bullhead City, Az 86430
Address

2. Lessee or Operator SAME AS BELOW
Name
Address

3. Driller ~~Wellotte & Askow~~
Name
Address

4. Location of well: T16N, R21W, Sec. 35, SE¼ SE¼ SW¼

5. Permit No. (if issued) 55-85599

DESCRIPTION OF WELL

6. Total depth of hole 140' ft.
7. Type of Casing STEEL
8. Diameter and length of casing 12 in. from 0' to 140', _____ in from _____ to _____.
9. Method of sealing at reduction points _____
10. Perforated from 100' to 140', from _____ to _____, from _____ to _____
11. Size of cuts ¼" x 3" Number of cuts per foot 10
12. If screen was installed: Length _____ ft. Diam _____ in. Type _____
13. Method of construction _____ (drilled) dug, driven, bored, jetted, etc.
14. Date started 9 (Month) 24 (day) 80 (year)
15. Date completed 9 (Month) 29 (day) 80 (year)
16. Depth to water 47' ft. (If flowing well, so state.)
17. Describe point from which depth measurements were made, and give sea-level elevation if available.
ground level approx. 550' above sea level
18. If flowing well, state method of flow regulation _____
19. REMARKS: _____

DO NOT WRITE IN THIS SPACE
OFFICE RECORD
Registration No. 55-85599
Received _____ By _____
Entered OCT 2 8 1980 By [illegible]
File No. B(16-21)35 cdd

(Well log to appear on Reverse side)



Topock - 2

LOG OF WELL

Indicate depth at which water was first encountered, and the depth and thickness of water bearing beds. If water is artesian, indicate depth at which encountered, and depth to which it rose in well.

FROM (FEET)	TO (FEET)	DESCRIPTION OF FORMATION MATERIAL
0'	50'	Boulders
50'	60'	SANDSTONE
60'	97'	" + CLAY
97	107	GRAVEL
107	130	Broken granite (sm. amount of clay).
130	140	Broken granite
		1st h²O 97'
		Bearing h²O strata 97 - 140'

I hereby certify that this well was drilled by me (or under my supervision), and that each and all of the statements herein contained are true to the best of my knowledge and belief.

Driller Wellette + A. Sikes
Name

POB 2268 Blue Ar. 86430
Address

Date 10-7-80

222 North Central Ave., Suite 850
Phoenix, Arizona 85004

Registration No. 55-85599
Owner of
Well Site Southwest Gas of Arizona

File No. B(16-21)35 cdd

COMPLETION REPORT

1. Completion Report to be filed with the Department within 30 days after installation of pump equipment.

2. The tested pumping capacity of the well in gallons per minute for a non-flowing well should be determined by measuring the discharge of the pump after continuous operation for at least 4 hours and for a flowing well by measuring the natural flow at the land surface.

3. Drawdown of the water level for a non-flowing well should be measured in feet after not less than 4 hours of continuous operation and while still in operation and for a flowing well the shut-in pressure should be measured in feet above the land or in pounds per square inch at the land surface.

4. The static groundwater level should be measured in feet from the land surface immediately prior to the well capacity test.

LOCATION OF THE WELL

Topock-2

T16N, R21W, Sec. 35, SE¼ SE¼ SW¼ .

Date Well Completed 9-24-80 Depth of Well 140'

1. Well Test:
Test Pumping Capacity 400 (Gal. per min.) Date Well Tested 10/15/80

Method of Discharge Measurement Current Meter (weir, orifice, current meter, etc.)

Static Groundwater Level 50' 8" ft. Drawdown 25' ft.

Total Pumping Lift 425' ft. Drawdown _____ lbs. (Flowing Well)

2. Equipment Installed:

Kind of Pump Submersible Turbine (turbine, centrifugal, etc.)

Kind of Power Elec (Elec., Nat. Gas, Etc.) H.P. Rating of Motor 60

I HEREBY CERTIFY that the above statements are true to the best of my knowledge and belief.

Signature

P.O. Box 1178
Address

12/10/80, 19
Date

Bullhead City Az 86430
City State Zip

Attachment 5
HNWR-1 Well Information

(*On CD-ROM only*)

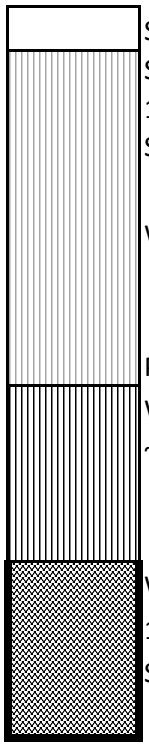
General Description of Sacramento Wash Irrigation Well
Havasu Nationa Wildlife Refuge
Summarized: Brad Guay, 11/24/2010

Water Quality

Depth (Ft below grade)

From	To	Temp °C	pH	TDS
0	10			
10	20			
20	30			
30	40	26.7°	8.0	495
40	50	30.2°	7.5	430
50	60	31.8°	7.5	429
60	70	32.0°	7.0	403
70	80	33.0°	7.0	398
80	90	32.5°	7.0	338
90	100	34.7°	6.5	356
100	110	33.5°	7.0	349
110	120	34.1°	7.0	392
120	130	33.5°	7.0	420
130	140	34.1°	7.0	435
140	150	30.8°	7.0	445
150	160	30.0°	7.0	435

Well Diagram



Stratigraphy

Depths

0 - 34'	**Silty Clay**, Lt. Br with some sand and gravel, saturated after 6'
35 - 74'	**Sand and Gravel,** mostly med-coarse sand, w/ some pea to cobble sized gravel; fluvial?, good water yield
75 - 82'	**Sand**, some clay and gravel; possibly interbedded layers; maybe fluvial/alluvial contact?, more sub-angular and sub-rounded material; @ 82' water bearing again, with foamy "milky coffee" appeareance; TDS drop
83 - 156.5'	**Sand, w/ gravel,** f-c sand with variable gravel; esp. coarse, hard gravel 85-92' that was water bearing; fairly uniform after 92', moderate water yield.

Attachment 6
Additional Topock-3 Well Information

(*On CD-ROM only*)

ENGINEERS TESTING LABORATORIES, INC.
3737 East Broadway Road
P. O. Box 21387
Phoenix, Arizona 85036
(602) 268-1381

423 South Olsen Avenue
Tucson, Arizona 85719
(602) 624-8894

2400 East Industrial Drive
Flagstaff, Arizona 86001
(602) 774-4881

Topock #3

LABORATORY REPORT

WATER QUALITY ANALYSIS - CHEMICAL

SPECIMEN NUMBER	SYSTEM NUMBER	CERTIFICATION NUMBER
	08-033	0010

NAME OF CLIENT: SOUTHWEST GAS CO.

ADDRESS: BOX 646

CITY	STATE	ZIP CODE	COUNTY
BULLHEAD CITY	AZ.	86430	MOHAVE

LAB USE ONLY
Lab Performing Test
Outside [4] 27
28 [1]

MAILING ADDRESS OF REPORT: GLEN D. DOLAN
ADDRESS: P.O. BOX 187

CITY	STATE	ZIP CODE
NEEDLES	CALIF.	92363

SYSTEM OR SOURCE NAME	CITY	WELL NUMBER

LOCATION OF SAMPLING POINT: #3 WELL
WELL NAME:

COUNTY	TOWNSHIP	RANGE	SECTION	COLLECTED BY
MOHAVE				DOLAN

LATITUDE	LONGITUDE	STATION NUMBER	DATE COLLECTED	HOUR
			2-26-79	

STORET NUMBER	CONTROL NUMBER	PRESERVATIVE ADDED?
		☐ YES ☐ NO

Lab No. 241-2915
Date Received 2-28-79
Time 8A

SPECIMEN UNSATISFACTORY
Reason: _____ CODE

SOURCE TYPE (check one)
☒ Well ☐ Surface ☐ Sewage ☐ Industrial ☐ Seepage

SOURCE DATA (check each applicable box)
☒ Public System ☐ Treated ☐ Routine Sample
☐ Individual System ☒ Untreated ☐ Re-Sample
☐ Semi Public System ☒ Special
☐ Grab Sample ☒ New Source
☐ Composite Sample ☐ Existing Source

SAMPLER'S COMMENTS: GIVE FULL ANALYSIS TO SEE IF WATER IS DRINKABLE.

10 ☐ ROUTINE WATER CHEMISTRY
11 ☐ Electrical Conductivity, mmhos/cm .21
12 ☐ pH 8.4

	ME/L	Mg/L
13 ☐ CATIONS		
14 ☐ Calcium		38.3
15 ☐ Magnesium		.9
16 ☐ Sodium		486
17 ☐ Iron		.98
18 ☐ Copper		.05
19 ☐ Manganese		0.02
20 ☐ Zinc		0.04
59 ☐ Potassium		
TOTAL CATIONS		
21 ☐ ANIONS		
22 ☐ Alk P ($CaCO_3$)		0.01
23 ☐ Alk MO ($CaCO_3$)		97.6
24 ☐ Chloride		616
25 ☐ Nitrate (10.0)		1.0
26 ☐ Sulfate		38.7
27 ☐ Phosphate		
28 ☐ Fluorides (1.4-2.4)		5.0
38 ☐ Nitrite		
60 ☐ Sulfide		
61 ☐ Silica		
TOTAL ANIONS		

	Mg/L
29 ☐ Solids	1376
30 ☐ Residue	
31 ☐ Total Dissolved Solids (Calc.)	1278.5
32 ☐ Hardness ($CaCO_3$)	41.8
62 ☐ Total Alkalinity as ($CaCO_3$)	80
33 ☐ Total Soluble Salts (EC)	138.2
34 ☐ V.S.S.	
35 ☐ Foaming Agents (MBAS)	
36 ☐ B.O.D.	
37 ☐ C.O.D.	
39 ☐ Kjeldahl Nitrogen Total	
40 ☐ Other	
63 ☐ Dissolved Oxygen (DO)	

	Mg/L
41 ☐ TRACE METALS (Mg/l)	
42 ☐ Arsenic (.05)	< .02
43 ☐ Silver (.05)	< 0.05
44 ☐ Chromium (0.05)	< 0.05
45 ☐ Cadmium (0.01)	< .0005
46 ☐ Lead (0.05)	< .02
47 ☐ Selenium (0.01)	< 0.01
48 ☐ Mercury (.002)	.0007
57 ☐ Barium (1.0)	< .5
58 ☐ Chromium Hexavalent	
50 ☐ SPECIAL	
49 ☐ Boron	
51 ☐ Radiological	
52 ☐ Oil and Grease	
53 ☐ C.C.E.	
54 ☐ Phenols	
55 ☐ Pesticides	
56 ☐ PHYSICAL	
☐ Color	
☐ Taste	
☐ Odor	
☐ Turbidity	

☐ Acceptable for Public Usage
☐ Rejected for Public Usage
☐ Based on Parameters Run
Evaluated by _____
Bureau of Water Quality Control
Date _____

PGS434671

Comments: CHLORIDE EXCEEDS RECOMMENDED LIMITS
SOLIDS EXCEED RECOMMENDED LIMITS

Analyst: John J. Kline
Date Reported 3/20/79

20-74

Topock #3

FOX TESTING LABORATORIES, INC.

201 PARIS BOX 1299
LUBBOCK, TEXAS 79408
(806) 763-4518

11/22/78

f- #3

Mineral
Water Analysis

Dater Received: 11/[illegible]/78 17-Nov-78 Sample Date
Lab Number 123[illegible]3
Date Tested: 11/27/78

For: Coley Chemcial Corporation P. O. Box 2039 Lubbock, Texas 79408

pH	7.6 mg/l	Chloride (Cl)	930 mg/l
Total Iron (Fe)	0.10 mg/l	'P' Alkalinity ($CaCO_3$)	2.0 mg/l
Manganese (Mn)	0.01 mg/l	Total Alkalinity ($CaCO_3$)	86.0 mg/l
Nitrogen Nitrate (N)	1.0 mg/l	Hydroxide (OH)	0 mg/l
Sulfate (SO_4)	150 mg/l	Bicarbonate (HCO_3)	82.0 mg/l
Nitrate (NO_3)	4.4 mg/l	Carbonate CO_3	4.0 mg/l
Fluoride (F)	6.2[illegible] mg/l	Magnesium (Mg)	3 mg/l
Silica (S_1O_2)	32.7 mg/l	Sodium (Na)	536 mg/l
Calcium (Ca)	46 mg/l	Dissolved Solids	1747.3 mg/l
Total Hardness	132.8 mg/l		

Other: _____ _____

_____ _____

This water sample ( ) does or (X) does not meet USPHS drinking requirements.

Reasons: Chloride should not exceed 250 mg/l. Fluoride should not exceed 1.2mg/l
Total Dissolved Solids should not exceed 500mg/l

Respectfully submitted,
Fonnie Fox
Fox Testing Laboratories, Inc.

PGS434668

COTEY CHEMICAL CORPORATION

Area Code 806 747-2096 Box 2039 Lubbock, Texas 79408

November 30, 1978

OFFICE &
WAREHOUSE
E. AVENUE G

Please find attached a copy of the analysis on the water sample you recently sent us. The well is most likely clogged with both hard water and calcium carbonate scale. We would recommed using our Dry Acid Special to clear up this problem.

Please also note the high chloride content and the statement that this water does not meet USPHS drinking requirements.

Very truly your,

COTEY CHEMICAL CORPORATION

Ken James
President

Encls:

PGS434669

Attachment 7
Topock-2/3 Pump Test Results

(*On CD-ROM only*)

Summary of Pumping Tests at Topock 2 and 3 Wells, PG&E Topock Compressor Station, Needles, California

PREPARED FOR: Pacific Gas and Electric Company

PREPARED BY: CH2M HILL

DATE: July 25, 2012

Introduction

In support of the groundwater remedy design, pumping tests were conducted in the Topock 2 and Topock 3 wells in December 2011. The purpose of these tests was to evaluate the pumping capacity and efficiency of these wells as a potential supply of fresh water for the remedy. The wells, which are currently owned and operated by Southwest Water, provide water to three residences and the PG&E Topock Compressor Station (referred herein as "Compressor Station"). The usage by the residences averages less than one gallon per minute (gpm), assuming continuous pumping. The Compressor Station uses about 100-110 gpm. The wells feed a storage tank in Arizona that serves the residential customers and two storage tanks at the Topock Compressor Station that provide water to the Compressor Station.

Both wells are equipped with the same make and model of pump, with a maximum pumping rate of about 200 gpm. The pumps are set at a depth of about 105 feet ('). Static depth to water at the time of the test ranged between 54' and 57', allowing for a maximum of 50' of available drawdown in each well. The Topock 3 well (referred to as SWW-2 by Southwest Water) was pumped in the afternoon of December 13th, between about 2:30 and 4:10 pm. The Topock 2 well (SWW-1) was pumped in the morning of December 14th, between about 8:30 and 10:00 am.

The pump test method was a step-drawdown test, where the pumping rate was increased incrementally in a series of steps while drawdown was measured in the pumping well. This test was designed to evaluate the performance of the well rather than measure the properties of the aquifer. The test method is based on an equation developed by Jacob (1946) that describes the drawdown in the well as a sum of a first order (laminar) component (BQ) and a second order (turbulent) component (CQ^2):

$$s = BQ + CQ^2$$

Where s represents drawdown, Q represents pumping rate, and B and C are constants specific to the well and aquifer.

Biershenk (1964) developed a graphical method to solve for B and C. By plotting s/Q against Q, the data from a step test forms a straight line with slope C and intercept B.

Topock 2 (SWW-1) Test Results

The Topock 2 well was pumped in a series of four steps at rates ranging from 108 to 202 gpm (Figure 1). The maximum drawdown observed was about 5.6'. This well appears to be fairly efficient. The driller's report from 1980 notes a drawdown of 25' at a pumping rate of 400 gpm, corresponding to a specific capacity of 16 gpm per foot. During the step test, the drawdown was about 5.6' at a pumping rate of 202 gpm, resulting in a specific capacity of 36 gpm per foot. The Beirshenk plot of the data is provided in Figure 2. From this plot, B is calculated to be 0.0217 and C is 0.00003. These values suggest that the well could produce over 900 gpm with the available drawdown. It is unlikely that the efficiency of a 30+ year old well would be more than double that when it was new. It is more likely that the step test has over-estimated the capacity of this well due to the inability of the current pump to adequately stress the well. When a well is not adequately stressed during the step test, the

turbulent flow term (CQ^2) may be underestimated. The step test did, however, indicate that the performance of the Topock 2 well has not declined dramatically since it was drilled. It remains a fairly efficient well, likely capable of producing at least 400 gpm.

Topock 3 (SWW-2) Test Results

The Topock 3 well was pumped in a series of four steps at rates ranging from 19 to 200 gpm (Figure 3). The maximum drawdown observed was about 49.5'. In contrast to Topock 2, the Topock 3 well appears to be no longer efficient. The driller's report from 1974 notes a drawdown of 10' at a pumping rate of 600 gpm, resulting in a specific capacity of 60 gpm per foot. During the step test, the drawdown was about 49.5' at a pumping rate of 200 gpm, resulting in a specific capacity of 4 gpm per foot. The pump exhibited surging, indicating intermittent cavitation due to lack of sufficient water depth above the pump intake.

The well was originally drilled to a depth of 250', with perforated casing from 88' to 130', 150' to 190', and 210' to 250'. It is assumed that this was the condition of the well when it was originally tested at 600 gpm. It was reported that the well was found to produce poor quality water and at some point the bottom 100' of the well were cemented shut. There is no record of what effect this had on the capacity of the well.

A video of the well taken by the Arizona Department of Environmental Quality (ADEQ) as part of their Topock Groundwater Study shows blank casing to a depth of 114' with stainless steel wire-wrapped screen from 114' to about 128' (ADEQ 2006). The well was reported by ADEQ to be blocked at 128' with sediment in the bottom and what appears to be a piece of railroad track iron extending about 1 foot up out of the bottom of the well. Based on the well video (ADEQ 2006), the stainless steel screen appears to be mostly open and in good condition, but the mild steel casing above the screen appears to be badly corroded and in relatively poor condition. In its current condition, the maximum production rate for this well is slightly less than 200 gpm. The Beirshenk plot of the data is provided in Figure 4. From this plot, B is calculated to be 0.048 and C is 0.001.

Conclusions

Step drawdown tests of approximately 1.5 hour duration were conducted on consecutive days at wells Topock 2 and Topock 3. These tests utilized the existing 200 gpm pumps installed in the wells. The Topock 2 well appears to be fairly efficient such that the 200 gpm pump installed in the well is not capable of producing enough drawdown to sufficiently stress the well for an aquifer test. The Topock 3 well is inefficient such that it can be pumped dry at a flow rate of 200 gpm. The two wells are located about 70' apart. There would be hydraulic interference if both wells were pumped at the same time. Consequently, it is likely that not much more water could be produced by pumping both wells than by pumping Topock 2 alone.

References

Arizona Department of Environmental Quality (ADEQ) 2006**.** *Topock Groundwater Study, Topock, Arizona*. August.

Biershenk, W.H., 1964. *Determining Well Efficiency by Multiple Step-Drawdown Tests*. Publication 64, International Association of Scientific Hydrology.

Jacob, C.E., 1946. Drawdown test to determine effective radius of artesian well. *Transactions, American Society of Civil Engineers*, Vol. 112, pp 1047-1070.

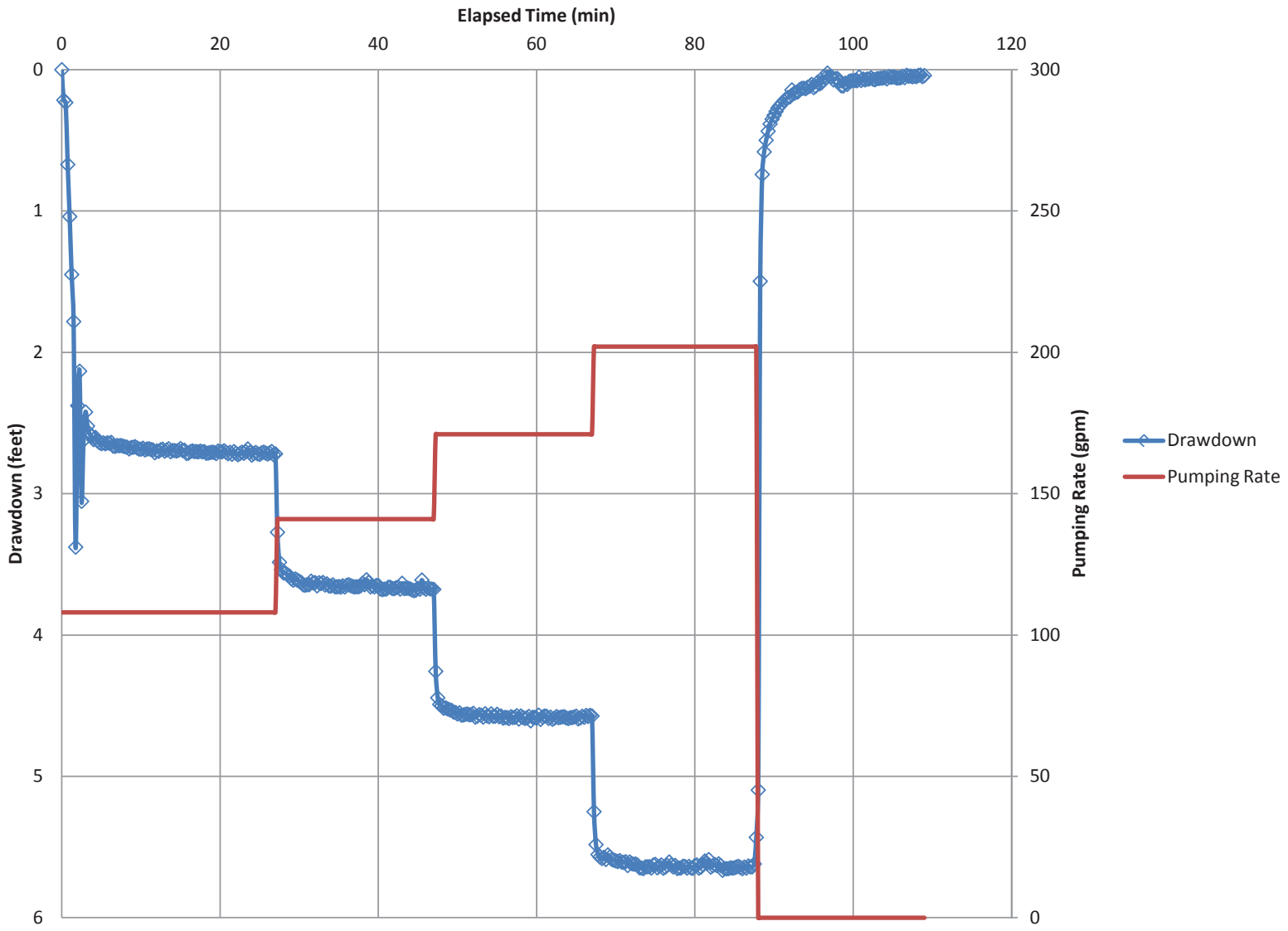


FIGURE 1
Topock-2 (SWW-1) Drawdown and Pumping Rate – December 2012
Groundwater Remedy Basis of Design Report
Intermediate (60%) Design
PG&E Topock Compressor Station
Needles, California

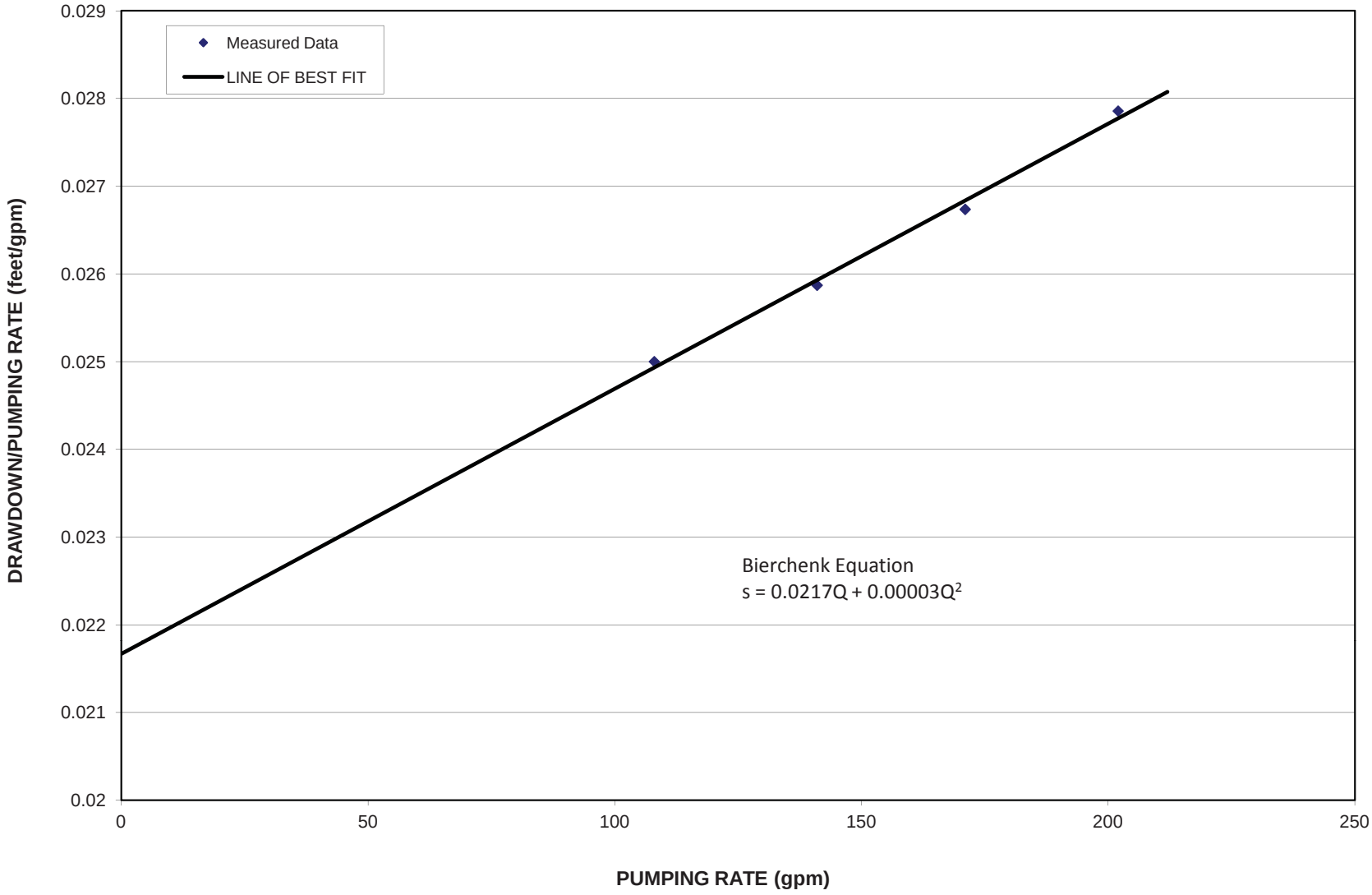


FIGURE 2
Hantush-Biershenk Plot of Topock-2 (SWW-1) Step Test – December 2012
Groundwater Remedy Basis of Design Report
Intermediate (60%) Design
PG&E Topock Compressor Station
Needles, California

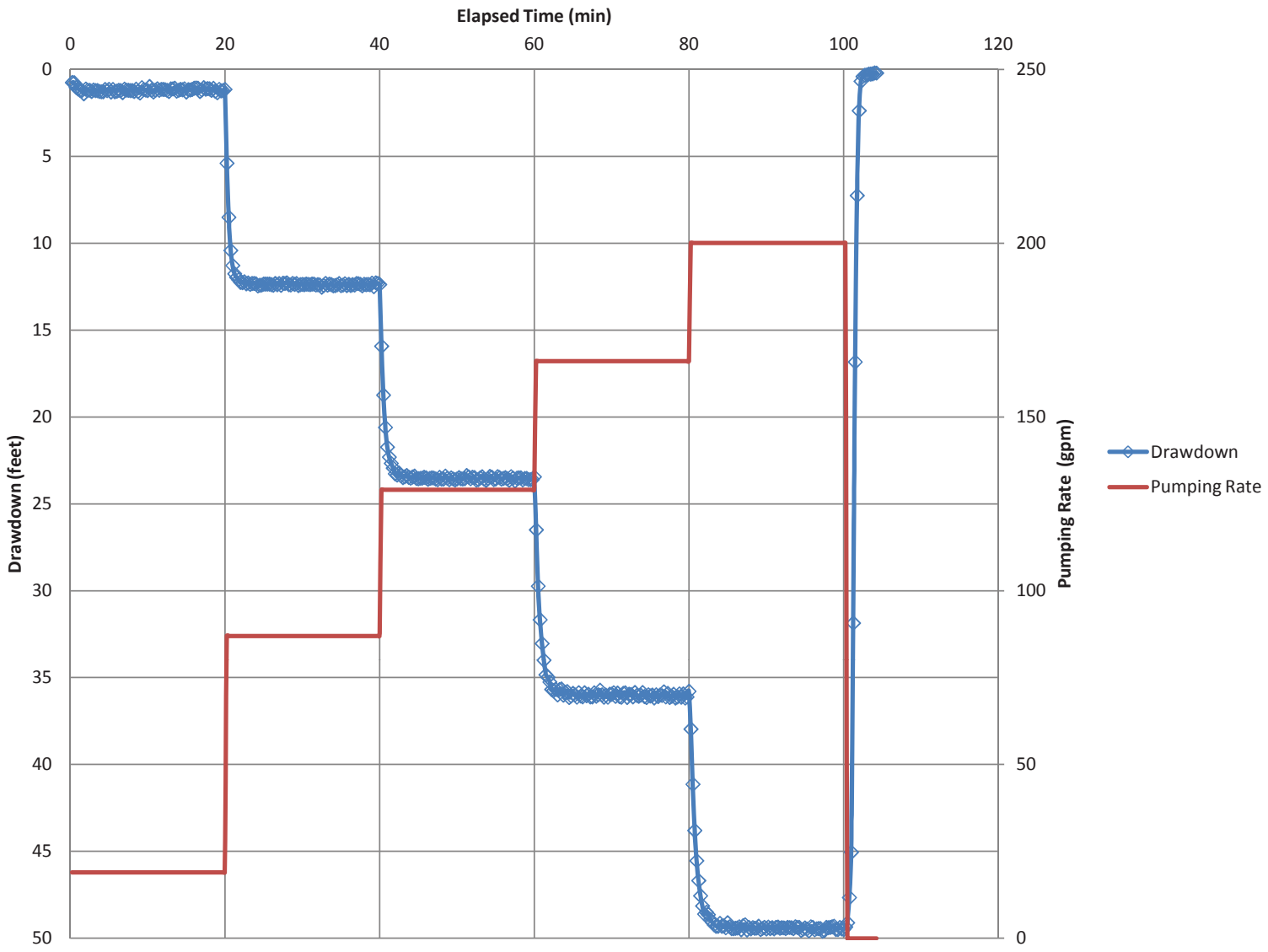


FIGURE 3
Topock-3 (SWW-2) Drawdown and Pumping Rate – December 2012
Groundwater Remedy Basis of Design Report
Intermediate (60%) Design
PG&E Topock Compressor Station
Needles, California

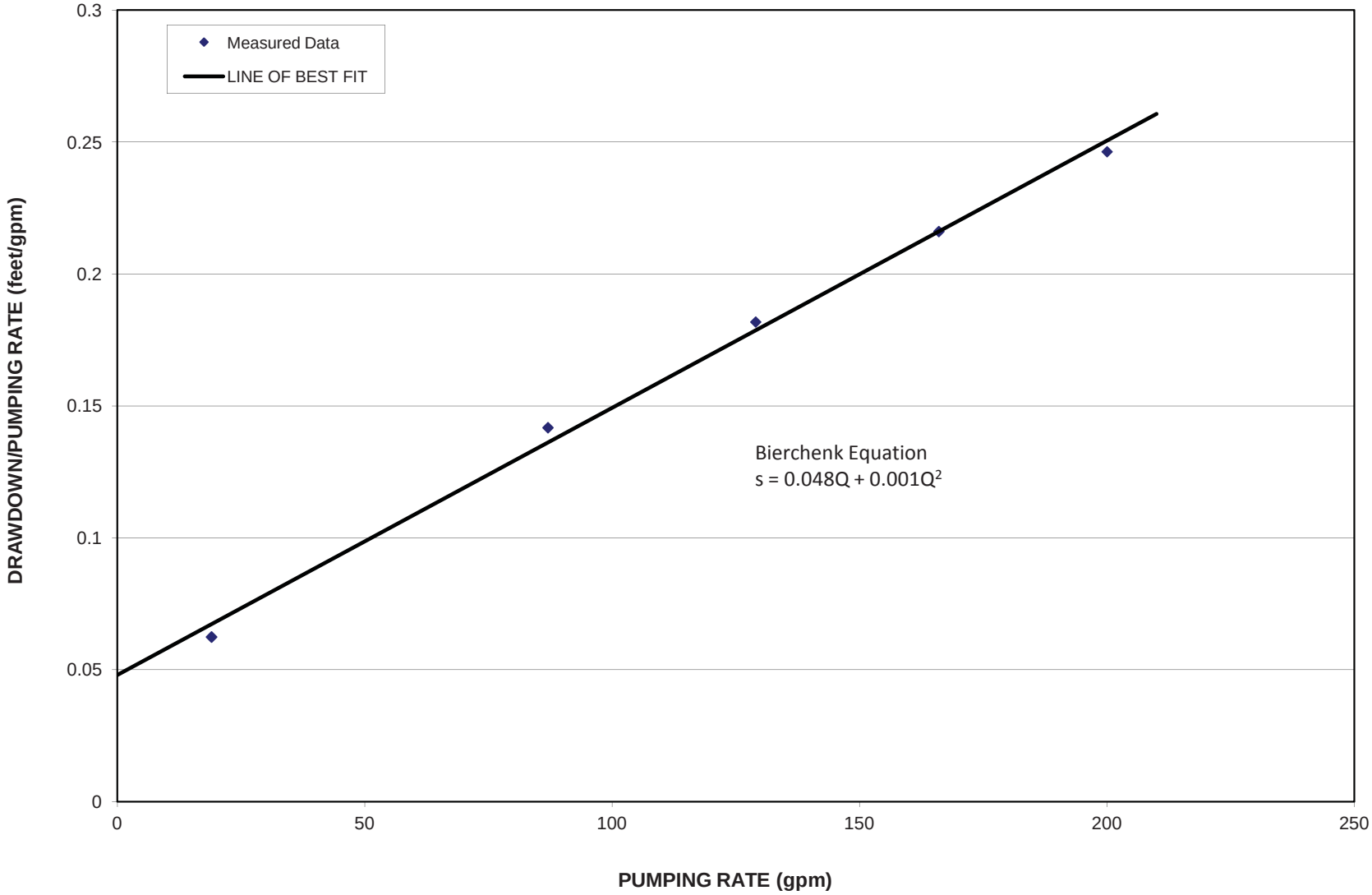


FIGURE 4
Hantush-Biershenk Plot of Topock-3 (SWW-2) Step Test – December 2012
Groundwater Remedy Basis of Design Report
Intermediate (60%) Design
PG&E Topock Compressor Station
Needles, California

Appendix K
Revised East Ravine Groundwater Investigation Addendum

(To be provided in a future submittal)

Appendix L
Draft Operations and Maintenance Manual

This appendix is presented under separate cover in a standalone volume, as well as on the CD-ROM version of the BOD Report.

Appendix M
Freshwater Pre-Injection Treatment System Design Basis Memorandum

Freshwater Pre-injection Treatment System Design Basis PG&E Topock Compressor Station, Needles, California

PREPARED FOR: Pacific Gas and Electric Company

PREPARED BY: CH2M HILL

DATE: April 4, 2013

1.0 Introduction

In compliance with the California Environmental Protection Agency, Department of Toxic Substances Control (DTSC) directive dated December 31, 2012 (DTSC, 2012), and as discussed at the January 16, 2013 Consultative Working Group (CWG) and January 17, 2013 Technical Working Group (TWG) meetings, Pacific Gas and Electric Company (PG&E) is including, in this 60-percent Basis of Design (BOD) Report, the design of a pretreatment system for polishing Arizona groundwater to California drinking water standards prior to injection for the purpose of the remedy. It is assumed that the primary source of the Arizona groundwater is water from the Havasu National Wildlife Refuge well (HNWR-1), and the secondary source is water from the current PG&E Topock Compressor Station (TCS) source wells (Topock-2/3). This assumption will be revisited after completion of the alternative freshwater source evaluation—the work plan is currently under review by DTSC and the United States Department of the Interior. The pretreatment system, referred to herein as the freshwater pre-injection treatment system (FWPTS), is located within the allowed footprint at the TCS, next to the planned remedy-produced water-conditioning plant. All components of the FWPTS are located on previously disturbed areas within the PG&E-owned parcel.

Pending agencies guidance on what level of treatment if any will be required for various constituents in the freshwater source, the conservative treatment goals of the FWPTS are arsenic removal to concentrations less than the federal and California maximum contaminant level (MCL) of 10 micrograms per liter (µg/L) and fluoride removal to concentrations less than the California MCL of 2 milligrams per liter (mg/L) (California Department of Public Health, 2013). This technical memorandum discusses the evaluation of available treatment technologies for arsenic and fluoride; the selection of technologies for bench-scale testing; the results from on-going bench-scale testing at CH2M HILL's Applied Science Laboratory (ASL) in Corvallis, Oregon; and the design basis/design criteria for the FWPTS. This document also includes a process flow diagram, a preliminary equipment layout, and a preliminary list of key equipment.

The design information presented herein has been developed based on Topock-specific information (that is, bench-scale testing results of HNWR-1 water available to date) and experience in designing and operating arsenic and fluoride groundwater treatment systems on non-Topock projects. Because of its location, the FWPTS will be designed to achieve a safe, harmonious, and sustainable operation within TCS over the anticipated decades-long life of the remedy. Additional engineering efforts are being conducted to complete the detailed design of the FWPTS and to optimize the system from a physical footprint perspective (system layout, building design, including coordination of facilities with the adjacent remedy-produced water conditioning building, etc.) and a long-term operational footprint perspective (waste generation, management of waste, including coordination with the remedy-produced water conditioning operation, etc.).

This information is based on ongoing studies and will be updated as additional bench-scale testing results become available, and as the detailed design/optimization efforts progresses (target completion in summer 2013). Once the detailed design is complete, this technical memorandum will be revised and submitted along with the detailed design documents. PG&E will also provide updates to state and federal agencies, interested Tribes, members of the CWG/TWG, members of the Clearinghouse Task Force, and the Technical Review Committee of progress and key findings from the efforts that PG&E is pursuing related to the FWPTS.

2.0 Freshwater Water Quality, Treatment Goals, and Design Flow Rates

PG&E has collected and analyzed six samples from HNWR-1 since November 2010. Analytical results available to date indicate that the naturally occurring arsenic and fluoride concentrations in HNWR-1 water are above the federal and California MCL of 10 µg/L for arsenic and above the California MCL of 2 mg/L for fluoride (Federal MCL for fluoride is 4 mg/L). Analytical results for HNWR-1 are presented in Table 1 (included at the end of this technical memorandum and also in Appendix J of the 60 percent BOD Report). As previously mentioned, the conservative treatment goals for the FWPTS are to remove arsenic to below 10 µg/L and fluoride to below to 2 mg/L.

The total freshwater supply flow rates are based on the sum of: (1) the modeled freshwater flows into the freshwater and Inner Recirculation Loop injection wells and (2) the TCS demand. The FWPTS will be designed to treat freshwater for remedy injection only. Exhibit 1 shows the freshwater and FWPTS design flow rates.

EXHIBIT 1
Design Flow Rates
Freshwater Pre-injection Treatment System Design Basis Memorandum,
PG&E Topock Compressor Station, Needles, California

Element	Unit	Minimum Flow	Nominal Flow	Maximum Flow
Freshwater Supply (HNWR-1)	gpm	260	560	1,010
Freshwater Pre-Injection Treatment System (FWPTS)[a]	gpm	150	450	900

[a] Freshwater source is greater than FWPTS because some of the freshwater will be used at the TCS as it is now.

3.0 Evaluation and Selection of Treatment Technologies

For this 60 percent design, PG&E has identified and evaluated proven treatment technologies for arsenic and fluoride that are United States Environmental Protection Agency (USEPA) Best Available Technologies and have been successfully used by municipalities and industry. Unproven technologies or technologies that have not been used in full-scale applications were not considered.

The initial list included nine technologies: anion exchange, activated alumina (AA), reverse osmosis (RO), electrodialysis reversal (EDR), lime softening, distillation, iron-based adsorbents, titanium-based adsorbents, and coagulation/filtration (see Exhibit 2). These technologies were evaluated and screened in a two-step process: (1) the initial screening was based the experience of the engineering team with the individual technology, and (2) the second-level screening was based on a set of criteria, namely treatment effectiveness, reliability and flexibility, operational complexity, waste generation, footprint, and cost effectiveness. After completion of the technology screening and evaluation process, the AA technology with disposal and regenerable adsorptive media was selected for bench-scale testing. For more details of this screening and a description of the evaluation processes, see Appendix A.

EXHIBIT 2
Technologies Considered for Arsenic and Fluoride Removal
Freshwater Pre-injection Treatment System Design Basis Memorandum,
PG&E Topock Compressor Station, Needles, California

Technology	Evaluation Status
Anion exchange	Screened out, significant waste generation
AA	**Selected for bench-testing** Primary treatment option is regenerable AA if arsenic and fluoride treatment are required
Titanium-based adsorbents	Screened out, similar as other adsorbents considered, with less experience.
Reverse osmosis (RO)	Screened out, significant waste generation.
EDR	Screened out, significant waste generation.
Lime softening	Screened out, significant waste generation.
Distillation	Screened out, significant energy use and capital cost.
Coagulation filtration	Screened out because this technology does not treat fluoride.
Iron-based adsorbents	Screened out because this technology does not treat fluoride.

4.0 Summary of Ongoing Bench-scale Testing Results

The objectives of bench-scale testing were to: (1) verify the effectiveness of each adsorptive media in removing arsenic and fluoride from HNWR-1 water to the treatment goals, (2) understand the time to break through (critical for equipment sizing and waste management), and (3) understand waste generation. From a water quality perspective, the average concentration of arsenic and fluoride in the Topock Background Study was 12.3 µg/L and 3.8 mg/L, similar to that in HNWR-1 (CH2M HILL, 2009). This section summarizes the testing and results to date as it relates to arsenic and fluoride treatment.

CH2M HILL's ASL employs a testing procedure for evaluating adsorptive media effectiveness in removing arsenic and fluoride in a small-diameter laboratory column analogous to the rapid small-scale column test method developed for assessing granular-activated carbon in a continuous flow system. This method significantly reduces the amount of time and water required for testing compared to pilot-scale and full-scale systems (USEPA, 1996). A groundwater sample was collected from HNWR-1 well in early January 2013 and was shipped to ASL for bench-scale testing.

The groundwater sample was processed continuously through the column, and the treated water was sampled and analyzed for arsenic and fluoride until breakthrough (defined as at least 70 percent of the average influent concentration). After the first breakthrough, the media was regenerated, and the test was repeated. Two treatment cycles (termed Service Cycle 1 and Service Cycle 2) were conducted. The rapid small-scale column test results provide information on adsorption capacity (extent of adsorption) and the rate of adsorption (adsorption kinetics), which are the two dominant factors impacting breakthrough in the media columns.

The rapid small-scale column test for arsenic and fluoride removal was performed using the following media:

- Regenerable AA (BASF AA-400G)
- Disposable AA (BASF AA-FS50)

Prior to passing the water over the media, the groundwater was pretreated as follows: the pH was adjusted to 6.0 with hydrochloric acid and the water was injected with chlorine to maintain a residual concentration of 1 mg/L for 60 seconds (this is to oxidize any arsenite present in the water to arsenate), and was followed by inline filtration.

Treatment Effectiveness and Time to Breakthrough

Figure 1 (located at the end of this memo) shows concentrations of arsenic and fluoride in treated water versus the number of bed-volumes of groundwater passed through (one bed-volume is equivalent to the amount of adsorptive media in the column).

As shown, the regenerable media (AA-400) was effective at removing both arsenic and fluoride to below the treatment goals (the MCL for each constituent). The performance during the second treatment cycle is similar to the first cycle. For arsenic, the effluent remained less than 1 µg/L over 6,000 bed-volumes (more than 20 days of operation at maximum design flow rate of 900 gallons per minute [gpm]). For fluoride, the treated water exceeded 2 mg/L between 800 and 2,400 bed-volumes. As shown on Figure 1, fluoride concentrations remained less than 2 mg/L for more than 1,500 bed-volumes (about 5 days of operation at the maximum design flow rate of 900 gpm). Based on these results, regenerable media was carried forward into the design phase of the FWPTS for removal of both arsenic and fluoride.

Unlike the regenerable media, the disposable media (AA-FS50) was only effective at removing arsenic and not fluoride. While some of the fluoride was removed, concentrations were greater than 2 mg/L, meaning treatment goal would not be achieved; therefore, the disposable media testing was discontinued.

Wastewater Generation

The amount of wastewater generated is primarily a function of runtime, or the number of bed-volumes that are processed, between media regenerations. The longer the groundwater can be treated before the adsorptive media needs to be regenerated, the smaller the total quantity of wastewater produced. Based on the bench-testing results, fluoride is the constituent that drives the frequency of media regenerations. The number of bed-volumes to reach breakthrough at 2 mg/L for fluoride is between 800 and 2,400, as seen in both service cycles on Figure 1.

Assuming that regenerating a vessel after 1,500 bed-volumes will meet the treatment goals, the number of media regenerations per year is estimated to be 70 per in-service vessel at the maximum flowrate of 900 gpm and 35 per in-service vessel at the nominal flowrate of 450 gpm. Based on these frequencies, the range of wastewater generated could be in the millions to tens of millions of gallons per year; therefore, it is critical to optimize the process and system design to minimize the amount of wastewater generated.

Section 5 discusses the regeneration process in more details and the ongoing evaluation of ways to extend the bed life, optimize regeneration procedures, and minimize wastewater generation.

5.0 Freshwater Treatment Process and System Description

As previously mentioned, regenerable AA was selected as the treatment technology to be carried forward into the design of the FWPTS. Regenerable AA is a porous, granular, aluminum media that adsorbs ions from solution. The USEPA has identified AA as an effective media to remove arsenic[1] and fluoride (USEPA, 1984 and 2003). This section describes the design philosophy, the treatment process, and the system configuration envisioned at this stage. This section also discusses the uncertainties with the ongoing design and the work that is currently underway or being planned to address these uncertainties.

5.1 Treatment System Description

Groundwater will be pumped and conveyed from the HNWR-1 well and the current TCS source wells (Topock-2 and -3) to the existing TCS storage tanks. Water will be pumped from these tanks and will be injected with hypochlorite for arsenic oxidation and with acid to reduce pH to 6 to 6.5; both hypochlorite and depressed pH improve fluoride and arsenic removal in the media vessels. After chemical injection, water will be passed through bag or cartridge filters to remove solids that would otherwise clog the media, reducing performance and runtime. With the solids removed, the water will be divided into up to three streams and each will be processed through a single treatment media vessel (configured in parallel) in a downward flow direction. Automatic valves will divert

[1] Best available technology - Federal Register: January 22, 2001 Volume 66, Number 14, Table I.F-1.

the flow to the proper vessels and will control the flow rate into each in service vessel. The fourth treatment media vessel will be in standby mode or in regeneration mode.

To maximize bed life, treatment media vessels will be brought on line in a staggered manner. This is similar to a treat and blend method normally used in drinking water treatment. This approach will result in the discharge from each in-service vessel having different concentrations, even exceeding the treatment goals, depending upon how far into the run the vessel is. At the combined treatment media vessel discharge, fluoride and arsenic concentrations will have been reduced to less than the treatment goals. Once the combined discharge concentration of fluoride (the limiting constituent) reaches the target range, the vessel with the longest runtime will be taken out of service for regeneration and replaced with the unit in standby. The result of this staggered approach is that it increases the fluoride loading on the media between regeneration cycles and extends the bed life between regenerations. The treated water will flow to the treated water tank after passing through bag or cartridge filters to prevent solids accumulation in the tank. In the treated water tank, a portion will be reserved for later use in backwashing and regeneration and the rest will be sent to the injection wells.

5.2 Media Regeneration Process

At some point along the treatment process, the adsorptive media will lose its adsorptive capacity and will need to be regenerated. This point is anticipated to be between 800 and 2,400 bed-volumes and the actual value will be verified during full-scale operation. For the purpose of the design, it is assumed that the media vessel will be regenerated after 1,500 bed-volumes. Media regeneration will be performed using a four-step process: (1) backwash; (2) caustic regeneration with 1 percent sodium hydroxide (NaOH); (3) bed-rinsing with treated water; and (4) neutralization with 1 percent sulfuric acid (American Water Works Association, 1999). The exact sequencing and duration of the entire regeneration process will be verified and optimized during the ongoing bench-scale testing. Regeneration is expected to take 2 to 8 hours each, and will be scheduled to be completed during day shifts.

In general, the first regeneration step is the backwashing step. Backwashing “fluffs up” the media bed to prevent compaction (enabling good flow conditions) and removes fines that form through physical abrasion of the media grinding itself into smaller particles during forward and backwash flows. Backwashing occurs in an upflow mode, the reverse of normal forward down-flow operation.

The second regeneration step uses a 1-percent NaOH solution to remove the adsorbed arsenic and fluoride from the adsorption media. The arsenic and fluoride de-sorb from the media when the pH rises above 10.5. The regeneration step occurs in an upflow mode.

The third step is to rinse the bed using treated water to flush any residual arsenic and fluoride from the bed; again, this step occurs in an upflow mode.

The last step is to reduce the pH back to operating levels (pH 6 to 6.5) by neutralizing the beds with a strong acid solution (1 percent sulfuric acid) in the fourth step. With the beds regenerated and neutralized, the media will have regained its adsorptive capacity. All processed water from these steps will be directed through bag or cartridge filters and to one of the backwash storage tanks.

Wastewater will be produced during the regeneration process, and Exhibit 3 shows the estimated volume of wastewater. The ongoing bench-scale testing will assist in refining the quality and quantity of waste generated and the approach to managing wastewater. The testing is anticipated to be completed in summer 2013.

EXHIBIT 3
Wastewater Generation Estimates
Freshwater Pre-Injection Treatment System Design Basis Memorandum, PG&E Topock Compressor Station, Needles, California

		Annual Wastewater Volumes (million gallons per year)[a]	
Flow Case	**Flowrate, gpm**	**At 1,500 bed-volumes**	**At 2,500 bed-volumes**
Nominal	450	5.5	3.3
Maximum	900	11.0	6.6

[a] The frequency is estimated using bench test results, as described above. Additional testing is being performed to help verify a waste minimization practice of recycling the regeneration solutions is under evaluation. Revised chemical use estimates will be provided in subsequent design phases.

5.3 Chemical and Media Use

Chemicals will be used in the treatment system. Chlorine in the form of calcium hypochlorite tablets is used to oxidize arsenite to arsenate. Arsenate is more readily removed by the treatment process. Acid is used in pretreatment to improve adsorption; acid and caustic are used in regenerating the media. The estimated chemical use is shown in Exhibit 4.

EXHIIBIT 4
Annual Chemical Usage Rates
Freshwater Pre-injection Treatment System Design Basis Memorandum, PG&E Topock Compressor Station, Needles, California

			93% Sulfuric Acid, gallons/year[a]		25% Caustic, gallons/year[a]	
Flow Case	**Flowrate, gpm**	**Hypochlorite, pounds/year[a]**	**At 1,500 BVs**	**At 2,500 BVs**	**At 1,500 BVs**	**At 2,500 BVs**
Nominal	450	4,600	61,000	44,000	25,000	15,000
Maximum	900	9,200	121,000	89,000	50,000	30,000

lbs – pounds
gal – gallons

[a] The chemical use is estimated using guidance manuals for design of AA, professional judgment, and bench test results. Additional testing is being performed to evaluate alternative chemicals and chemical use minimization alternatives. Revised chemical use estimates will be provided in subsequent design phases.

The AA media will need periodic makeup to replace the media that is lost due to attrition and chemical effects. Regular inspection of the beds is needed to maintain the beds. The bench-scale test results to date showed a minimal loss of capacity in the second cycle. During detailed design, the means and procedures for making up and replacing the media will be established. Cranes and hoists may be used during these activities.

5.4 Controls Philosophy

The system will be automated to reduce the need for continuous operator oversight. System automation will be controlled using a programmable logic controller that will communicate with the groundwater remedy supervisory control and data acquisition system at the Central Maintenance Facility. Pneumatic valves will be automated to control flow. Online fluoride, pH, turbidity, and conductivity sensors will be incorporated to enable remote process monitoring and control. The fluoride analyzer will be periodically checked against a bench-top spectrophotometer. Arsenic cannot be monitored using an online analyzer. Grab samples will be collected

periodically and tested in the sample room (located in the Remedy Produced Water Conditioning Building or the Central Maintenance Facility) to monitor arsenic levels.

5.5 Other Related Systems and Infrastructure

Electricity will be provided from the compressor station via a transformer located in the neighboring Remedy Produced Water Conditioning Building. The new building will have a heating, ventilation, and air conditioning (HVAC) system for only critical equipment such as electrical and controls equipment.

5.6 Design Philosophy/Uncertainties in Design

As previously mentioned, the FWPTS will be designed to achieve a safe, efficient, and sustainable operation within the compressor station over the anticipated decades-long life of the remedy. Although regenerable AA was selected as the adsorption media for removal of arsenic and fluoride in this design, additional engineering efforts are currently being conducted to complete the detailed design of the FWPTS and to optimize the system from both physical and long-term operational footprint perspectives. The forthcoming agencies' guidance on what level of treatment, if any, for the various constituents could affect the design. For example, if fluoride treatment is not required, the treatment process would change to using disposable granular ferric hydroxide media (rather than regenerable AA), using the same treatment vessels described above. The resulting change would eliminate the need for the regeneration steps and regeneration-related equipment and chemicals. The building and outdoor tank area could be reduced in size.

In light of the continued design/bench testing efforts and the forthcoming agencies guidance, the conceptual design can be thought of in two main elements, each with its own design approach:

5.6.1.1 Core Elements

These are components that are considered to be neutral of the technology selected or process variables such as wastewater generation and will not likely sustain a large shift from the ongoing efforts (for example, bag filters and treatment vessel size). This flexibility is possible in the design because the bag filters are sized based on flow rate, and the treatment media vessels are sized based on hydraulic loading rates (volumetric flow divided by cross-section area) and media depth and are not dependent on media selected.

5.6.1.2 Flexible Elements

These are components that could sustain a large shift from the ongoing efforts and will most likely change in terms of quantities (not types) if the treatment requirements changed to only arsenic removal or if actual removal effectiveness differs significantly from that seen in the bench-scale testing. For example, the volume of backwash water could be reduced if the effectiveness of the regeneration process exceeds expectation. For these elements, a conservative design basis is being selected for the frequency of regeneration and chemical usage. This will result in larger storage vessels, increased chemical usage, and larger volumes of wastewater generated. Future optimization efforts will be completed to reduce the uncertainty in these items.

6.0 Design Information

Process calculations used to develop the design criteria were prepared using the conservative assumption that the AA vessels each needed to be regenerated every 1,500 bed-volumes (or a little more than 5 days of operation) at maximum flow of 900 gpm. After the bench testing is complete, these values will be revised as needed. It is expected that the tank volumes will remain the same and the delivery frequency will be reduced; therefore, the equipment design is expected to remain unchanged.

Design information is presented in Tables 2, 3, and 4 and on Figures 2, 3, and 4 at the end of this technical memorandum.

7.0 References

American Water Works Association. 1999. *Water Quality and Treatment - A Handbook of Community Water Supplies (5th Edition).* McGraw-Hill, R.D. Letterman Editor.

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United States Environmental Protection Agency (USEPA). *Design Manual: Removal of Fluoride from Drinking Water Supplies by Activated Alumina,* EPA/600/2-84-134, August 1984.

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Tables

Table 1

SUMMARY OF HNWR-1 WELL SAMPLE RESULTS

Freshwater Sources Evaluation Technical Memorandum

PG&E Topock Compressor Station, Needles, California

	Location:	HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01
	Sample Date:	11/10/2010	2/23/2012	3/14/2012	4/4/2012	6/27/2012	1/22/2013
Parameter	**Units**						
Field							
Dissolved oxygen	mg/L	**5.33**	**3.52**	**3.29**	**3.72**	---	---
Oxidation reduction potential	mV	**159**	**172**	**200**	**112**	**33.5**	---
pH	pH units	**7.84**	**7.68**	**7.61**	**8.07**	**7.51**	---
Salinity	%	**0.42**	**0.0662**	**0.0537**	**0.0509**	**0.439**	---
Specific conductance	µS/cm	**870**	**1,024**	**830**	**787**	**6,791**	---
Temperature	°C	**35.9**	**38.3**	**38.1**	**38.0**	**37.9**	---
Turbidity	NTU	**5.10**	**5.10**	**2.50**	---	**8.00**	---
Anions							
Chloride	mg/L	---	**130**	**130**	**130**	**130**	---
Fluoride	mg/L	**3.80**	---	---	---	**4.00**	**3.90**
Nitrate (as nitrogen)	mg/L	**2.50**	**2.60**	**2.50**	**2.50**	**2.60**	---
Sulfate	mg/L	**47.0**	**45.0**	**44.0**	**45.0**	**44.0**	---
General Chemistry							
Alkalinity, bicarb as CaCO3	mg/L	---	**110**	**110**	**110**	**100**	---
Alkalinity, carb as CaCO3	mg/L	---	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)	---
Alkalinity, hydroxide	mg/L	---	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)	---
Alkalinity, total as CaCO3	mg/L	**100**	**110**	**110**	**110**	**100**	---
Ammonia as nitrogen	mg/L	ND (0.1)	**0.13**	**0.12**	**0.15**	ND (0.1)	---
Cyanide	mg/L	---	---	ND (0.01)	ND (0.01)	ND (0.01)	---
Deuterium	0/00	**-75.3**	**-73.8**	---	---	**-77.1**	---
Oxygen 18	0/00	**-10.3**	**-10.2**	---	---	**-10.2**	---
Soluble silica	mg/L	**28.6**	---	---	---	**25.9**	---
Specific conductance	µS/cm	**740**	---	---	---	---	---
Total dissolved solids	mg/L	**490 J**	**480**	**510**	**430**	**440**	---
Total Kjeldahl Nitrogen	mg/L	ND (0.4)	---	---	---	---	---
Total organic carbon	mg/L	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	---
Total suspended solids	mg/L	---	---	ND (10)	---	ND (10)	---
Herbicides							
2,4,5-T	µg/L	---	---	ND (2.7)	ND (0.26)	---	---
2,4,5-TP (Silvex)	µg/L	---	---	ND (2.7)	ND (0.26)	---	---
2,4-D	µg/L	---	---	ND (2.7)	ND (0.26)	---	---
2,4-DB	µg/L	---	---	ND (2.7)	ND (0.26)	---	---
4-Nitrophenol	µg/L	---	---	ND (2.7)	---	---	---
Dalapon	µg/L	---	---	ND (4.4)	ND (0.42)	---	---
Dicamba	µg/L	---	---	ND (2.7)	ND (0.26)	---	---
Dichlorprop	µg/L	---	---	ND (2.7)	ND (0.26)	---	---

Table 1

SUMMARY OF HNWR-1 WELL SAMPLE RESULTS

Freshwater Sources Evaluation Technical Memorandum

PG&E Topock Compressor Station, Needles, California

	Location:	HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01
	Sample Date:	11/10/2010	2/23/2012	3/14/2012	4/4/2012	6/27/2012	1/22/2013
Parameter	**Units**						
Herbicides							
Dinoseb	µg/L	---	---	ND (2.7)	ND (0.26)	---	---
MCPA	µg/L	---	---	ND (2.7)	ND (0.26)	---	---
MCPP	µg/L	---	---	ND (2.7)	ND (0.26)	---	---
Pentachlorophenol	µg/L	---	---	ND (2.7)	ND (0.26)	---	---
Metals							
Aluminum, dissolved	µg/L	ND (50)	---	ND (50)	ND (50)	ND (50)	---
Antimony, dissolved	µg/L	ND (10)	ND (10)	ND (10)	ND (0.5)	ND (0.5)	---
Arsenic	µg/L	---	---	---	---	---	**16.0**
Arsenic, dissolved	µg/L	**15.0**	**15.0**	**16.0**	**15.0**	**16.0**	**16.0**
Barium, dissolved	µg/L	**130**	**110**	**110**	**110**	**110**	---
Beryllium, dissolved	µg/L	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)	---
Boron, dissolved	µg/L	**380**	---	---	---	---	---
Cadmium, dissolved	µg/L	ND (3.0)	ND (3.0)	ND (3.0)	ND (3.0)	ND (3.0)	---
Calcium, dissolved	µg/L	**23,000**	**19,000 J**	**19,000**	**20,000**	---	---
Chromium, Hexavalent	µg/L	**17.5**	**15.0**	**18.0**	**14.0**	**15.0**	---
Chromium, total dissolved	µg/L	**19.2**	**16.0**	**18.0**	**17.0**	**18.0**	---
Cobalt, dissolved	µg/L	ND (3.0)	ND (3.0)	ND (3.0)	ND (3.0)	ND (3.0)	---
Copper, dissolved	µg/L	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)	---
Iron, dissolved	µg/L	ND (20)	**37.0**	ND (20)	**25.0**	**38.0**	---
Lead, dissolved	µg/L	ND (10)	ND (10)	ND (10)	ND (10)	ND (10)	---
Magnesium, dissolved	µg/L	**4,000**	**3,100**	**3,200 J**	**3,100 J**	---	---
Manganese, dissolved	µg/L	ND (10)	**1.90**	**0.64**	**1.70**	**1.70**	---
Mercury, dissolved	µg/L	ND (0.2)	ND (0.2)	ND (0.2)	ND (0.2)	ND (0.2)	---
Molybdenum, dissolved	µg/L	**11.0**	**9.40**	**10.0**	**9.00**	**9.10**	---
Nickel, dissolved	µg/L	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)	---
Potassium, dissolved	µg/L	**5,100**	**4,400**	**4,000**	**3,700**	---	---
Selenium, dissolved	µg/L	**0.73**	**0.87**	**0.75**	**0.75**	**0.71**	---
Silver, dissolved	µg/L	ND (3.0)	ND (3.0)	ND (3.0)	ND (3.0)	ND (3.0) J	---
Sodium, dissolved	µg/L	**130,000**	**130,000**	**130,000**	**130,000**	---	---
Thallium, dissolved	µg/L	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	---
Vanadium, dissolved	µg/L	**20.0**	**21.0**	**22.0 J**	**20.0**	**20.0**	---
Zinc, dissolved	µg/L	ND (10)	ND (10)	**16.0**	ND (10)	ND (10)	---
Perchlorate							
Perchlorate	µg/L	---	---	ND (2.0)	ND (2.0)	---	---
Pesticides							
4,4-DDD	µg/L	---	---	ND (0.053)	ND (0.052)	---	---

Table 1

SUMMARY OF HNWR-1 WELL SAMPLE RESULTS

Freshwater Sources Evaluation Technical Memorandum

PG&E Topock Compressor Station, Needles, California

	Location:	HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01
	Sample Date:	11/10/2010	2/23/2012	3/14/2012	4/4/2012	6/27/2012	1/22/2013
Parameter	**Units**						
Pesticides							
4,4-DDE	µg/L	---	---	ND (0.053)	ND (0.052)	---	---
4,4-DDT	µg/L	---	---	ND (0.053)	ND (0.052)	---	---
Aldrin	µg/L	---	---	ND (0.027)	ND (0.026)	---	---
alpha-BHC	µg/L	---	---	ND (0.027)	ND (0.026)	---	---
alpha-Chlordane	µg/L	---	---	ND (0.027)	ND (0.026)	---	---
beta-BHC	µg/L	---	---	ND (0.027)	ND (0.026)	---	---
delta-BHC	µg/L	---	---	ND (0.027)	ND (0.026)	---	---
Dieldrin	µg/L	---	---	ND (0.053)	ND (0.052)	---	---
Endo sulfan I	µg/L	---	---	ND (0.027)	ND (0.026)	---	---
Endo sulfan II	µg/L	---	---	ND (0.053)	ND (0.052)	---	---
Endosulfan sulfate	µg/L	---	---	ND (0.053)	ND (0.052)	---	---
Endrin	µg/L	---	---	ND (0.053)	ND (0.052)	---	---
Endrin aldehyde	µg/L	---	---	ND (0.053)	ND (0.052)	---	---
gamma-BHC	µg/L	---	---	ND (0.027)	ND (0.026)	---	---
gamma-Chlordane	µg/L	---	---	ND (0.027)	ND (0.026)	---	---
Heptachlor	µg/L	---	---	ND (0.027)	ND (0.026)	---	---
Heptachlor Epoxide	µg/L	---	---	ND (0.027)	ND (0.026)	---	---
Methoxy chlor	µg/L	---	---	ND (0.27)	ND (0.26)	---	---
Toxaphene	µg/L	---	---	ND (2.7) J	ND (2.6) J	---	---
Polyaromatic Hydrocarbons							
1-Methyl naphthalene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
2-Methyl naphthalene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Acenaphthene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Acenaphthylene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Anthracene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
B(a)P Equivalent	µg/L	---	---	ND (0.19)	ND (0.18)	---	---
Benzo (a) anthracene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Benzo (a) pyrene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Benzo (b) fluoranthene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Benzo (ghi) perylene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Benzo (k) fluoranthene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Chrysene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Dibenzo (a,h) anthracene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Fluoranthene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Fluorene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Indeno (1,2,3-cd) pyrene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Naphthalene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---

Table 1

SUMMARY OF HNWR-1 WELL SAMPLE RESULTS

Freshwater Sources Evaluation Technical Memorandum

PG&E Topock Compressor Station, Needles, California

Location:		HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01
Sample Date:		**11/10/2010**	**2/23/2012**	**3/14/2012**	**4/4/2012**	**6/27/2012**	**1/22/2013**
Parameter	**Units**						
Polyaromatic Hydrocarbons							
PAH High molecular weight	µg/L	---	---	ND (0.0)	ND (0.0)	---	---
PAH Low molecular weight	µg/L	---	---	ND (0.0)	ND (0.0)	---	---
Phenanthrene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Pyrene	µg/L	---	---	ND (0.22)	ND (0.2)	---	---
Polychlorinated Biphenyls							
Aroclor 1016	µg/L	---	---	ND (0.53)	ND (0.52)	---	---
Aroclor 1221	µg/L	---	---	ND (1.1)	ND (1.0)	---	---
Aroclor 1232	µg/L	---	---	ND (0.53)	ND (0.52)	---	---
Aroclor 1242	µg/L	---	---	ND (0.53)	ND (0.52)	---	---
Aroclor 1248	µg/L	---	---	ND (0.53)	ND (0.52)	---	---
Aroclor 1254	µg/L	---	---	ND (0.53)	ND (0.52)	---	---
Aroclor 1260	µg/L	---	---	ND (0.53)	ND (0.52)	---	---
Total Petroleum Hydrocarbons							
TPH as diesel	µg/L	---	---	**190**	ND (51) J	---	---
TPH as gasoline	µg/L	---	---	ND (100)	ND (100)	---	---
TPH as motor oil	µg/L	---	---	ND (53)	ND (51)	---	---
Volatile Organic Compounds							
1,1,1,2-Tetrachloroethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,1,1-Trichloroethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,1,2,2-Tetrachloroethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,1,2-Trichloroethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,1,2-Trichlorotrifluoroethane (Freon 113)	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,1-Dichloroethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,1-Dichloroethene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,1-Dichloropropene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,2,3-Trichlorobenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,2,3-Trichloropropane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,2,4-Trichlorobenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,2,4-Trimethylbenzene	µg/L	---	---	ND (1.0)	ND (1.0) J	---	---
1,2-Dibromo-3-chloropropane	µg/L	---	---	ND (2.0)	ND (2.0)	---	---
1,2-Dibromoethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,2-Dichlorobenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,2-Dichloroethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,2-Dichloropropane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,3,5-Trimethylbenzene	µg/L	---	---	ND (1.0)	ND (1.0) J	---	---
1,3-Dichlorobenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---

Table 1

SUMMARY OF HNWR-1 WELL SAMPLE RESULTS

Freshwater Sources Evaluation Technical Memorandum

PG&E Topock Compressor Station, Needles, California

Location:		HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01
Sample Date:		**11/10/2010**	**2/23/2012**	**3/14/2012**	**4/4/2012**	**6/27/2012**	**1/22/2013**
Parameter	**Units**						
Volatile Organic Compounds							
1,3-Dichloropropane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
1,4-Dichlorobenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
2,2-Dichloropropane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
2-Chlorotoluene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
4-Isopropyltoluene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Acetone	µg/L	---	---	ND (10)	ND (10)	---	---
Acrolein	µg/L	---	---	ND (20)	ND (20)	---	---
Acrylonitrile	µg/L	---	---	ND (20)	ND (20)	---	---
Benzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Bromobenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Bromochloromethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Bromodichloromethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Bromoform	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Bromomethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Carbon disulfide	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Carbon tetrachloride	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Chloro methane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Chlorobenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Chloroethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Chloroform	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
cis-1,2-Dichloroethene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
cis-1,3-Dichloropropene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Dibromochloromethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Dibromomethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Dichlorodifluoromethane	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Ethylbenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Hexachlorobutadiene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Isopropylbenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
m,p-Xylenes	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Methyl ethyl ketone	µg/L	---	---	ND (10)	ND (10)	---	---
Methyl isobutyl ketone	µg/L	---	---	ND (10)	ND (10)	---	---
Methyl tert-butyl ether (MTBE)	µg/L	---	---	ND (1.0)	ND (1.0) J	---	---
Methylene chloride	µg/L	---	---	ND (5.0)	ND (5.0)	---	---
N-Butylbenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
N-Propylbenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
o-Xylene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
p-Chlorotoluene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---

Table 1

SUMMARY OF HNWR-1 WELL SAMPLE RESULTS

Freshwater Sources Evaluation Technical Memorandum

PG&E Topock Compressor Station, Needles, California

Location:		HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01	HNWR-01
Sample Date:		**11/10/2010**	**2/23/2012**	**3/14/2012**	**4/4/2012**	**6/27/2012**	**1/22/2013**
Parameter	**Units**						
Volatile Organic Compounds							
sec-Butylbenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Styrene	µg/L	---	---	ND (1.0)	ND (1.0) J	---	---
tert-Butylbenzene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Tetrachloroethene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Toluene	µg/L	---	---	ND (2.5)	ND (2.5)	---	---
trans-1,2-Dichloroethene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
trans-1,3-Dichloropropene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Trichloroethene	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Trichlorofluoromethane (Freon 11)	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Vinyl chloride	µg/L	---	---	ND (1.0)	ND (1.0)	---	---
Xylenes, total	µg/L	---	---	ND (2.0)	ND (2.0)	---	---

Notes:

---	not collected or not available.
%	percent
0/00	differences from global standards in ppt.
°C	degrees Celcius.
J	analyte was present, but reported value was estimated.
mg/L	milligrams per liter.
mV	millivolts.
ND	parameter not detected at the listed reporting limit.
NTU	nephelometric turbidity units.
µg/L	micrograms per liter.
µS/cm	microSiemens per centimeter.

TABLE 2
Design Criteria for Arsenic and Fluoride Treatment System
Freshwater Pre-injection Treatment System Design Basis Memorandum, PG&E Topock Compressor Station, Needles, California

Subject	Criteria	Comments/Reason
OPERATIONAL CRITERIA		
Maximum Groundwater Injection Flow Capacity	900 gpm	
Minimum Groundwater Injection Flow Capacity	75 gpm	
Average Groundwater Injection Flow Capacity	450 gpm	
SITE CIVIL		
Location	Designated freshwater treatment at PG&E Topock Compressor Station near Needles, California.	
Building Finish Floor Elevation	Finished first floor, Elevation 626 feet (NGVD88).	
Grading	Longitudinal Slopes: Minimum 1% away from structures (2% desirable).	
Vehicle Access	WB 50 (turning radius for semi-truck and trailer with 50-foot wheel base). HS 20 (wheel loading on access roadways and parking areas). 50-foot minimum turning radius. Existing site accommodates truck circulation. Roads will be constructed at new facility for maintenance activities.	Required for delivery of chemicals, pumps, motors, and fire vehicles.
Site Constraints	Proposed facility located within the boundary of the existing area designated for FWPTS. Access in and out of the FWPTS must be maintained.	No modifications to the perimeter site fence or entrance gate will be made.
Parking	No parking will be required for new facility.	
Pedestrian Traffic	Limited to paved roadways, sidewalks are not located between existing facilities.	
PROCESS EQUIPMENT, MOTORS, VALVES, AND ANCILLARIES		
Treatment Process	Pre-oxidation, influent pH adjustment, followed by ligand exchange with activated alumina for arsenic and fluoride removal. Periodic regeneration of media with sodium hydroxide followed by bed neutralization with sulfuric acid.	Design criteria listed below is what is expected from planned pre-purchase bid, but not a guarantee of what equipment will be selected. The information in this section will be verified during the detailed design.
Activated Alumina Treatment		
Treatment Objective	Arsenic and fluoride removal	
Number of Vessels	Four: three online, one on standby	
Residence Time	5 minutes empty bed contact time	USEPA guidance.
Vessel Height	10.5 feet overall	
Vessel Diameter	8 feet	4 to 8 gpm/ft^2 hydraulic loading.
Materials of Construction	Low-carbon steel with epoxy lining that is NSF 61 listed.	

TABLE 2

Design Criteria for Arsenic and Fluoride Treatment System

Freshwater Pre-injection Treatment System Design Basis Memorandum, PG&E Topock Compressor Station, Needles, California

Subject	Criteria	Comments/Reason
Media	AA-400G regenerable media	BASF, Delta Adsorbents, or equal.
Performance Limits		
Effluent Arsenic Concentration	< 10 µg/L	
Effluent Fluoride Concentration	< 2 mg/L	
Blended Fluoride Effluent Target Concentrations before Regeneration Initiated	Fluoride 1.6 to 1.8 mg/L	
Waste Volume	< 1,000,000 gal/year goal	
Caustic (Sodium Hydroxide) Feed System		
Chemical Feed System	One 4,300-gallon FRP tank with tank pad	Tank located in a containment area. Weekly fill frequency is the design basis,
	One chemical feed skid with two controllable chemical feed pumps and controls	Solution concentration will be 25% to prevent pipe clogging due to low temperatures during winter months
Safety Equipment	One eyewash and shower unit One instant hot water unit Personal protective equipment	
Coatings	Chemical-resistant coatings in chemical areas	
Controls	Chemical flow meter flow rate and total Chemical feed pump speed control	
Chlorine Feed System		
Chemical Feed System	One calcium hypochlorite tablet feeder system—HDXLPE (with oxidation resistant liner) mix tank, feed pump, tablet hopper, controller and panel with disconnect. Sized for 0.2 to 2 lbs/hour of chlorine. Three days' minimum tablet capacity.	Feed system located in a containment area.
Safety Equipment	One eyewash and shower unit	
Coatings/Finishes	Chemical resistant coatings in chemical areas	
Controls	Chemical flow meter flow rate and total Chemical feed pump speed control	
Sulfuric Acid Feed System		
Chemical Feed System	One 2,400-gallon carbon steel with baked phenolic lining. Desiccant drier installed on vent sulfuric acid tank with tank pad.	Tank will be located in a containment area. Weekly fill frequency is the design basis,
	One chemical feed skid with two controllable chemical feed pumps	Solution concentration will be 93%.
Safety Equipment	One eyewash and shower unit	
Coatings/Finishes	Chemical resistant coatings in chemical areas	
Controls	Chemical flow meter flow rate and total Chemical feed pump speed control	
Backwash Tanks and Treated Water Tanks		

TABLE 2
Design Criteria for Arsenic and Fluoride Treatment System
Freshwater Pre-injection Treatment System Design Basis Memorandum, PG&E Topock Compressor Station, Needles, California

Subject	Criteria	Comments/Reason
Number	Four	
Capacity	4 18,000-gallons tanks	52,000 gallon capacity for backwash tanks and 10,000 minimum capacity for treated water tank.
Flow Meters		
Type	Magnetic	
Number	Nine	
Flow Control Strategy	FWPTS receives raw water from existing TCS storage tanks when level is above set point (CH2M HILL, 2013) A booster pump with variable frequency drive will vary the flow through the treatment plant to maintain set point water levels in the treated water tank and prevent pump operating in existing freshwater storage tanks are at water levels below the setpoint. AA vessel inlet control valves equalize flows through each vessel.	
Pressure Transmitters	Furnished before/after AA vessels.	
Static Mixer		
Number	Two (one inlet, one regeneration)	
Diameter	One 10-inch, one 4-inch	
Type	Wafer style with integral injection ports	
Piping Materials		
Process	PVC Schedule 80, per ASTM D1784, ASTM D1785, and NSF/ANSI 14 and NSF 61 listed	
Regeneration	PVC, Schedule 80, per ASTM D1784, and ASTM D1785	
Treatment Media Vessel Manifold	PVC Schedule 80, per ASTM D178, ASTM D1785, NSF/ANSI 14 and NSF-61 listed	
Potable Water	Buried: Copper, Type K, per ASTM B88 Exposed: Copper, Type L, per ASTM B88 or CPVC Sch. 80	
Process Piping Installation	Major process piping headers will be installed in pipe trenches inside the treatment building and buried outside the building. Media vessel piping will be aboveground. Actuated valves will be installed above grade whenever possible.	
Existing Compressor Station Interface	Inlet from existing water storage tanks	
YARD PIPING		
Design Criteria	Appendix C, Basis of Design Report (CH2M HILL, 2013)	
CORROSION CONTROL		
Design Criteria	Appendix C, Basis of Design Report (CH2M HILL, 2013)	

TABLE 2

Design Criteria for Arsenic and Fluoride Treatment System

Freshwater Pre-injection Treatment System Design Basis Memorandum, PG&E Topock Compressor Station, Needles, California

Subject	Criteria	Comments/Reason
	ARCHITECTURAL/STRUCTURAL	
Building Code	Appendix C, Basis of Design Report (CH2M HILL, 2013)	
Building Design Concept	Single building joined together with Remedy Produced Water Conditioning System	May be modified during detailed design.
Building Construction Materials	Appendix C, Basis of Design Report (CH2M HILL, 2013)	
Loads	Appendix C, Basis of Design Report (CH2M HILL, 2013)	
	HVAC	
Codes/Standards	Appendix C, Basis of Design Report (CH2M HILL, 2013)	
Design Conditions		
Site Elevation	See Section C.2 Civil, Appendix C, Basis of Design Report (CH2M HILL, 2013)	
Cooling Load Basis	Building envelope heat gain and internal heat gains from equipment.	
System Type		
Process Building	The building will be ventilated and cooled by a packaged air conditioning unit (Appendix C, Basis of Design Report [CH2M HILL, 2013]). A thermostat will be located near the electrical controls and will maintain the desired temperature in that area.	
	PLUMBING	
Lavatory/Toilet Room	No facilities provided.	
Potable Water	Emergency shower/eye wash stations.	Per 2010 California Plumbing Code, and ANSI Z358.1.
Nonpotable Water	The nonpotable water supply will have a reduced pressure backflow preventer. Nonpotable water will be supplied for wash down water. Wash down hose valves, hoses and hose racks will be furnished in the area as required.	Per 2010 California Plumbing Code.
	ELECTRICAL	
Electrical Load	The electrical load will consist of process pumps, motor operated valves, filter system, control panel and instrumentation, building HVAC, convenience receptacles and interior and exterior lighting. Power distribution will be sized in accordance with NFPA 70 (National Electric Code) to operate process and facility loads. Short-circuit current interrupting capacity of power distribution equipment will be coordinated with existing power distribution system.	.
Service Voltage	480V, 3-phase, 3-wire power will be supplied from XFMR 099	

TABLE 2
Design Criteria for Arsenic and Fluoride Treatment System
Freshwater Pre-injection Treatment System Design Basis Memorandum, PG&E Topock Compressor Station, Needles, California

Subject	Criteria	Comments/Reason
Utilization Voltage	Appendix C, Basis of Design Report (CH2M HILL, 2013)	
Redundancy Requirements	Power distribution system redundancy will be limited to equipment supporting the operation of back-up process and facility equipment (i.e. motor control combination starters, and breakers,). Power distribution system for FWPTS will incorporate spare breakers and fuses. Supporting quick replacement of failed components. Backup power by diesel generator located at Transwestern Bench.	.
Manufacturers of Electrical Equipment, Grounding, Lightning Protection, Illumination, Emergency Lights, Stand-by/Backup Power, Raceways, and Duct Banks	Appendix C, Basis of Design Report (CH2M HILL, 2013)	
SECURITY		
Security	None	All security covered through TCS main facility
CONTROL AND TELEMETRY		
Control and Telemetry Design Criteria	The treatment vessels will be a packaged system with the equipment manufacturer providing a fully configured programmable logic controller based system control panel with panel-mounted operator interface terminal. The control panel will be specified with an uninterruptible power supply to provide true online conditioned power sized to operate the connected load for 30 minutes.	
Communications, Other Networks, Supervisory Control and Data Acquisition, Instrumentation	Appendix C, Basis of Design Report (CH2M HILL, 2013)	
Environmental Requirements	Equipment and instrumentation will be suitable for the following conditions: Air-conditioned Spaces: 10°C to 35°C and a relative humidity of 10 to 80 percent. Non-air-conditioned Spaces: 0°C to 50°C and a relative humidity of 10 to 95 percent. Outdoors: 0°C to 60°C and a relative humidity of 5 to 100 percent.	Environmental controls, such as heaters, fans, and air conditioning will be provided to maintain equipment within the operating conditions recommended by the manufacturer.
Standards/References	Appendix C, Basis of Design Report (CH2M HILL, 2013)	

TABLE 3
Major Equipment List
Freshwater Pre-injection Treatment System Design Basis Memorandum,
PG&E Topock Compressor Station, Needles, California

Quantity	Name	Description
4	Treatment Media Vessels	8-inch-diameter low-carbon steel with epoxy lining (6 gpm/ft^2 hydraulic loading rate)
1	Caustic Tank	4,300-gallon tank with fittings (25% caustic) - FRP
1	Caustic Feed System	Pre-engineered skid with two chemical metering pumps for 25% caustic feed (1.5 to 12 gph)
1	Hypochlorite Feeder	Calcium hypochlorite tablet feeder: HDXLPE (with oxidation-resistant liner) mix tank, feed pump, tablet hopper, controller, and panel with disconnect
1	Sulfuric Acid Tank	2,400-gallon, (93% sulfuric acid), desiccant drier installed on vent. Baked phenolic lining on steel.
1	Acid Feed System	Pre-engineered skid with two chemical metering pumps for 93% sulfuric acid (1.5 to 12 gph)
1	Pre-treatment Wafer-Style Static Mixer	With integral injection ports
1	Regeneration Wafer-Style Static Mixer	With integral injection ports
2	Booster Pumps	Centrifugal pump with variable frequency drive
3	Filters skids with replaceable elements	Package unit with differential pressure indication and alarm. Bag or cartridge type
2	Recycle Pumps	Centrifugal pump with VFD
2	Backwash Water Transfer Pumps	Centrifugal pump 35 gpm @ 45’ TDH
2	Backwash and Regeneration Pumps	Centrifugal pump 455 gpm (9 gpm/ft^2 hydraulic loading rate) with VFD
2	Treated Water Pumps	Centrifugal pump with VFD

TABLE 4

Mass Balance Table

Design Basis Memorandum,
PG&E Topock Compressor Station, Needles, California

DRAFT

Stream #	1	2	3	4	5a	5b	5c	5d	6a	6b	6c	6d	7a	7b	7c
									To Backwash Tank				To Evaporation Ponds		
Waste Stream	Downstream of the Booster Pumps	To the Media Filters	To the Treated Water Teank	To the Injection Wells	Back-wash	Regener-ation	Rinse	Neutrali-zation	Back- wash Stream	Regener-ation Stream	Rinse Stream	Neutrali-zation Stream	Back- wash Stream	Regener-ation Stream	Rinse Stream
Maximum Flow (gpm)	900	900	900	900											
Maximum Flow (ac-ft/Year)	1452	1452	1452	1452											
Arsenic (mg/L)	0.015					0.6				0.6				0.6	
Arsenic (lbs/yr)	15.643					6.8				6.8				6.8	
Fluoride (mg/L)	3.800					107.9				107.9				107.9	
Fluoride (lbs/yr)	3,963					1136.0				1136.0				1136.0	
pH		6.5	6.5	6.5	6-7	12 - 12.5	6.5	12-6.5	6-7	12 - 12.5	6.5	12-6.5	6-7	12 - 12.5	6.5
Chlorine (mg/L)	1.5	1.5	1.0	1.0											
Calcium Hypochlorite (lb/year)	9,164														
Caustic (gal/year)						50,458									
Sulfuric Acid (mg/L)	150.0														
Acid (gal/year)	346,709							121,317							
Wastewater Volume (MG/yr)					0.84	1.26	1.26	7.59	0.84	1.26	1.26	7.59	0.84	1.26	1.26
Wastewater Volume (ac-ft/yr)					2.59	3.87	3.88	23.29	2.59	3.87	3.88	23.29	2.59	3.87	3.88
Nominal Flow (gpm)	450	450	450	450											
Nominal Flow (ac-ft/Year)	726	726	726	726											
Arsenic (mg/L)	0.015					0.6				0.6				0.6	
Arsenic (lbs/yr)	7.821					3.4				3.4				3.4	
Fluoride (mg/L)	3.800					107.9				107.9				107.9	
Fluoride (lbs/yr)	1,981					568.0				568.0				568.0	
pH		6.5	6.5	6.5	6-7	12 - 12.5	6.5	12-6.5	6-7	12 - 12.5	6.5	12-6.5	6-7	12 - 12.5	6.5
Chlorine (mg/L)	1.5	1.5	1.0	1.0											
Calcium Hypochlorite (lb/year)	4,554														
Caustic (gal/year)						25,229									
Acid (gal/year)	150.0							60,659							
Waste Volume (gal/yr)	173,355				0.42	0.63	0.63	3.79	0.42	0.63	0.63	3.79	0.42	0.63	0.63
Waste Volume (ac-ft/yr)					1.29	1.94	1.94	11.65	1.29	1.94	1.94	11.65	1.29	1.94	1.94
Assumptions Bed volumes per backwash/regeneration - 1,500 Number of vessels in service - 3															

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GROUNDWATER REMEDY PROJECT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CA

GENERAL

FRESHWATER PRE-INJECTION TREATMENT SYSTEM - REGENERABLE ACTIVATED ALUMINA MASS BALANCE

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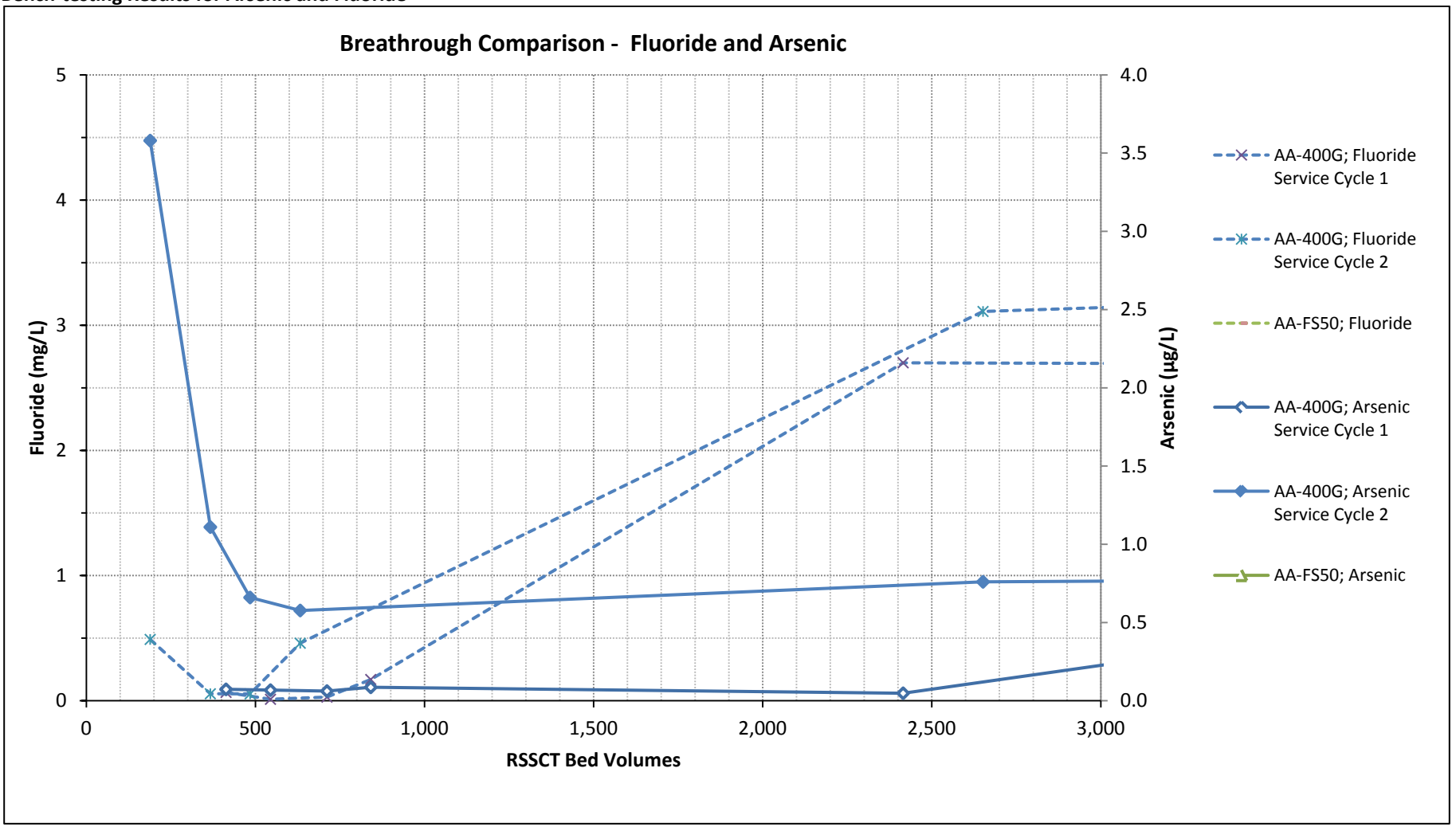
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Figures

FIGURE 1

Bench-testing Results for Arsenic and Fluoride



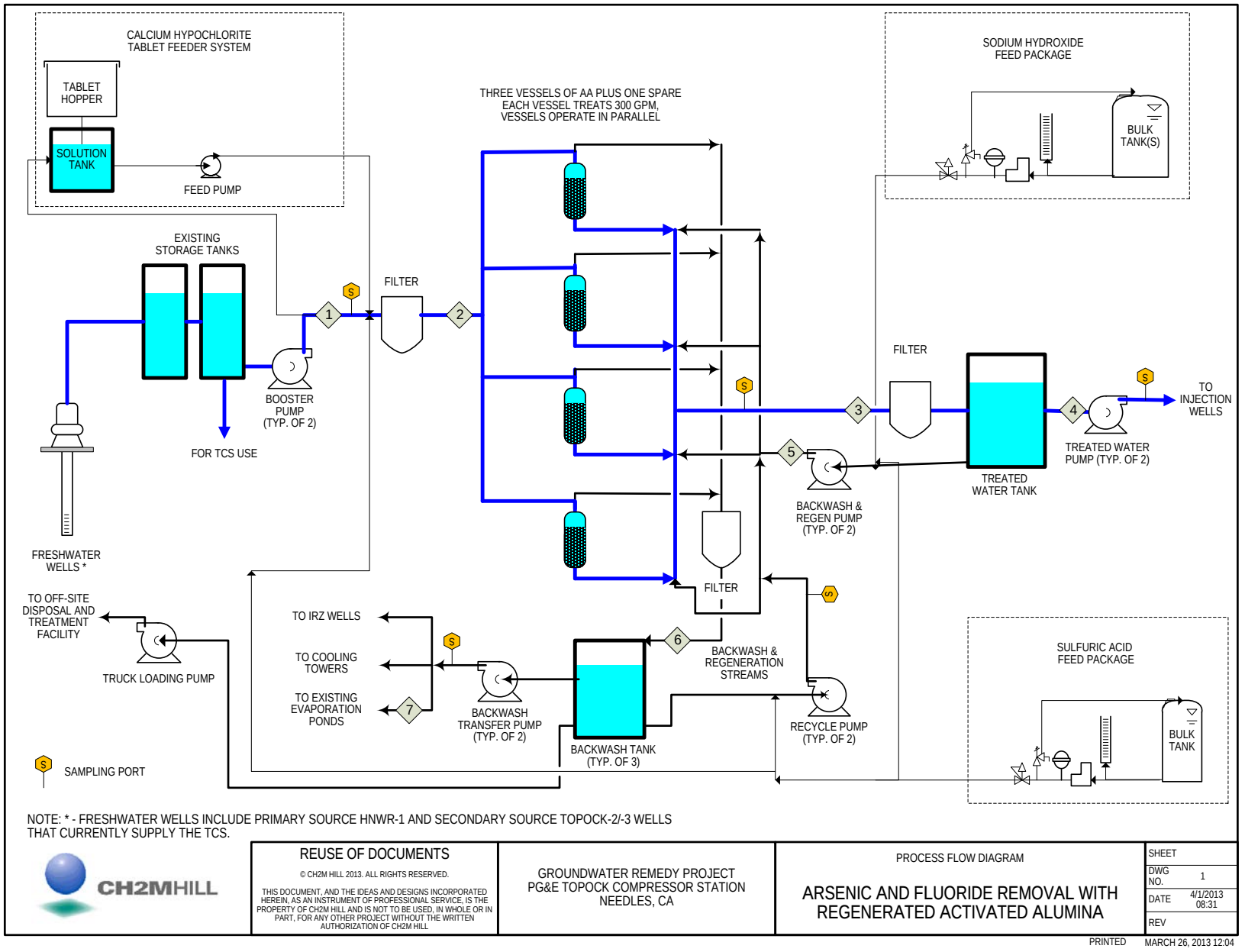
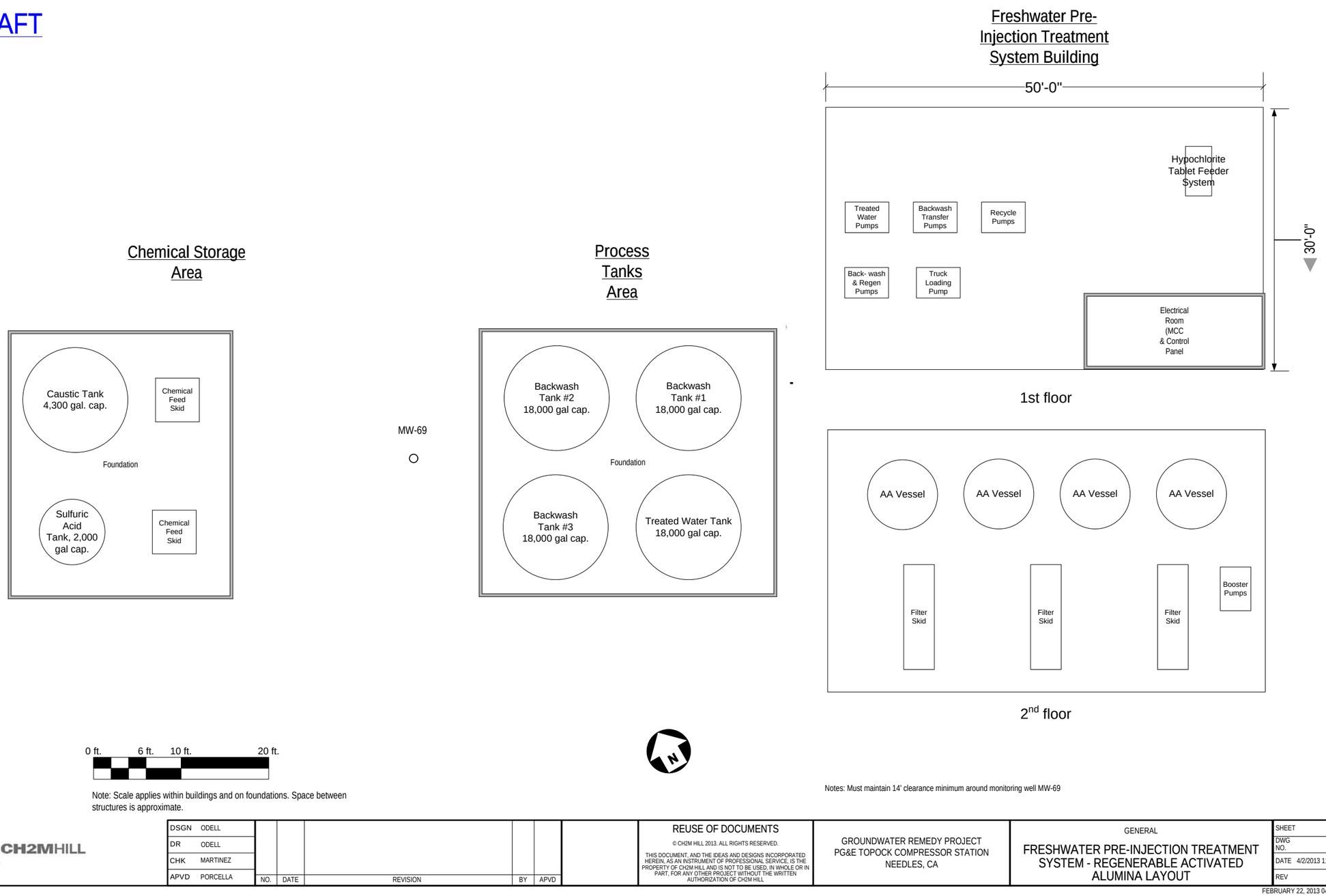


FIGURE 2
Process Flow Diagram

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Note: Scale applies within buildings and on foundations. Space between structures is approximate.

Notes: Must maintain 14' clearance minimum around monitoring well MW-69

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GROUNDWATER REMEDY PROJECT
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CA

GENERAL

FRESHWATER PRE-INJECTION TREATMENT SYSTEM - REGENERABLE ACTIVATED ALUMINA LAYOUT

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FIGURE 3
Equipment Layout

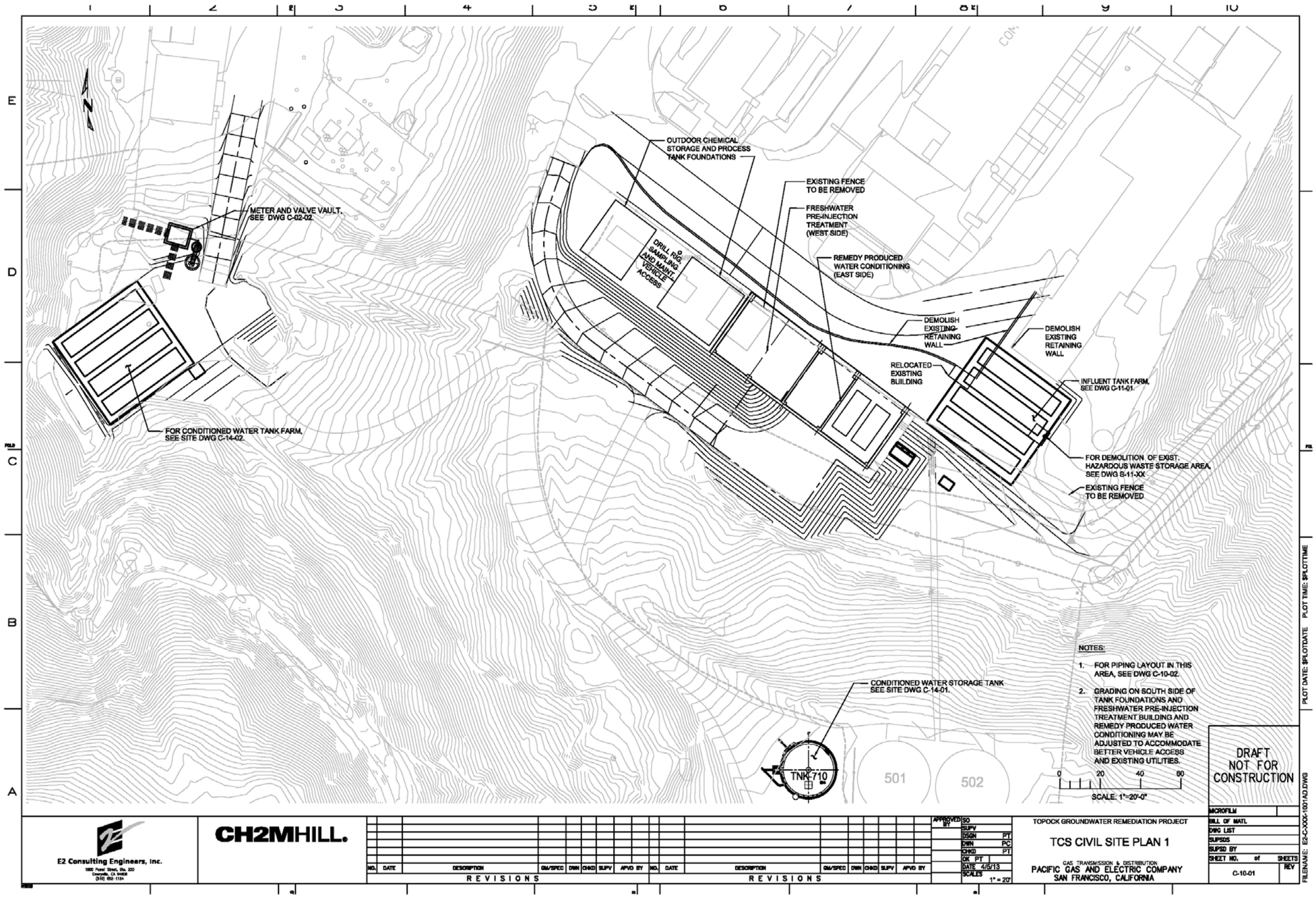


FIGURE 4
Site Layout

Appendix A
Arsenic and Fluoride Treatment Technology Screening

APPENDIX A

Arsenic and Fluoride Treatment Technology Screening

As part of the pre-conceptual design work, several treatment technologies were identified and screened to help select an effective and efficient treatment process. After technology identification, the list was screened qualitatively. A more detailed screening was completed on a short list of five technologies. Bench-scale testing was then performed to select the technology to carry forward into design.

A.1 Initial Screening

The United States Environmental Protection Agency, water and wastewater utilities, industrial concerns, research universities and centers, and industry groups have published numerous case studies and reports on testing and performance of these technologies in treating arsenic and fluoride in water (American Water Works Association, 1999; Odell, 2010). The initial list of technologies evaluated for the Topock freshwater pre-injection treatment system was developed from those technologies that have been successfully used by municipalities and industry. Unproven technologies or technologies that have not been used in full-scale applications were not considered in the screening. The initial list included anion exchange, activated alumina (AA), reverse osmosis (RO), electrodialysis reversal (EDR), lime softening, distillation, iron-based adsorbents, titanium-based adsorbents, and coagulation/filtration. The status of selection is summarized in Table A-1.

TABLE A-1
Technologies Considered for Arsenic and Fluoride Removal
Design Basis Memorandum,
PG&E Topock Compressor Station, Needles, California

Technology	Status
Anion exchange	Screened out, significant waste generation.
AA	**Selected for bench-testing. Primary treatment option is regenerable AA if arsenic and fluoride treatment required.**
Titanium-based adsorbents	Screened out, similar as other adsorbents considered, with less experience.
RO	Screened out, significant waste generation.
EDR	Screened out, significant waste generation.
Lime Softening	Screened out, significant waste generation.
Distillation	Screened out, significant energy use and capital cost.
Coagulation Filtration	Screened out, this process does not treat fluoride. If arsenic-only treatment is required, this technology would be screened out due to more residuals are generated, additional chemicals are used, and the process is more complex than iron-based adsorbents.
Iron-based Adsorbents	Screened out, this process does not treat fluoride. **If arsenic-only treatment required, this process may be used.**

A brief process description is provided below.

Anion Exchange. Anions such as fluoride, nitrate, arsenate, selenate, and chromate can be removed from water by using ion exchange with resin. This physical-chemical process involves an easily displaceable ion on the solid phase, exchanging with an unwanted ion in the water that adsorbs to the solid phase. To accomplish the exchange reaction, a packed bed of ion-exchange resin beads is used. Source water is continually passed through the bed in a downflow or upflow mode until the adsorbent is exhausted, as evidenced by the appearance (breakthrough) of the unwanted contaminant at an unacceptable concentration in the effluent.

The most useful ion-exchange reactions are reversible. In the simplest cases, the exhausted bed is regenerated using an excess of the displaceable ion in the form of salt brine. Ideally, no permanent media structural change occurs during the exhaustion/regeneration cycle. This is a proven technology, is widely used, and is easy to automate, but it generates considerable wastewater.

Activated Alumina*.* AA is a semi-crystalline porous inorganic adsorbent, is a proven technology for fluoride removal, and effectively removes arsenic. The removal mechanism, which is one of exchange of contaminant anions for surface hydroxides on the alumina, is generally called adsorption, although ligand exchange is a more appropriate term for the highly specific surface reactions involved. Packed beds of AA are used in water treatment plants in a similar manner to anion exchange. Regeneration is accomplished using a basic solution like sodium hydroxide (caustic). The adsorbent media can be purchased in a disposable form as well. In this case, the spent media is disposed in an offsite facility. This is a proven technology, is widely used, is easy to automate, but it generates considerable wastewater.

Titanium-based adsorbents*.* These are porous adsorbents made with titanium that work similarly to AA in that surface hydroxides exchange with fluoride in the water stream. Similarly, caustic is used to regenerate the adsorbent in the packed beds. This is a newer process with fewer systems in service.

Reverse Osmosis. RO is a membrane water treatment system in which water is pressurized to more than 100 pounds per square inch and is directed through small pores in a synthetic membrane. Treated water is produced through the other side of the small pores while larger particulates are retained on the inlet side of the membrane. RO is effective in removing uranium, radium, arsenic, fluoride, nitrates, microbial contaminants, and many chemicals. Because of the high pressure required for the process, RO systems typically are energy-intensive and have high initial costs. Furthermore, these systems can require more operator attention and can require membrane integrity testing. RO systems also risk fouling and scaling from hard water, colloids, and bacteria. The fouling and scaling increase the pressure drop and result in a shorter lifetime for the membrane or frequent chemical cleaning. In addition, this process generates considerable volumes of wastewater.

Electrodialysis Reversal. EDR is a membrane water treatment process that relies on polarizing electrodes to remove contaminants. The ions in the water are attracted to the membrane by a cathode or anode. Once attracted to the membrane, the ion is transported electrically through the membrane. EDR systems reverse the polarity of the electrodes every 15 to 20 minutes. This process releases accumulated ions and has the following advantages:

- Breaks up scale and reduces the potential for scaling.
- Reduces microbiological growth on the membrane.
- Reduces membrane cleaning frequency.

EDR systems operate at higher pressures than most water treatment systems but not as high as RO systems. They are maintenance intensive and generate considerable volumes of wastewater.

Lime Softening. Hardness in water is characterized by elevated levels of magnesium and calcium. Lime softening removes the hardness by mixing lime (slaked or hydrated) during the treatment process. The lime addition increases the pH of the water and causes the magnesium and calcium to precipitate out. Flocculation and sedimentation units are employed to provide a sufficient time and space to accumulate solids. Magnesium requires a higher pH than calcium to cause precipitation and results in water with a pH as high as 11. Carbon dioxide is used commonly to reduce the pH back to desired levels. This process, although used often, requires

careful chemical dosing and process monitoring, requires large amounts of chemicals, and generates large amounts of waste sludge.

Distillation. To distill water, water is heated until boiling and vaporized. The resulting steam is collected and condensed in a clean storage tank. Distillation is effective in removing metals, hardness, and particulates because they do not vaporize with the water. The boiling process also kills bacteria and some viruses. Distillation is ineffective in removing contaminants with a lower boiling point than water, such as benzene. These contaminants must be removed before condensation or recontamination will occur. This process is straightforward to operate but uses high amounts of energy and requires costly metal alloys for construction.

Coagulation Filtration. Coagulation is a process in which smaller particles in suspension attach to one another through electrostatic forces. As the particles attach to one another, larger particles start to form. Aluminum and ferric salts are the most commonly used compounds to enhance coagulation because aluminum or iron hydroxide is formed. Once finished with the coagulation process, the water is filtered through a media filter or microfilter to remove the aggregated particles. Coagulation filtration has been found very effective in removing arsenic from water. While often some form of pretreatment is needed (usually chlorine oxidation), coagulation filtration systems can achieve over a 90 percent reduction in arsenic. However, this process does not treat fluoride. The process is relatively easy to operate.

Iron-based Adsorbents. Contaminated water is passed through a pressure vessel that contains iron based adsorbents that remove arsenic. Granular ferric hydroxide is a common example that is in an amorphous crystalline form. Iron-based adsorbents have been shown effective in removing arsenic (not fluoride) at pH levels normally found in drinking water; however, best performance happens at lower pH levels. Lower pH levels may result in the need for more operator attention and the possibility of handling hazardous chemicals. Once the media has been lost its adsorbent capacity, the spent media is replaced.

A.1.1 Initial Screening Results

As a result of the screening, two technologies were retained for further evaluation:

- Anion exchange
- AA adsorption

The following technologies were rejected based on the reasons listed below.

- **EDR and RO:** processes generate large residual wastewater streams that must be disposed of.
- **Lime softening:** generates large volume of waste sludge that is difficult and costly to dispose of.
- **Titanium-based adsorbents:** effective at very low pH or with expensive rare earth metals and has the fewest number of operating systems.
- **Distillation:** high cost for energy use.
- **Iron-based adsorbents**: this technology does not remove fluoride.
- **Coagulation/ filtration**: this technology does not remove fluoride.

A.2 Second-level Screening

The two remaining technologies were screened at a second level with AA divided into regenerable and disposable forms. The screening criteria were as follows:

1. Treatment Effectiveness
   - Ability to achieve treatment goals
2. Reliability and Flexibility
   - Ability to allow variation in influent water
   - Expandability
3. Operational Complexity

- Ease of operation
- Safety

4. Waste Generation
   - Quantity and quality
5. Footprint
6. Cost Effectiveness

As a result of the screening, anion exchange was not carried forward and was dropped from further consideration because of its lower effectiveness, greater operational complexity, the wastewater volumes generated, and its higher operating cost. The four processes—regenerable AA and disposable AA—were advanced to bench-scale testing.

A.3 Bench-scale Testing

As described in the body of the Design Basis Technical Memorandum, bench-scale testing was performed after the technology screening. Testing showed that regenerable AA was the technology that best met design needs if both arsenic and fluoride removal is required. Disposable AA was eliminated from further evaluation.

A.4 References

American Water Works Association. 1999. *Water Quality and Treatment - A Handbook of Community Water Supplies*, 5th Edition. Ed. by R.D. Letterman.

Odell, Lee H. 2010. *Treatment Technologies for Groundwater*. American Water Works Association.