PACIFIC GAS AND ELECTRIC COMPANY
TOPOCK COMPRESSOR STATION

DRAFT

IN-SITU HEXAVALENT CHROMIUM REDUCTION PILOT TEST WORK PLAN
Floodplain Reductive Zone Enhancement

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LIST OF ACRONYMS

BLM	United States Bureau of Land Management
CACA	Corrective Action Consent Agreement
CMS	Corrective Measures Study
Cr_{dis}	dissolved chromium
CrVI	hexavalent chromium
Cr_{tot}	total chromium
CrIII	trivalent chromium
DTSC	California Department of Toxic Substances Control
EPA	United States Environmental Protection Agency
EVO	emulsified vegetable oil
ft/ft	foot per foot
IDW	investigation-derived waste
IM	Interim Measures
MEAL	methanol, ethanol, acetate, and lactate
mg/L	milligrams per liter
msl	mean sea level
µg/L	micrograms per liter
ORP	oxidation/reduction potential
PG&E	Pacific Gas and Electric Company
psi	pounds per square inch
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RWQCB	Regional Water Quality Control Board – Colorado River Basin
SAFPM	Sampling, Analysis and Field Procedures Manual
TDS	total dissolved solids
TOC	total organic carbon
WDR	Waste Discharge Requirements
ZVI	zero-valent iron

1.0 INTRODUCTION

Pacific Gas and Electric Company (PG&E) is addressing the presence of hexavalent chromium (CrVI) in groundwater at the Topock Compressor Station (Compressor Station), under the oversight of the California Environmental Protection Agency's Department of Toxic Substances Control (DTSC). To support the Resource Conservation and Recovery Act (RCRA) Corrective Measures Study (CMS) for the Topock site, PG&E is evaluating technologies for remediation of CrVI in groundwater.

This work plan presents the approach and description of field activities proposed for a pilot in-situ CrVI reduction test at the Topock site. The purpose of the pilot test is to evaluate in-situ technologies that would reduce CrVI in groundwater at the Topock site to trivalent chromium (CrIII). The results of the pilot testing will be used to:

- Evaluate the feasibility and performance of selected in-situ reductants under actual site conditions
- Provide additional information on site conditions necessary to develop an enhanced reductive zone along the river floodplain.
- Assist with the selection of preferred in-situ reductant(s) for long-term site management

The remainder of Section 1.0 of this work plan provides background information and a description of the Topock site. Section 2.0 presents an overview of in-situ CrVI reduction technologies, describes the methodologies and reducing agents that may be used to implement in-situ treatment and presents preliminary results of site specific bench-scale testing. Section 3.0 of this work plan describes the activities to be performed prior to implementation of the pilot test. The proposed approach and schedule for conducting the pilot test are discussed in Sections 4.0 and 6.0, respectively, of this work plan. Section 5.0 presents procedures for waste management and equipment decontamination to be followed during drilling, development and sampling of the proposed pilot test wells.

1.1 PROJECT BACKGROUND

PG&E's Topock Compressor Station is located in San Bernardino County, approximately 15 miles southeast of Needles, California (Figure 1). 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. Under the terms of the CACA, PG&E was directed to conduct a RCRA Facility Investigation (RFI), and to implement corrective measures to address CrVI released in the Bat Cave Wash Area near the PG&E Topock Compressor Station. The source was chromium salt historically used as a corrosion inhibitor in the station's cooling towers. DTSC is the lead administering agency for the project.

PG&E is proceeding with the corrective measures process to select and implement a long-term remedy for the site. PG&E submitted a CMS work plan in December 2002, pursuant to the RCRA corrective action process, and in accordance with the CACA. The DTSC approved the CMS work plan in June 2003.

Concurrently with the CMS, and in compliance with DTSC's directive, PG&E commenced implementation of interim measures (IM) in March 2004. The objective of the IM is to provide hydraulic control of the CrVI plume in the floodplain by maintaining a net landward groundwater gradient. The current elements of the IM include groundwater extraction from the pumping center at well TW-2D, groundwater treatment, and management of extracted groundwater. The IM is a part of the overall corrective measures process for the site. It is one step toward establishing a long-term remedial approach for the site. The IM may or may not be part of the recommended long-term corrective measures for the site.

Evaluation of additional potential remedies identified in the CMS Work Plan is ongoing. This in-situ pilot study is proposed to collect information to evaluate the efficacy of various in-situ CrVI reduction technologies in the CMS.

1.2 SITE DESCRIPTION

1.2.1 Geology and Hydrogeology

The Topock site is characterized by arid conditions, with precipitation averaging less than 5 inches per year and high temperatures. Vegetation at the Topock site is very sparse, except in the southern part of the Colorado River floodplain where stands of tamarisk and occasional mesquite trees occur. Topography near the site is abrupt, rising from around 450 feet above mean sea level (msl) at the Colorado River to over 1,200 feet msl within a mile to the south and southwest.

The local near-surface geology consists of recent and older river deposits in the floodplain area, progressing westward to older alluvial fan deposits derived from the local mountains. The sequence of unconsolidated alluvial fan and fluvial deposits comprise the principal groundwater aquifer at the site, collectively referred to as the Alluvial Aquifer. In the floodplain area, the alluvial fan deposits interfinger with and are replaced by the fluvial deposits. The unconsolidated alluvial and fluvial deposits are underlain by bedrock formations consisting of Miocene consolidated/cemented conglomerate and sandstone (Miocene Conglomerate unit), which in turn are underlain by pre-Tertiary metamorphic and igneous crystalline bedrock. Because the Miocene Conglomerate and bedrock have very low permeability, groundwater movement occurs primarily in the overlying unconsolidated deposits.

Numerous groundwater monitoring wells at the site are screened in the shallow portion of the alluvial aquifer. Well clusters, such as those at MW-20, MW-24, MW-34, MW-36 and MW-39 also include wells screened at deeper levels of the alluvial aquifer. The measured saturated thickness of the alluvial aquifer ranges from as little as 30 feet (at MW-32) to as great as 180 feet (at MW-33) along the Colorado River floodplain. In the vicinity of the proposed floodplain pilot test, the saturated thickness of the alluvial aquifer ranges from about 77 feet (well PE-1) to approximately 96 feet (well MW-39). The total saturated thickness of the alluvial aquifer is greatest in the western upland portion of the study area, where it can exceed 200 feet.

Natural groundwater gradients in the alluvial aquifer are relatively flat, on the order of 10^{-4} to 10^{-3} feet per foot. Consequently, the average groundwater velocity at the site can be very low. Gradient directions vary over seasons and years, but in the upland portion of the study area they generally run to the northeast. An upward vertical gradient has been observed in alluvial aquifer well clusters and between bedrock and the unconsolidated deposits. Groundwater gradients in the floodplain are directed predominantly westward towards the pumping center at TW-2D. Gradients between individual well pairs in the floodplain can show a northern, southern or downward component, depending on their location relative to TW-2D. Data collected from floodplain wells in March 2005 indicate landward gradients ranging from 0.0024 foot per foot (ft/ft) to 0.0035 ft/ft, and a downward vertical gradient of approximately 0.005 ft/ft at well MW-36 reflecting the influence of pumping from well TW-2D (CH2M Hill, 2005c). Current estimates of groundwater seepage velocity in the vicinity of the pilot test area under the influence of TW-2D pumping range from about 0.1 to 1 foot per day.

Interactions between groundwater and the Colorado River are complex. The daily fluctuations in river stage cause the surface water-groundwater interaction at this site to be very dynamic. Pressure transducers have been installed in floodplain wells near the Colorado River to more closely monitor the changes in water levels and to better define the surface water-groundwater interaction. Draft transducer data collected by CH2M Hill from well MW-39 from April 30, 2004 to April 14, 2005, show daily groundwater elevation fluctuations on the order of one foot. The difference between the minimum and maximum elevations during that period was approximately six feet, and the maximum elevation change during any one-month period was about five feet (increasing from March 14 to April 14, 2005). During the monitoring period prior to March 2005, the groundwater elevation at MW-39 typically changed no more than one foot per month.

1.2.2 Groundwater Quality

Groundwater in the site area exhibits variable total dissolved solids (TDS) concentrations. In general, TDS concentrations increase with depth. Samples collected from most of the shallow monitoring wells exhibit TDS concentrations in the range of 1,000 to 3,000 milligrams per liter (mg/L). However, groundwater sampled in bedrock wells and the deeper alluvium wells contains higher TDS concentrations (8,000 to 12,000 mg/L). Water samples from the Colorado River exhibit TDS concentrations ranging from 400 to 800 mg/L.

Major ions are dominated by sodium and chloride, with sulfate also significant in some wells. Oxidation-reduction potential (ORP) measurements in wells in the upland portion of the alluvial aquifer generally reflect oxidizing conditions in which CrVI is stable. Dissolved oxygen concentrations range from 3.0 to 7.2 mg/L. Nitrate concentrations up to 77 mg/L have been measured.

Reducing conditions are observed in shallow floodplain monitoring wells, as well as in deeper wells immediately adjacent to the Colorado River. Under these conditions, CrVI is converted to the relatively immobile CrIII. This naturally occurring reduction zone along the river appears to act as a barrier to CrVI migration.

Extensive site characterization has been performed to quantify the distribution of CrVI in groundwater at the Topock site. Monitoring wells have been installed near and along Bat Cave Wash, to the east of the wash, and in the Colorado River floodplain. Analytical results indicate that most of the chromium found in affected groundwater is in the hexavalent form. Figure 2 illustrates the CrVI distribution using analytical data from the March 2005 sampling event. The areal extent of the CrVI plume is approximated by the dashed contour representing 0.05 mg/L (the California drinking water maximum contaminant level for total chromium). Figure 3 shows CrVI concentrations in groundwater in an east-west cross-sectional view, between well MW-20 and the river. Vertical profiles for the majority of the site indicate that where CrVI is present in significant concentrations, it is present throughout the saturated alluvium. In the floodplain, CrVI concentrations are consistently lower or non-detectable at shallow depths, where reducing conditions have been measured.

The impact of chromium on groundwater is primarily controlled by the oxidation state of the metal, which greatly affects solubility. The two most common oxidation states of chromium are CrIII and CrVI. CrIII exists as a relatively non-reactive cation that is virtually insoluble in water above a pH of 6.2. Conversely, CrVI exists as a highly water-soluble oxy-anion.

2.0 OVERVIEW OF TECHNOLOGY

The following subsections describe various aspects of in-situ CrVI reduction technologies that will be evaluated in the proposed pilot test.

2.1 IN-SITU TECHNOLOGY DESCRIPTION

The proposed pilot test will evaluate the in-situ reduction of CrVI to CrIII, and the subsequent geochemical fixation of the CrIII onto the aquifer matrix. The concept of in-situ reduction was pioneered in the 1970s by MWH personnel, and was first tested in California at a chromium-impacted site in the early 1980s. Since that time, chromium reduction has been applied at sites throughout the world in varied geohydrological regimes, using a variety of approaches (Rouse et al., 2001) (Rouse, 2001). Table 1 is a representative list of sites in California and elsewhere at which the in-situ reduction of CrVI has been successful.

CrVI can be reduced to the trivalent form by many electron donors such as organic carbon, ferrous iron, and reduced sulfur. Soil containing organic carbon can reduce CrVI by the reaction:

$$\mathbf{2Cr_2O_7^{-2} + 3C + 16H^+ \rightarrow 4Cr^{+3} + 3CO_2 + 8H_2O}$$

The CrIII forms chromium hydroxide, which binds to the aquifer matrix.

CrVI can be reduced to the trivalent form by ferrous iron, either in solution or in various ferrous-bearing silicates such as olivene, amphibolite, mica, and chlorite. A proposed reaction for the reduction of CrVI by ferrous biotite is given by Palmer and Puls (1994) as:

$$\mathbf{[Fe(II), K^+]biotite + Fe^{+3} \rightarrow [Fe(III)]biotite + K^+ + Fe^{+2}}$$

The resultant ferrous ions in solution react with CrVI according to:

$$\mathbf{HCrO_4^- + 3Fe^{+2} + 7H^+ \rightarrow Cr^{+3} + 3Fe^{+3} + 4H_20}$$

The CrIII and ferrous iron form oxyhydroxides, which sorb to the aquifer matrix. As such, CrIII is in a geochemically stable form, similar to the mode of occurrence of most natural chromium in soil and rock. The second reaction of ferrous iron with CrVI would also be applicable in the case of direct addition of ferrous iron to the aquifer or with the reduction of background ferric iron to the ferrous state by a chemical reductant like calcium polysulfide. Note that there are several reductants that can be considered for in-situ reduction, as described further in Section 2.3.

The reduction of CrVI to CrIII can also be facilitated by indigenous bacteria. Soluble organic carbon substrates such as lactate, ethanol, acetic acid (vinegar), molasses, or emulsified vegetable oil can be introduced into the groundwater, providing a food source to stimulate the growth of naturally-occurring bacteria. The increased rate of microbial respiration depletes the supply of dissolved oxygen and creates reducing conditions.

An important consideration with the use of in-situ reductants is the potential for temporary solubilization/mobilization of other reducible metals that naturally reside in the aquifer matrix, such as iron, manganese and arsenic. Data collected during the application of in-situ reductants at other sites shows that this is a temporary phenomenon associated with the creation of reducing conditions. Once conditions return to background, these metal ions re-precipitate in the aquifer matrix. A monitoring program is proposed in this workplan to confirm the temporary nature of this phenomenon. The reduction of chromium is generally a one-way reaction; after the aquifer returns to ambient conditions, CrIII typically does not re-oxidize to CrVI.

Experience at other chromium-affected sites has shown that there are two key elements to a successful in-situ remedial program:

- Selection of the appropriate reducing agent, considering site geochemistry and hydrology

- Design of the proper reductant delivery system, to ensure contact between the contaminant and the reductant

These elements are discussed in the following sections.

2.2 REAGENT SELECTION

A number of chemical and biological reagents have been used for in-situ treatment of CrVI in groundwater. These reagents work by altering geochemical conditions in the aquifer, creating a reducing environment in which CrVI reduction occurs spontaneously. The reducing environment is maintained for a period of time (generally weeks to months, depending on the reductant) through the addition of a reductant solution. Selection of the appropriate reductant, and the quantity and concentration of the solution, requires an understanding of the geochemical, biological, and hydrologic conditions at the site.

2.2.1 Chemical Reduction

In-situ chemical reduction involves the injection of either reduced sulfur-based reagents (such as bisulfite, metabisulfate, sodium hydrosulfite (also know as dithionite), or calcium polysulfide; or iron-based reagents (such as ferrous sulfate, ferrous chloride, or emulsified zero-valent iron [ZVI]) into the aquifer. When contacted by any of these reductants, CrVI is reduced to insoluble CrIII and is sorbed to soil as chromium hydroxide/oxide, resulting in a commensurate removal of soluble chromium from groundwater. Chemical reductants can be introduced into the aquifer using injection wells or infiltration basins. The reductant can be spread through the aquifer using the natural hydraulic gradient, or using a recirculation system consisting of injection and extraction wells. The equipment and installation techniques for introducing and spreading the reductant are well established, and are considered conventional technologies.

2.2.2 Biological Reduction

Reduction of CrVI to CrIII also occurs under biologically-induced reducing conditions (measured as a negative oxidation-reduction potential). The reduction of CrVI is not a biological reaction, but occurs spontaneously after the microbes have created reducing conditions. Soluble organic carbon substrates such as lactate, ethanol, acetic acid (vinegar), molasses, or emulsified vegetable oil can be introduced into the groundwater, providing a food source to stimulate the growth of naturally-occurring bacteria. Increasing the supply of soluble organic carbon increases the rate of microbial respiration, which depletes the supply of dissolved oxygen and creates reducing conditions. The simple carbon substrates are supplied to the subsurface via a reagent mixing and delivery system.

Bench-scale microcosm testing is typically used to select the most effective carbon substrates for biological reduction. Microcosms are jars or similar containers filled with CrVI-containing soil and groundwater from the site, to which various amendments are added in a laboratory setting. Microcosm testing is used to evaluate carbon substrate efficiency and to generate transformation rate data (time required to reduce CrVI to CrIII with each electron donor). For chemical reduction, relatively simple jar tests are typically performed. A summary of the approach and results of bench scale testing that was conducted for the Topock site is discussed in Section 2.2.3**.**

Now that microcosm testing has been found to produce favorable results, pilot testing is proposed to evaluate reagent performance at the field level, and to determine full scale design parameters such as reductant concentrations and quantities, and the optimal reagent delivery and mixing system (as discussed in Section 2.4).

2.2.3 Bench Test Results

This section summarizes results of microcosm testing conducted using aquifer matrix and groundwater samples collected from well MW39-D at the Topock site. The microcosm tests were performed as described in the report entitled *In-situ Remediation Bench-scale Testing* submitted to DTSC on January 14, 2005 (CH2M Hill, 2005a).

The primary objective of the bench-scale testing was to evaluate the capabilities of a number of chemical and biological reagents selected to reduce CrVI to CrIII, given the particular geochemical and microbiological conditions at the Topock site. The tests included:

- Chemical reduction using dithionite, ZVI, and calcium polysulfide.

- Biologically induced reduction using molasses; methanol, ethanol, acetic acid, and lactate (MEAL); and emulsified vegetable oil (EVO).

All of the tested chemical and biological reagents were successful at reducing CrVI to CrIII in a brief time period. Based on MWH's previous experience, the chemical reagents were expected to produce the most rapid reductions in CrVI concentrations, as these reagents do not rely on microbial respiration to develop reducing conditions. Dithionite and calcium polysulfide promoted decreases in CrVI concentrations from over 11,000 micrograms per liter (µg/L) to less than 0.2 µg/L within six hours. Reaction rates in ZVI-amended microcosms were much slower, probably because corrosion of ZVI must occur (producing ferric iron) before the CrVI can be reduced. CrVI concentrations with ZVI decreased from over 11,000 µg/L to about 2,400 µg/L after three days, to about 700 µg/L after seven days, and to less than 0.2 µg/L within 19 days.

The microcosms amended with the biological reagents MEAL, EVO and molasses also exhibited decreases in CrVI concentrations from over 11,000 µg/L to less than the analytical detection limit of 0.2 µg/L over the study period. Of the biological reagents, molasses promoted the most rapid decreases in CrVI concentrations, from over 11,000 µg/L to less than 0.2 µg/L within eight days. The MEAL- and EVO-amended microcosms both exhibited decreases in CrVI concentrations nearly identical to the ZVI-amended microcosms, with initial CrVI concentrations of over 11,000 µg/L declining to about 2,500 µg/L after four days, to about 700 µg/L after eight days, and to less than 0.2 µg/L within 19 days. EVO has a larger number of carbon molecules in the compound, and microorganisms require more time to break down these more complex compounds.

The differences in the rate of reduction of CrVI concentrations observed among the biological reagents are likely due to differences in the initial reagent concentrations and the time required to establish reducing conditions. The molasses-amended microcosms had higher concentrations of reducing agents than the MEAL- and EVO-amended microcosms. Furthermore, it generally takes longer to generate the conditions needed to reduce CrVI to CrIII using complex carbon reagents like EVO, as compared to using simple carbon reagents like the food-grade MEAL or molasses. It is important to note that biological reagents that produce rapid CrVI reduction rates have shorter half-lives than more complex carbon reagents and may be metabolized so quickly that the compounds will not travel far from the injection wells. Reagents that react more slowly are typically more persistent in the environment. These compounds may result in better distribution in the aquifer, resulting in a larger treatment zone and less infrastructure required to contact the CrVI plume.

Analysis of dissolved chromium (Cr_{dis}) and total chromium (Cr_{tot}) concentration data collected during the study suggests that the reduced chromium (CrIII) precipitated to aquifer soils in all of the study microcosms. In the MEAL- and EVO-amended microcosms, Cr_{dis} and Cr_{tot} concentrations declined in parallel with CrVI concentrations, indicating that chromium precipitated to aquifer soils as it was reduced. Molasses-amended microcosms showed Cr_{dis} and Cr_{tot} concentrations declining more slowly than CrVI concentrations, suggesting that some of the chromium required a longer time to precipitate to aquifer soils. Similar behavior was observed with the calcium polysulfide reagent, and this behavior was even more pronounced with the dithionite reagent. The ZVI-amended microcosms behaved similarly to the MEAL- and EVO-amended microcosms, with chromium precipitating to aquifer soils as it was reduced.

In all of the microcosms, the CrVI was reduced and precipitated to aquifer soils within the study period of 69 days. Reoxidation of CrIII to CrVI was not observed in any of the microcosms during the study.

Concentrations of CrVI in the control (untreated) microcosms decreased throughout the study period, especially in the intrinsic (unsterilized) control where initial CrVI concentrations of over 11,000 µg/L decreased to about 4,200 µg/L after eight days, and to less than the analytical detection limit of 4 µg/L within 69 days. Concentrations of CrVI in the sterilized control (which theoretically had no microbial activity) decreased less rapidly than in the intrinsic control microcosms, with the initial CrVI concentration of over 11,000 µg/L declining to about 9,200 µg/L after eight days, and to about 1,300 µg/L after 69 days. Changes in CrVI concentration in these control microcosms (both sterile and intrinsic) are not related to the introduction of biological or chemical reagents. However, natural organic carbon is present in the aquifer at the Topock site, and provides a food supply for microbial respiration. The intrinsic control results suggest that the respiration of native (intrinsic) microbes in these microcosms created moderately reducing anaerobic conditions that reduced CrVI to CrIII. It is possible that sterilization was not completely effective in the sterile control microcosms, or that abiotic processes contributed to the reduction in CrVI concentrations in these controls.

Further discussion regarding proposed additional bench scale testing to be performed is provided in Section 3.6.

2.3 REAGENT DELIVERY SYSTEMS

In addition to the selection of an appropriate reductant, successful implementation of in-situ remediation of CrVI requires adequate delivery and mixing of reagents in the subsurface. Reductant solution can be delivered to the subsurface through:

- Infiltration Basins - An infiltration basin may be particularly well suited to treating residual chromium in the soil and pore water of the vadose zone, if present. The gravel in Bat Cave Wash has the ability to receive CrIII and secondary precipitate without plugging (as can happen with wells). However, a basin allows for oxygen delivery to the subsurface, and oxygen will consume the reductant. Surface basins rely on natural hydraulic head as the distribution driver, so there may be a lag of weeks to months before the solution migrates to the saturated zone.
- Injection Wells - Introduction of the reductant solution through permanent or temporary wells works best in permeable sediments, but the wells and/or aquifer matrix may become fouled by the formation of secondary precipitates from the reductant solution, or by bacterial growth. The reductant solution can be gravity fed or pressure injected into the well.
- Direct-Push Injection Rods - Introduction of the reductant solution through direct-push steel rod is well suited for sites where the water table is shallow and the vadose zone does not contain obstructions, such as cobbles (this is not the case at the Topock site). When the reductant solution is delivered under high pressure, sub-horizontal fractures may be formed, allowing the reductant solution to migrate laterally from the introduction point, and then diffuse into the aquifer.

Delivery system operating methods used to remediate CrVI in groundwater at other sites, and worth considering at the Topock site, include:

- Introducing reagent through well(s) or basin(s) positioned hydraulically upgradient of the affected area, followed by passive migration across the affected aquifer.

- Introducing reagent through a lesser number of wells positioned hydraulically up-gradient or cross-gradient of the affected area, followed by active circulation through the affected area, capture via extraction wells, and reinjection into the area requiring treatment.

Both of these delivery approaches have benefits and limitations. With a passive flow system, reductant solutions are allowed to flow with the natural groundwater gradient through the affected area. Passive flow systems often require a dense network of wells or injection points to achieve adequate distribution of reagent in the subsurface.

With an active recirculating system, groundwater dosed with a reductant solution is injected, and then is drawn through the target treatment zone to extraction wells located on the opposite side of the plume. The recirculation system provides for containment and re-injection of any excess reagent, and can greatly decrease the time required for the reagent to contact the contaminant plume. However, active pumping uses more energy than passive flow. The equipment and installation techniques for passive and recirculating systems are well established, and are considered conventional technologies.

3.0 PRE-IMPLEMENTATION CONSIDERATIONS

The following sections describe activities that will be conducted prior to implementation of the pilot test.

3.1 FLOODPLAIN PILOT TEST LOCATION EVALUATION

Four areas within the floodplain were evaluated to compare their suitability as locations for the floodplain in-situ pilot test. Potential Test Area 1 (PTA-1) is located northeast of well TW-2. PTA-2 is located due east of well TW-2. PTA-3 is located along the floodplain monitoring transect (the line of wells extending from MW-20 to MW-34). PTA-4 is located south of the transect. Each of these potential test areas is oriented along the general floodplain groundwater flow direction toward extraction well TW-2 with the exception of PTA-3 which is oriented along the transect (Figure 4A). The four PTAs were evaluated based upon the following seven criteria:

- Proximity and orientation to well TW-2
- Susceptibility to influence from extraction well PE-1
- Knowledge and suitability of stratigraphy and groundwater chemistry
- Implications for future plume monitoring
- Topography
- Potential biological impacts
- Proximity to potential cultural resources

These seven criteria were ranked for each PTA using the following scale:

- Excellent
- Good
- Fair
- Poor
- Unacceptable

A ranking of unacceptable for any one of the seven criteria indicates that the PTA location is not suitable for the pilot test resulting in that PTA being removed from further evaluation. The criteria developed and used for evaluating sites for the in situ pilot study will not be identical to the criteria ultimately used for siting facilities for full-scale application of an in situ treatment system (if in-situ treatment is selected as part of the final remedy).

The criteria rankings are summarized in Table 2. Please refer to Figure 4A for the locations of the PTAs and wells referred to in the following evaluations.

3.1.1 Proximity and Orientation to Well TW-2

Groundwater extraction from well TW-2 is expected to be the dominant influence on groundwater flow direction and gradient in the floodplain area during the in-situ pilot test, with groundwater flow direction generally toward TW-2 and a steeper gradient (i.e. higher groundwater velocity) closer to TW-2. One of the objectives of the pilot test is to evaluate the transport of injected reductant solution under pumping-influenced conditions. To monitor this transport, monitoring wells should ideally be located directly downgradient of the selected injection point. Therefore, PTAs located closer to extraction well TW-2 and oriented along the flow direction toward TW-2 were given higher rankings. Additionally, PTAs located closer to the pumping centers at TW-2 and PE-1 will have a higher certainty of capture by TW-2 and PE-1, in order to ensure that there is no release of injected reagents towards the Colorado River.

> PTA-1 is one of the two PTAs closest to well TW-2, and is oriented toward TW-2. It is more distant from PE-1 than PTA-2 and therefore is slightly less likely to be within the combined capture zone of TW-2 and future PE-1. PTA-1 was given a ranking of good for this criterion.
>
> The proximity of PTA-2 to well TW-2 is similar to that of PTA-1, and likewise is oriented in the general direction of groundwater flow toward TW-2. It is located well within the combined capture zone of TW-2 and future PE-1. PTA-2 was given a ranking of excellent for this criterion.
>
> PTA-3 is located somewhat farther from well TW-2, and is oriented along the existing well transect rather than directly toward TW-2. The orientation along the transect makes maximum benefit of the existing wells and data, but would result in some monitoring wells within PTA-3 being somewhat cross-gradient to the expected flowlines. PTA-3 was given a ranking of fair for this criterion.

PTA-4 is the farthest from TW-2, but is oriented directly toward TW-2. PTA-4 was given a ranking of poor for this criterion.

3.1.2 Susceptibility to Influence from Extraction Well PE-1

It is anticipated that groundwater extraction from well PE-1 may occur during the floodplain in-situ pilot test. Pumping from PE-1 is expected to alter the groundwater flow direction and gradient in the area between PE-1 and TW-2. A simple, uni-directional groundwater gradient is most desirable for the pilot test. Therefore, PTAs located farther from potential influence of pumping from well PE-1 were ranked higher for this criterion.

PTA-1 is located the farthest from PE-1, and was given a ranking of excellent for this criterion.

PTA-2 is located closer to TW-2 than to PE-1, and it is expected that pumping from TW-2 would be the dominant influence on groundwater flow direction and gradient at this location. PTA-2 was given a ranking of good for this criterion.

PTA-3 is located much closer to PE-1 than to TW-2, and groundwater flow direction and gradient in this area could be strongly influenced by pumping from PE-1. PTA-3 was given a ranking of poor for this criterion.

PTA-4 is located closer to PE-1 than to TW-2, and groundwater flow direction and gradient in this area could be strongly influenced by pumping from PE-1. PTA-4 was given a ranking of poor for this criterion.

3.1.3 Knowledge and Suitability of Stratigraphy and Groundwater Chemistry

Detailed knowledge of the stratigraphy and groundwater chemistry within the pilot test area are essential in planning and executing a successful in-situ pilot test. Therefore, PTAs located closer to locations with more extensive historical data were ranked higher for this criterion. Sites with historical data that indicated unacceptable conditions for a pilot test were ranked unacceptable.

Although the overall stratigraphy and groundwater chemistry of the floodplain is generally well understood, there are no existing groundwater monitoring wells within PTA-1 or in the immediate vicinity. Understanding of the stratigraphy and groundwater chemistry at this location would be based on interpolation of data from other wells located over 130 feet away. PTA-1 was given a ranking of poor for this criterion.

Although there are no existing wells within its boundary, PTA-2 runs parallel to and approximately 100 feet north of the existing floodplain well transect. The transect represents the greatest density of stratigraphic and groundwater chemistry data within the floodplain, and its proximity and similar orientation to PTA-2 simplify the extrapolation of data to PTA-2. PTA-2 was given a ranking of good for this criterion.

PTA-3 encompasses the central portion of the floodplain well transect which represents the greatest density of data within the floodplain. PTA-3 was given a ranking of excellent for this criterion.

PTA-4 is located to the south of the floodplain well transect, and encompasses the MW-42 well cluster. Historical groundwater data from the MW-42 well cluster indicate chromium concentrations in groundwater that are much lower than those needed to evaluate the performance of the in-situ pilot test. Therefore, PTA-4 was given a ranking of unacceptable for this criterion.

3.1.4 Implications for Future Plume Monitoring

Performance of the in-situ pilot test is expected to result in the removal of chromium from the groundwater at certain monitoring wells within the pilot test area of influence. It is anticipated that wells previously used to monitor plume concentrations and boundaries would not be effective for those purposes for minimum of one year after completion of the pilot test, and possibly as long as several years. PTAs encompassing wells that could be rendered unusable for plume monitoring purposes were ranked lower for this criterion.

Existing wells are not expected to be influenced by performance of the in-situ pilot test at PTA-1. PTA-1 was given a ranking of excellent for this criterion.

Existing wells are not expected to be influenced by performance of the in-situ pilot test at PTA-2. PTA-2 was given a ranking of excellent for this criterion.

Numerous floodplain transect wells could be rendered unusable for plume monitoring by performance of the pilot test at PTA-3. The transect wells provide groundwater chemistry data critical to evaluating the performance of interim measures in the floodplain area. Therefore, PTA-3 was given a ranking of unacceptable for this criterion.

PTA-4 encompasses the MW-42 well cluster. This well cluster could be rendered unusable for plume monitoring purposes if the in-situ pilot test is performed here. PTA-4 was given a ranking of fair for this criterion.

3.1.5 Topography

Well drilling locations are limited to areas with a slope less than 0.09 foot per foot based on the limitations of the drill rig to provide a level drilling platform and a vertical hole (the drill rig is 35 feet long and has hydraulic leveling jacks with a maximum lift of 3 feet, resulting in a maximum slope of 3 feet per 35 feet, or approximately 0.09 foot per foot). The topography of the floodplain at the four PTA locations is nearly identical, and is equally suitable for the in-situ pilot test (Figure 2). Therefore, PTA-1, PTA-2, PTA-3 and PTA-4 were all given a ranking of good for this criterion.

3.1.6 Potential Biological Impacts

There are no known potential impacts to specific species that vary between the four PTAs. Areas towards the southern portion of the floodplain generally have more dense vegetation that may provide breeding habitat for the southwestern willow flycatcher during portions of the year. Activities and impacts within this biologically sensitive area should be minimized. Therefore, the rankings for this criterion were based upon the amount of vegetation removal that would be required, with PTAs requiring less vegetation removal ranking higher.

> PTA-1 and PTA-2 are located in an area with relatively sparse saltcedar. The site is located outside the BLM-designated biologically sensitive area. PTA-1 and PTA-2 were given a ranking of good for this criterion.
>
> PTA-3 is located in an area of scattered, but slightly denser saltcedar. The site is located near the edge of the BLM-designated biologically sensitive area. PTA-3 was given a ranking of fair for this criterion.
>
> PTA-4 is located in an area with the densest saltcedar. The site is located within the BLM-designated biologically sensitive area. PTA-4 was given a ranking of poor for this criterion.

3.1.7 Proximity to Potential Cultural Resources

The project area lies within a larger area of significant cultural and tribal sacred site resources and all activities must be conducted in a manner which recognizes and respects these resources. In addition, the Colorado River itself is of spiritual and cultural importance to local tribes. The four PTAs (Figure 3) all lie approximately equal distance from identified cultural resources. Therefore, PTA-1, PTA-2, PTA-3 and PTA-4 were all given a ranking of fair for this criterion.

3.1.8 Summary and Recommendations

PTA-3 and PTA-4 were removed from further evaluation because each had a ranking of unacceptable for at least one evaluation criterion. The rankings of PTA-1 and PTA-2 were largely similar with the exception of the knowledge and suitability of stratigraphy and groundwater chemistry. There is greater confidence in the anticipated stratigraphy and groundwater chemistry at PTA-2 because of its proximity and identical orientation to the floodplain well transect. There is far less data in the vicinity of PTA-1, and therefore greater uncertainty in the stratigraphy and groundwater chemistry at that location. Although it is located closer to the transect, PTA-2 is far enough from the transect that none of the transect wells should be affected by the in-situ pilot test. Based on the evaluation performed, PTA-2 is recommended as the location for the floodplain in-situ pilot test.

3.2 PROPOSED PILOT TEST APPROACH

The proposed pilot test will attempt to enhance the existing reducing environment in the floodplain adjacent to the Colorado River (Figure 5). The test area will be located entirely within the zone of influence of the planned pumping at TW-2. Two food-grade reagents, lactate and emulsified soybean oil, will be introduced into the groundwater to stimulate the growth of aerobic bacteria, thereby depleting the supply of dissolved oxygen and enhancing the reducing environment. These conditions should reduce CrVI to CrIII between the injection well and pumping well TW-2. The induced gradient generated by pumping groundwater from TW-2 will allow the test to monitor the potential radius of impact of the reagents, their persistence, and their effectiveness at reducing CrVI under active circulation conditions.

Based on the results of bench-scale testing, along with literature reports for other sites, emulsified vegetable oil is believed to be one of the most persistent biological reagents, while lactate should be more mobile and faster reacting. It is proposed that these reagents be tested together at the floodplain. This mixture has been used successfully at other sites, and has been found to be effective while exhibiting no negative synergistic effects. Section 4.1 discusses the proposed reagent dosage to be used during the pilot test. These dosages have been estimated based on available site data. These estimates will be further refined as part of reductant demand testing as described in Section 3.6.

The proposed test area is approximately 200 feet east of the current TW-2 extraction wells, towards the Colorado River. A two-level injection well cluster (PTI-1S/D) will be installed to allow for controlled injection into both the shallow fluvial deposits and deeper alluvial fan deposits of the aquifer in this area. Concentrations of CrVI and geochemical conditions vary vertically in this area. Data collected at the site (e.g. well MW-39 cluster) indicate that reducing conditions are present in the shallowest groundwater within the fluvial deposits along the floodplain, and low to non-detectable levels of CrVI are present. The reducing conditions diminish with depth and also with distance from the river. There is a general correlation between the transition to more oxidizing conditions and the depth at which the alluvial fan deposits are found. It is likely that because of this, the shallowest portions of the saturated zone in the floodplain will require less reagent than the deeper layers, and in fact may not require reagent addition at all. To evaluate the effects of treatment within the various lithologic and geochemical conditions, several multi-level monitoring well nests will be installed. Multi-level monitoring well nests PT-1 and PT-2 will be installed approximately 20 feet and 50 feet west of the injection well cluster, to monitor the development of the enhanced reductive zone as it moves toward TW-2. In addition, to address the potential influence of new extraction well PE-1, multi-level well nests PT-3 and PT-4 will be installed at radial distances of 15 and 20 feet southwest and southeast of PTI-1S/D. The locations of these well clusters are designed to provide good spatial coverage for the expected spread of the treatment zone from PTI-1S/D. Furthermore, at the request of DTSC, multi-level well nests PT-5 and PT-6 will be located 50 feet west and 25 feet north of PTI-1S/D, which is expected to be largely outside the treatment radius, and thus will provide information as to whether the injected solution has migrated outside of the intended treatment zone.

At each multi-level monitoring well nest, three vertical zones will be targeted for monitoring, using three individual well casings installed within one boring and separated by bentonite seals. Details regarding drilling methodology and well design are presented in Section 3.3.

3.3 ACCESS AGREEMENTS

Permission for access and placement of components of the pilot test will be obtained from the Bureau of Land Management (BLM) through approval of a workplan at the local BLM field office level. The proposed pilot test well locations and access route are presented in Figure 5.

3.4 PERMITTING

It is anticipated that the injection of reductant and tracer solutions as proposed for the pilot test will require the issuance of Waste Discharge Requirements (WDR) by the Colorado River Basin Regional Water Quality Control Board (RWQCB). The WDR will specify how the test will be conducted and the monitoring and reporting that will be required by the RWQCB. This work plan, in addition to a completed Report of Waste Discharge Form 200, will provide the information needed for the RWQCB staff to prepare the WDR. The WDR will be considered for adoption by the RWQCB at a regular board meeting. Generally, depending on staff availability, at least three months is required from submittal of the work plan until the WDR is approved.

Well construction permits will be obtained from the San Bernardino County Department of Public Health, Environmental Health Services Safe Drinking Water Permit Section for the additional wells that will be installed.

PG&E has entered into an agreement with the federal agencies under which remedial work at the site will be conducted in compliance with Section 121 of CERCLA, 42 U.S.C. § 9621. Pursuant to Section 121, no local, state, or federal permits are required for any portion of any remedial action conducted on federal property, provided that the remedial action meets specified conditions. PG&E will work with the DTSC and federal agencies to determine and obtain those permits that are actually required prior to implementation of the pilot study.

3.5 WELL INSTALLATION

Injection well cluster PTI-1S/D, and the six monitoring well nests (PT-1 to PT-6) will be installed on the floodplain in the area west of the monitoring well MW-20 Bench. All wells will be installed during one mobilization, if possible. The wells will be drilled using a rotosonic drilling rig equipped with a 10-inch outside diameter drill casing. The borehole for the PTI-1D will be drilled to total depth (i.e. the top of the bedrock) first; continuous coring and geologic logging will be performed at this location and for each of the nested monitoring well drilling locations. PG&E will then confer with DTSC regarding gravel pack and screen size for the deep well; the selection of shallower screened intervals (if applicable) and gravel pack for that location will also be made at that time. The total depth of drilling at each location (except PTI-1S) will be approximately 120 feet or until the Miocene Conglomerate bedrock is encountered, so that the deepest well screens can be placed at the bottom of the saturated alluvium. At PTI-1S the total depth of the boring will be approximately 70 feet so that the well screen is roughly centered within the saturated fluvial material.

Soil samples will be collected from the recovered continuous core at approximately 10-foot intervals within the saturated zone. These soil samples will be submitted to a California-certified analytical laboratory for CrVI and total organic carbon (TOC) analysis. In addition, soil will be reserved for use in reductant demand testing as further discussed in Section 3.4.

Injection well cluster PTI-1S/D will be constructed within two separate borings. PTI-1S will be constructed with a 4-inch diameter schedule 80 PVC casing and 0.02-inch slotted screen. The screen interval will be 40 feet in length extending from an approximate elevation of 440 feet to 400 feet msl, corresponding with the lowest portion of the shallow saturated fluvial deposits as shown in Figure 3. PTI-1D will be constructed with a 4-inch diameter schedule 80 PVC casing and 0.02-inch slotted screen. The screen will be 40 feet in length extending from an approximate elevation of 400 feet to 360 feet msl corresponding with the full saturated thickness of the alluvial fan deposits at this location as shown in Figure 3. The screened intervals of these two wells (PTI-1S and PTI-1D) will together allow for injection over a total of 80 feet of saturated thickness.

To evaluate the effects of treatment within the various lithologic and geochemical conditions, several multi-level monitoring well nests will be installed. At each monitoring well nest, a single 10-inch diameter boring will be drilled. Three 2-inch diameter schedule 40 PVC casings with 10 feet of 0.02-inch slotted screen will be installed in each boring. The screens will be placed at the following approximate elevations: 435-425 feet msl, 410-400 feet and 375-365 feet msl. These screened intervals were selected based on the lithologic conditions encountered at existing wells MW-39 and MW-20 in the pilot test area. The individual wells in each well nest will be installed from the deepest to shallowest. Number 212 filter sand will be placed from 2 feet below to 2 feet above each screen. Bentonite chips will be installed using a tremie pipe between the screened depths.

Following well construction, each well will be developed using a surge block, bailer, and submersible pump. During development, temperature, pH, specific conductance, and turbidity will be measured using field instruments.

All drilling, well installation, well development, and associated field activities will be performed in accordance with the applicable procedures contained within the *Sampling, Analysis, and Field Procedures Manual, PG&E Topock Program, Revision 1* (SAFPM), or the version of that document that is current at the time the field activities are performed (. All newly installed wells will be monitored and sampled at least twice for the analytes described in Section 4.2 prior to the injection of reagents, to establish baseline conditions. Purging and sampling will be performed with the pump intake placed in the middle of the screened interval, and will follow the methods in the SAFPM (CH2M Hill, 2005b).

3.6 SOIL AND GROUNDWATER REDUCTANT DEMAND

Representative soil collected from the saturated fluvial and alluvial fan deposits during drilling of PTI-1S/D and groundwater samples collected from each well will be used in a microcosm study to refine the dosages of emulsified soybean oil that support conversion of the CrVI to CrIII. For each test (one for fluvial soil/groundwater and one for alluvial soil/groundwater), the groundwater will be analyzed for CrVI, redox potential, sulfate, pH, and TOC. Batch microcosms will be prepared with the soil and groundwater and dosed with 0, 10, 25, 50, 100, 150, 200, 300 and 450 mg/L of the emulsified oil on a total organic carbon basis. The concentrations of CrVI, sulfate, and TOC as well as pH and redox potential will be determined after 0, 1, 2, and 4 weeks.

The results of these tests will be evaluated to determine if the dosage of reagent discussed in Section 4.1 should be adjusted in secondary injections subsequent to the initial pilot test injection. This data will also be useful for more accurate estimates for a potential future full-scale system.

Since this data will only be used for design optimization and not for 'proof of concept,' strict maintenance of anaerobic conditions during sample gathering, preparation and testing is not necessary. Any oxygen introduced into the samples during these steps will only serve to increase the apparent reductant demand, resulting in an additional degree of conservatism in future dosing calculations, and the magnitude of such changes is likely to be low with reasonably careful sample handling. Additionally, this data will be cross-verified with actual field observations during the pilot test when selecting full-scale design parameters.

3.7 TRACER TEST

Concurrent with the pilot test injection, a short-duration tracer test will also be initiated to better understand the flow conditions in the pilot test area. The conservative, non-toxic tracer potassium bromide will be injected in wells PTI-1S/D. Monitoring in the nearby well network will demonstrate the injected solution migration and confirm the gradient influenced by extraction wells TW-2 and PE-1. The test data will also be used to refine estimates of aquifer porosity, dispersivity, and groundwater velocity, which will be useful for pilot test interpretation and potential full-scale design.

4.0 IMPLEMENTATION PLAN

Following well installation and sampling, the pilot test will commence with the introduction of the emulsified vegetable oil and lactate solution. This section discusses the reagent dosage and methodology for reagent introduction.

4.1 REAGENT DOSAGE

Calculation of a target reagent dose consists of two parts:

1 Determining the amount of reagent needed to satisfy the static reductant demand of a certain volume of soil and groundwater in an aquifer (which can be referred to as static demand). This amount can be estimated stoichiometrically.

2 Determining the amount of reagent needed to treat new groundwater flowing into that volume of aquifer after dosing, for a given period of time (which can be referred to as dynamic demand). Calculation of this amount requires additional assumptions, such as the persistence of the reductant in the subsurface and the groundwater flux through the area.

For purposes of this test, there is a wide range of acceptable doses. Smaller than optimal doses may result in incomplete treatment of a given area, but can be adjusted via stronger secondary doses after the first injection. Larger than optimal doses will result in complete treatment and a residual reagent that may continue to treat new groundwater flowing into the treatment zone for an extended period of time.

Data from the bench-scale study (CH2M Hill, 2005a) showed effective treatment for all biological reduction systems at a dosage of 450 mg/L of reagents. This value can therefore be considered an upper bound of required dosage to meet the static reductant demand; smaller doses may be possible. This possibility will be studied in more detail via the reductant demand testing described in Section 3.4.

To select a starting dose for this pilot test, calculations were performed in consultation with Terra Systems, Inc. Terra Systems, Inc. is a firm specializing in organic substrate use for biologically-induced reduction. The calculations reflect that the substrate is indirectly used by bacteria for the reduction of various electron acceptors and CrVI. The calculations estimate the quantity of soybean oil, lactate (assuming 4 percent of the soybean oil by weight), food grade emulsifiers, and yeast extract which is recommended as a nutrient source. The reagent dose requirements were calculated for the floodplain pilot test based on a maximum estimated area of treatment effectiveness of 10,000 $feet^2$ and a maximum saturated thickness of 100 feet. An estimated groundwater seepage velocity of approximately 0.1-foot per day was assumed.

Input used for the model was based on existing site data, including the following parameters and values: 4 mg/L of dissolved oxygen, 2 mg/L nitrate and 10 mg/L CrVI. In addition, it was assumed that approximately 250 mg/L of available sulfate would be consumed, based on a review of the data from the bench scale pilot test. The following table shows the estimated quantity of soybean oil, lactate, emulsifier, yeast extract, and water needed for the pilot test.

Estimated Soybean Oil, Lactate, Emulsifier, Yeast Extract, and Chase Water Requirements for Floodplain Pilot

Component	Pounds	Gallons
Soybean Oil	7,641	996
Sodium Lactate	306	28
Emulsifier	831	100
Yeast Extract	14	
Water	1,470	536
Total Reagent Volume	13,262	1,660
Chase Water	35,747	4,290

Based on the above calculations, a total of volume of approximately 6,000 gallons (1,700 gallons of prepared emulsified vegetable oil and sodium lactate solution followed by a 4,300-gallon chase of clean treated groundwater) will be introduced into each of wells PTI-1S/D.

4.2 REAGENT INTRODUCTION

The reagent and chase water will be allowed to gravity feed if possible, but depending on the rate of flow a pump will be available to assist in injection. The injection pressures will be kept below 50 pounds per square inch (psi). No permanent aboveground equipment will be employed during the pilot test. The proposed approach will minimize the duration and nature of site disruptions, by using temporary hoses to convey batches of reagents from transportable containers to the injection wells. Extracted and treated groundwater from the currently operating extraction system will be used as the dilutant and chase water for the reagent. The groundwater will be blended with the reagents in above ground transportable containers and the resulting mixture will be sent to the injection well via hose. The transportable containers and hoses will be removed from the area following the injection, leaving only the monitoring wells on site. Flow rate and pressure, volumes and blended reagent concentrations will be carefully monitored and recorded during reagent introduction. As discussed in Section 3.4, the reagent dose and volume of the solution to be introduced may be modified after reviewing reductant demand test data, and may also be adjusted to target various well depths based on the results of soil and groundwater sampling during well installation. Any changes to the approach proposed in this work plan will be first communicated to and approved by the DTSC.

4.3 PILOT TEST MONITORING

Monitoring of reagent flow (rate and volume) into the injection well and water levels in nearby monitoring wells will be conducted throughout the duration of injection.

Groundwater monitoring will be conducted to evaluate the effectiveness of the reagent introduction. It is anticipated that the chemical nature of groundwater near the injection well will change soon after the introduction of the reagent. However, it may take some time for the effect to reach the monitoring wells and for the reductive zone to be created by biological activity.

It is planned to conduct groundwater monitoring and sampling immediately following injection, and then daily for the first week, weekly for the first month, and then monthly thereafter (as described in detail below). It is anticipated that the conservative bromide tracer will be detected first, followed later by detections of the reductant or the influence of the reductant. Field instruments and test kits will be used to monitor for the arrival of the bromide tracer and reductant effect in the pilot test monitoring well network. Samples will be collected for laboratory analysis of the various analytes listed below and in Table 3 after detections are noted in the field.

Groundwater sampling will be performed according to the methods described in the SAFPM (CH2M Hill, 2005b). Weekly groundwater monitoring and sampling will continue until the influence of the reductant is noted at the furthest pilot test monitoring well, or until such time as it appears that the reductant is no longer migrating. Monthly monitoring and sampling will be conducted for at least six months thereafter. Monitoring will include field analysis of pH, temperature, dissolved oxygen, ORP, specific conductance, and CrVI (by means of a HACH field test kit). Groundwater samples will be submitted to an analytical laboratory and analyzed for the following:

- CrVI by United States Environmental Protection Agency (EPA) Method 7199
- Total chromium, iron (ferric and ferrous), manganese, and arsenic, by EPA Method 6010B
- Calcium, magnesium, potassium, and sodium by EPA Method 6010B
- Carbonate/bicarbonate alkalinity by Standard Methods 2320
- Nitrate, nitrite, chloride, phosphorus (as phosphate), and sulfate by EPA Method 300.0.
- Total Organic Carbon by EPA Method 415.1
- Sulfide by EPA Method 376.1
- Volatile fatty acids by EPA Method 300.M
- Ammonia by EPA Method 350.2
- Methane by EPA RSK SOP 175

Samples will be taken more frequently at the beginning of the test, and less often as the test progresses, as summarized below:

Sampling Phase 1: Day 1 (day following completion of injection) through Day 5. Shallow, middle, and deep casings of PT-1, PT-3, and PT-4 will be monitored daily using field instruments/test kits for CrVI, bromide, pH, temperature, dissolved oxygen, ORP, and specific conductance. Samples will be collected for laboratory analysis of bromide if bromide is detected using a field kit/meter.

Sampling Phase 2: End of Week 1 (Day 7) through end of Week 3 (Day 21). Shallow, middle, and deep casings of PT-1 through PT-6 will be monitored weekly using field instruments/test kits for CrVI, bromide, pH, temperature, dissolved oxygen, ORP, and specific conductance. Samples will be collected for laboratory analysis of bromide, volatile fatty acids, and total organic carbon if bromide is detected using a field kit/meter. Samples will be collected for laboratory analysis of all analytes specified in Table 3 if field measurements of CrVI concentration differ by more than 20 percent from the baseline sample results or if ORP differs by more than 50 millivolts from the baseline sample results.

Sampling Phase 3: End of Week 4 (Day 28) through end of Month 6 (Week 24, Day 168). Shallow, middle, and deep casings of PT-1 through PT-6, and extraction wells TW-2D and PE-1 will be monitored monthly (every 4 weeks) using field instruments/test kits for CrVI, bromide, pH, temperature, dissolved oxygen, ORP, and specific conductance. Samples will be collected for laboratory analysis of all analytes specified in Table 3 from the shallow, middle, and deep casings of PT-1 through PT-4 monthly (every 4 weeks), from the shallow, middle, and deep casings of PT-5 and PT-6 bi-monthly (every 8 weeks), and from extraction wells TW-2D and PE-1 bi-monthly (every 8 weeks).

A preliminary schedule of analyses for the Floodplain Area In-Situ Field Test is presented in Table 3. The frequency of the monitoring and parameters may be modified as the pilot test progresses, depending on the results obtained in the field. Any modification of the WDR-required monitoring and sampling must be first authorized by the appropriate regulatory agencies.

4.4 REPORTING

It is anticipated that frequent communications between the PG&E project team and DTSC will occur during the course of the pilot test. Additionally, quarterly update reports will be prepared and submitted beginning immediately after the introduction of reagents, and continuing for the duration of the test period. These reports will contain all data obtained during the test. A final written summary report of findings, including a complete data set, will be submitted within approximately three months of completion of the pilot test. This report will include a discussion of treatment efficiencies, recommendations, and considerations for development of a possible full-scale in-situ remedial plan.

5.0 WASTE MANAGEMENT AND EQUIPMENT DECONTAMINATION

Several waste materials will be generated during the drilling, development, and sampling of the proposed pilot test wells. These investigation-derived waste (IDW) materials will include groundwater, drill cuttings, decontamination rinsate, and incidental trash.

5.1 IDW MANAGEMENT

Drill cuttings generated during drilling of the pilot test wells will be contained in lined roll-off bins temporarily staged at the drilling sites. After sampling and characterization of the drill cuttings are completed, the cuttings bins will be removed from the drilling sites for disposal by PG&E. The drill cuttings will be screened for chromium. If the drill cuttings are characterized as a hazardous waste, they will be transported off site for disposal at a permitted hazardous waste facility. It is anticipated that the cuttings bins will be temporarily staged at the drilling sites for no longer than 45 days.

Water generated during drilling, well development, and sampling activities will be collected in drums or portable storage tanks temporarily located at each drilling site, transferred by forklift or truck to storage tanks in a staging area for characterization and treatment or disposal at a permitted facility. Elevated chromium concentrations are anticipated in the groundwater removed from the pilot test wells. Therefore, secondary containment will be provided for the storage tanks in the staging area.

Incidental trash will be collected from the work area at the conclusion of each workday and placed in a trash collection bin.

All IDW management will be performed in accordance with the procedures specified in the SAFPM (CH2M Hill, 2005b).

5.2 EQUIPMENT DECONTAMINATION

Down-hole drilling and development equipment, and the back end of the drill rig, will be steam cleaned prior to starting work at each new drilling site. Steam cleaning will be performed on a decontamination pad such that all rinsate can be contained and collected. Rinsate from the decontamination of drilling equipment will be transferred to the cuttings bin or water storage tank that contains material from the borehole last drilled.

All equipment decontamination will be performed in accordance with the methods specified in the SAFPM (CH2M Hill, 2005b). Water used for sampling equipment decontamination will be transferred at the end of each workday into the water storage tank that contains water from the wells sampled that day.

6.0 SCHEDULE

The following preliminary schedule has been developed to clarify the sequencing and approximate duration of tasks. It does not show time required prior to the test for permitting and workplan approval. This information is shown graphically in Figure 6.

- Installation and development of injection/monitoring wells (one month)
- Pre-injection baseline sampling (two events/two weeks)
- Tracer testing (one month, concurrent with reagent injection)
- Introduction of reagents (batch) (Phase 1 Field Test, one week)
- Monitoring and sampling events:
  - Weekly for the first month after injection
  - Monthly for months one to six after injection (six months)
- Interim data review after each sampling round; determination if multiple injections are needed based on tracer tests, current and expected TW-2 pumping plans
- Reintroduction of reagents as appropriate
- Preparation and submittal of an interim report at six months.
- Follow-on monitoring and sampling program beyond six months as appropriate

Current biological resource-driven constraints on the floodplain (due most notably to the potential presence of the Willow Flycatcher) are not anticipated to interfere with the pilot test well installation schedule or the pilot test activities.

The project schedule includes a preliminary data report, which will occur after approximately six months of testing to maintain the overall CMS schedule. It is anticipated that data useful for the CMS process will be obtained at this six-month point, and that continued testing beyond six months will yield additional information that may be useful in a full scale design.

Currently anticipated key dates for this program are:

- Submittal of final addendum to this Work Plan – September 2005

- Field mobilization/start of project – October 2005
- Six month interim report submittal – May 2006

7.0 REFERENCES

CH2M Hill, 2005a, *In-Situ* Remediation Bench-scale Testing, PG&E Topock Compressor Station, Needles, California, Prepared for Pacific Gas and Electric Company, January.

CH2M Hill, 2005b, Sampling, Analysis, and Field Procedures Manual, PG&E Topock Program, PG&E Topock Compressor Station, Needles, California, Prepared for Pacific Gas and Electric Company, March 31.

CH2M Hill, 2005c, Performance Monitoring Report No. 16, PG&E Topock Compressor Station, Interim Measures No. 2, March 1 through 31, 2005, Prepared for Pacific Gas and Electric Company, April 15.

Palmer, Carl D, and Robert Puls, 1994, Natural Attenuation of CrVI in Ground Water and Soils, EPA/540/S-94/505, U.S. Environmental Protection Agency Ground Water Issue, October.

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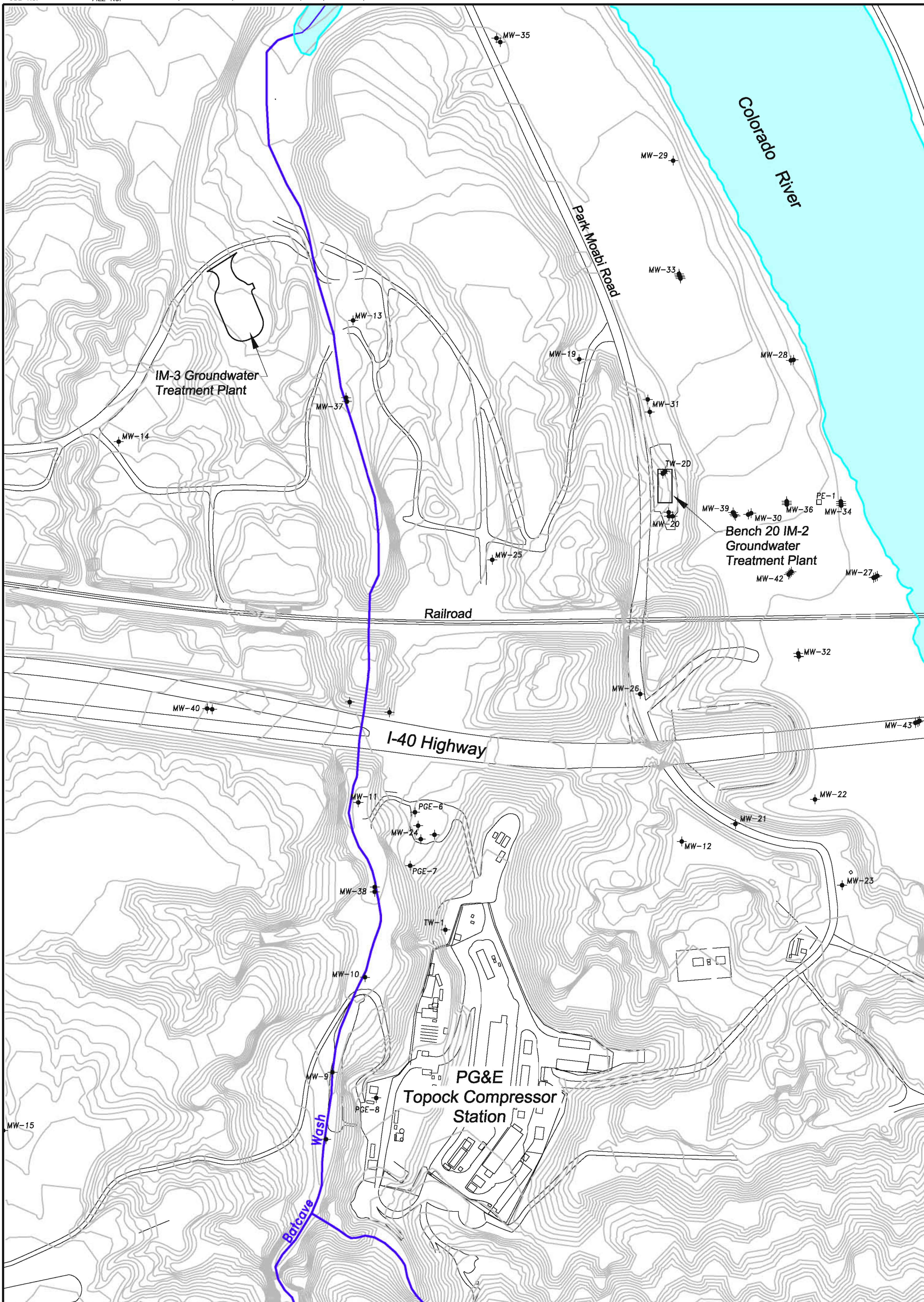
JOB No. -- FILE No. INDSVR\INDUSTRIAL\CAD MLUEBKE\PGE\TOPOCK\SP 1 05



Legend

- Current Well Locations
- Potential Extraction Well

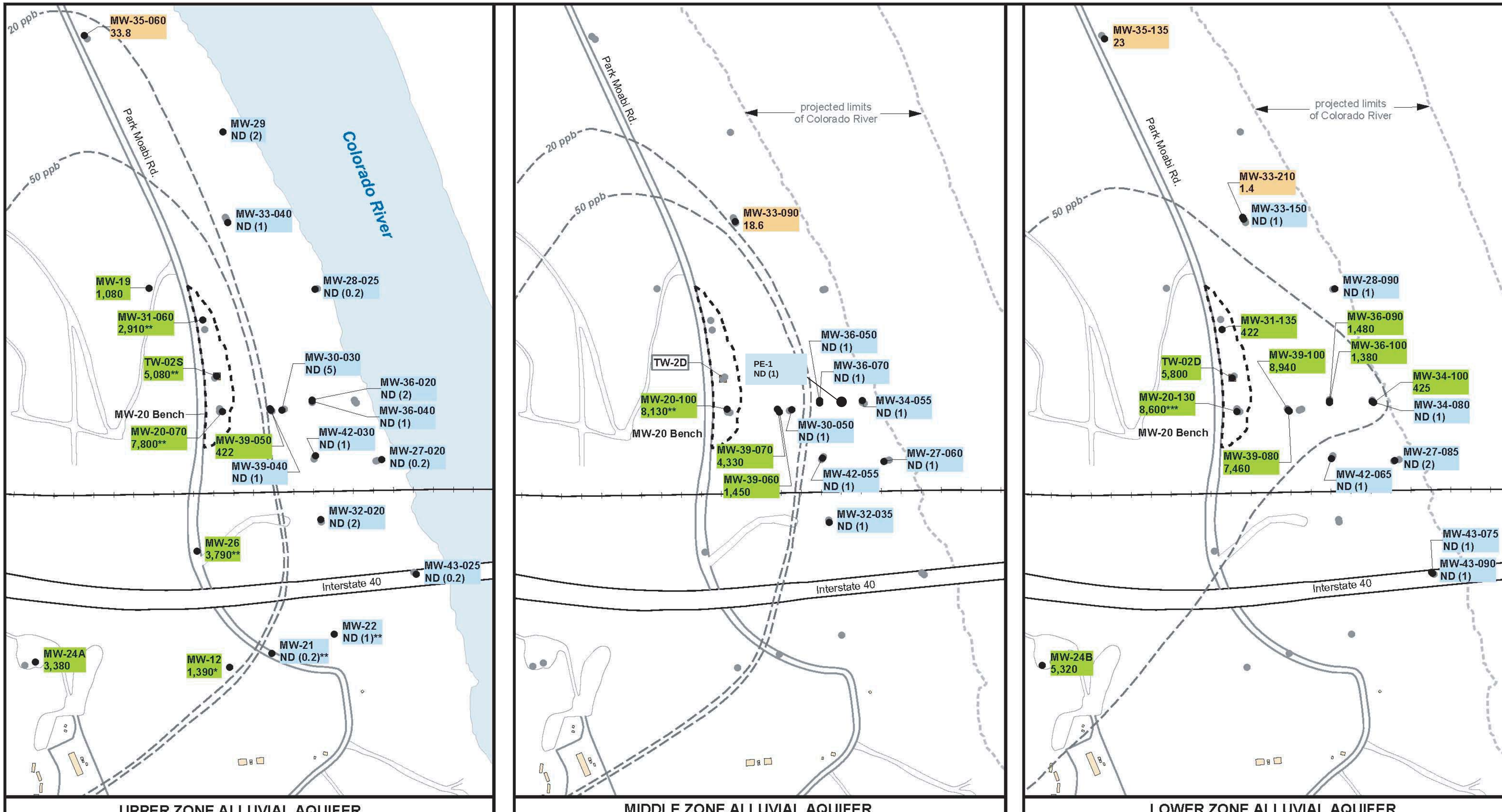
0 FEET 300
SCALE

MWH

PG & E
TOPOCK FACILITY
NEEDLES, CALIFORNIA

SITE PLAN

FIGURE 1



ND (1)	Not detected at listed reporting limit (ppb)
41	Less than 50 ppb
3,810	Greater than 50 ppb

Notes:
Results listed are from March 2005 sampling events.
Results marked * are from September 2004 sampling events.
Results marked ** are from December 2004 sampling events.
Results marked *** are from January 2005 sampling events.

Hexavalent Chromium Concentrations in Groundwater
March 2005 Sampling Events

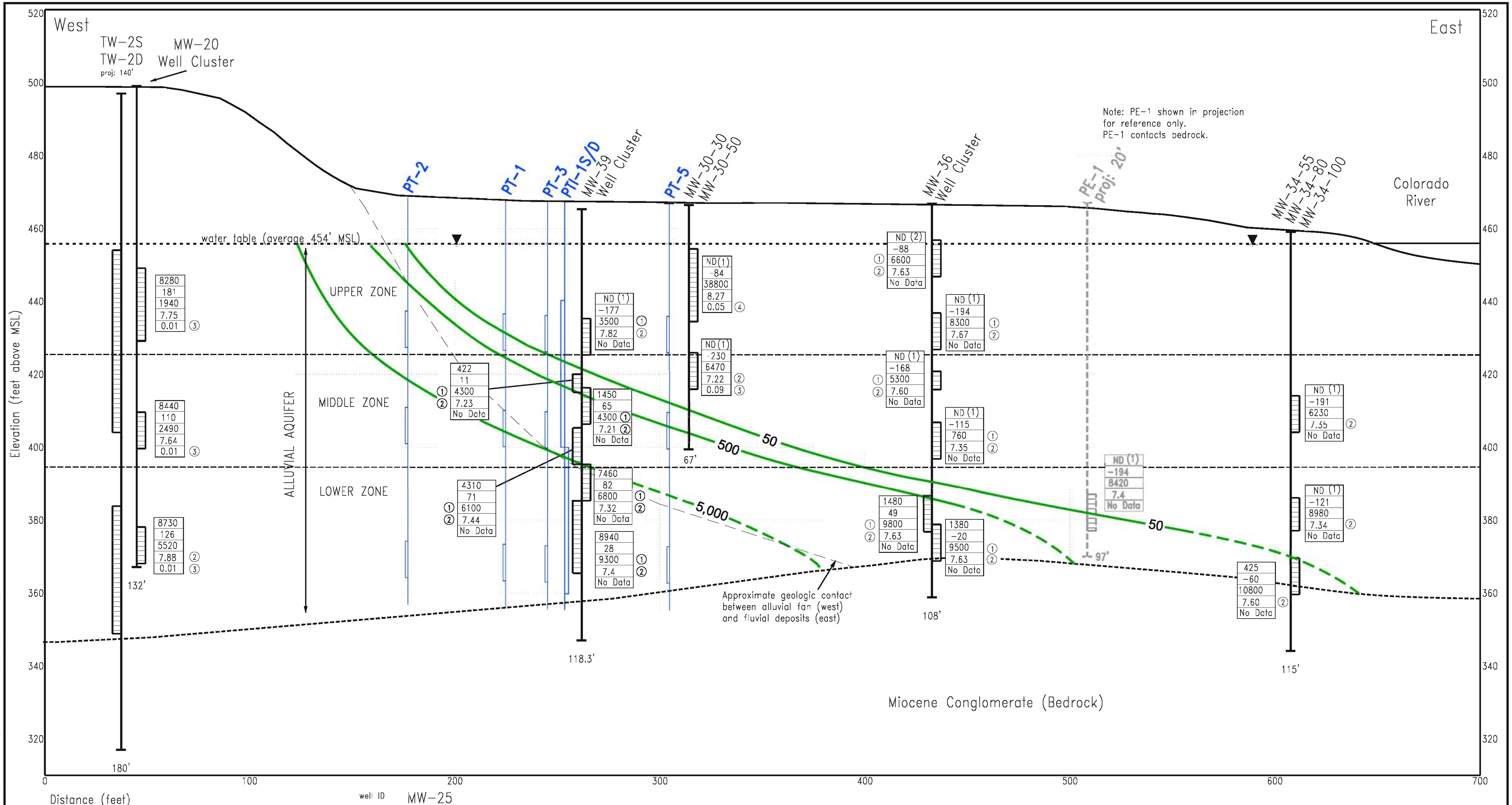
Concentrations in micrograms per liter (µg/L)
equivalent to parts per billon (ppb)
ND = not detected at listed reporting limit.

N

Feet
0 400 800
1 inch equals 400 feet

FIGURE 2
HEXAVALENT CHROMIUM CONCENTRATIONS IN ALLUVIAL AQUIFER, MARCH 2005
Provided by CH2Mhill

MWH



well ID MW-25

water level

well screen

total depth of boring 105'

1.4	Hexavalent chromium (micrograms per liter or ppb)
-103	Oxidation-reduction potential (millivolts)
8420	Total dissolved solids in mg/L
7.4	pH
0.05	Ferrous iron in mg/L
ND	Not detected above the posted reporting limit
(green line)	Interpreted isoconcentration contour of hexavalent chromium

Groundwater Sampling Results, March 2005

① Data from June 2004
② Data from April 2005
③ Data from November 2001
④ Data from September 2000

Notes: bgs = below ground surface
MSL = mean sea level

Blue color indicates new wells to be installed, they have been projected southward into this cross section.

Taken from CH2MHill

MWH

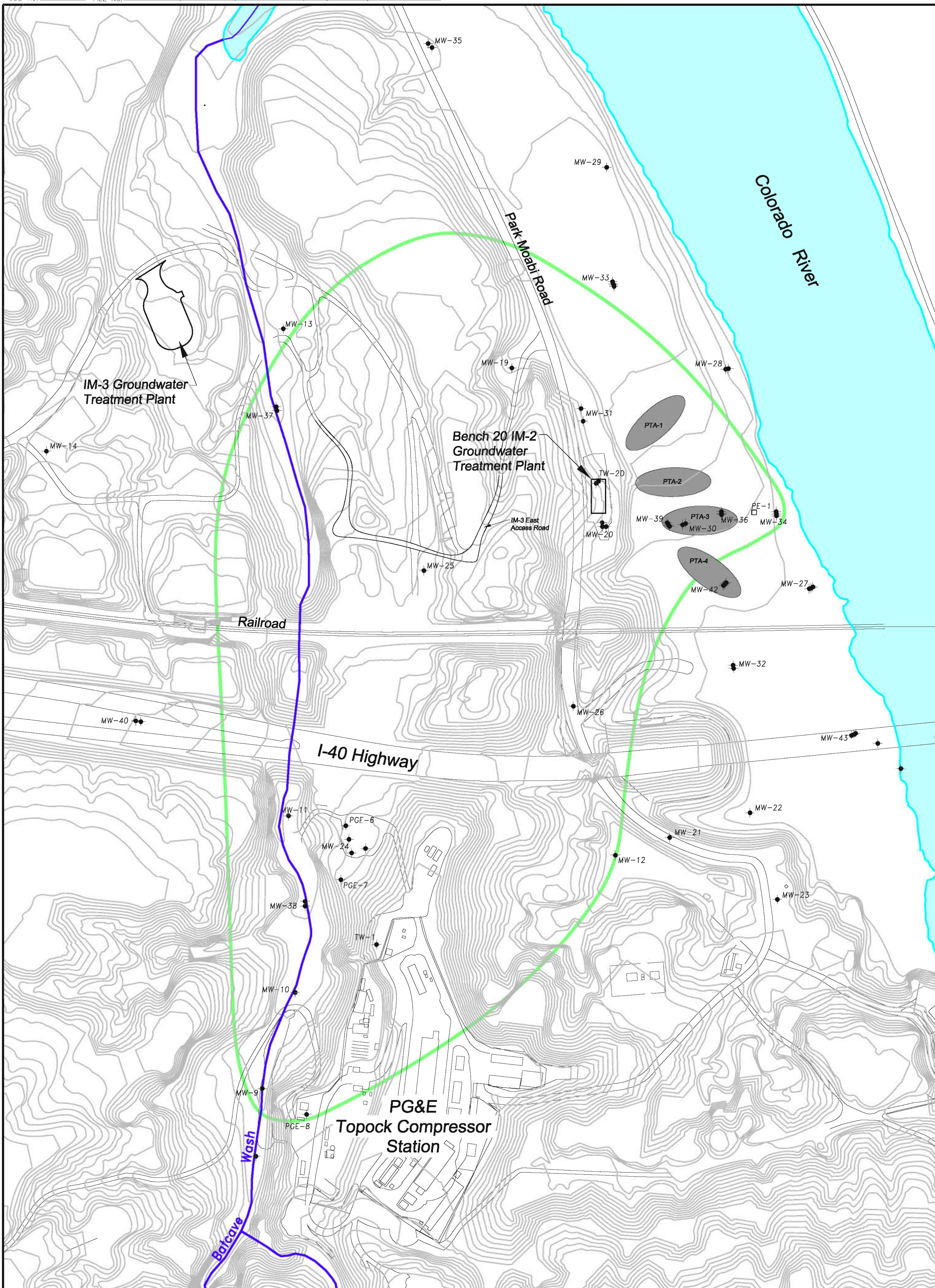
P G & E
TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

VERTICAL CROSS SECTION HEXAVALENT CHROMIUM CONTOURS

FIGURE 3

JOB No. --- FILE No. INDSVR\INDUSTRIAL\CAD MLUEBKE\PGE\TOPOCK\CROSS SECTION 5 05

JOB No. -- FILE No. INDSVR\INDUSTRIAL\CAD MLUEBKE\PGE\TOPOCK\PILOT 7 28 05



Legend

- Current Well Locations
- Potential Extraction Well
- Interpreted Limit of Groundwater with a Concentration of Hexavalent Chromium that Exceeds 50 ppb
- Potential Pilot Test Areas (PTAs)

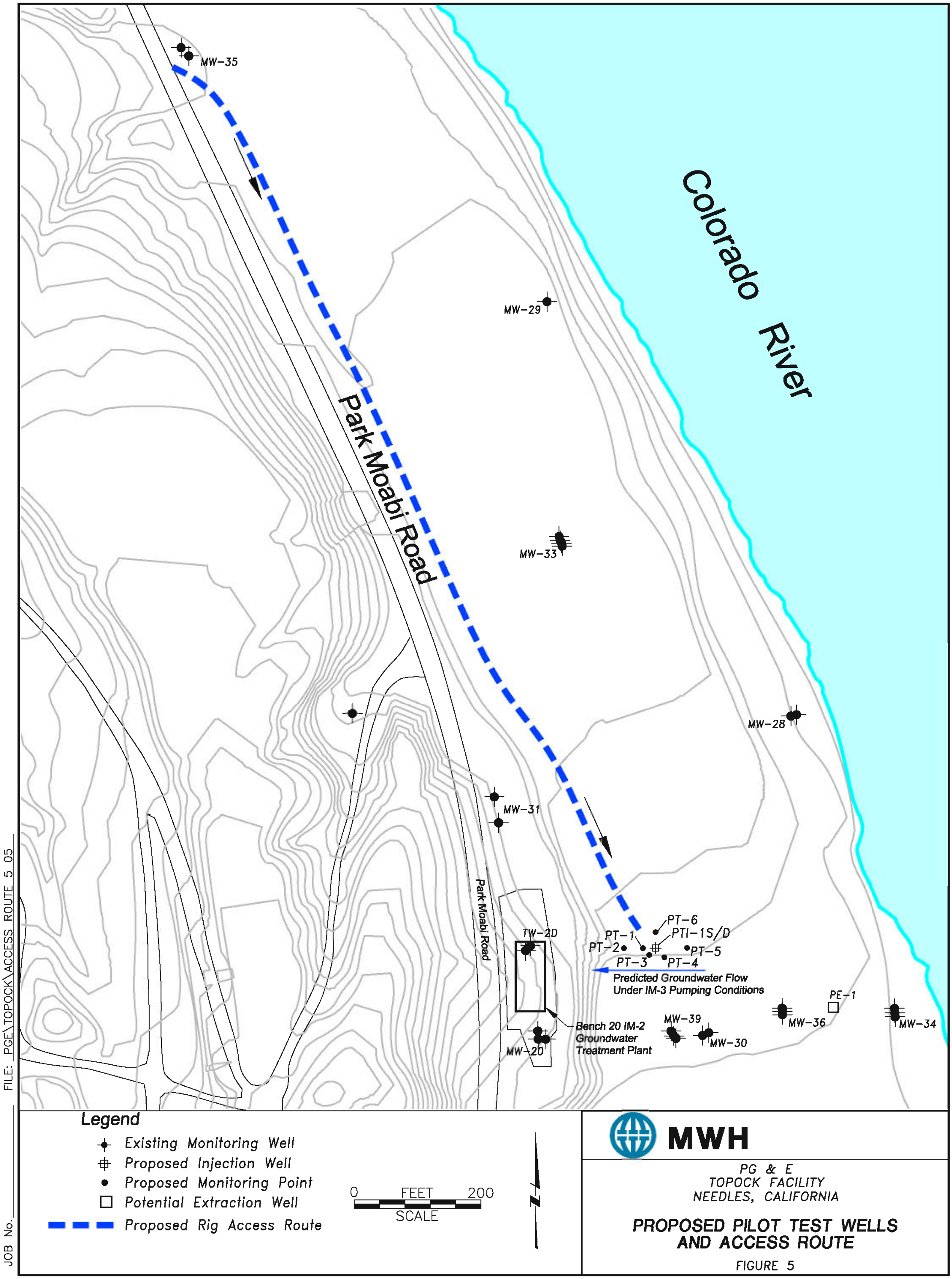
0 FEET 300
SCALE

MWH

PG & E
TOPOCK FACILITY
NEEDLES, CALIFORNIA

LOCATION AND EXTENT OF POTENTIAL PILOT TEST AREAS SHOWING LOCATION CRITERIA

FIGURE 4A



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NEEDLES, CALIFORNIA

PROPOSED PILOT TEST WELLS AND ACCESS ROUTE

FIGURE 5

Figure 6
PG&E Topock Compressor Station
Preliminary Project Schedule

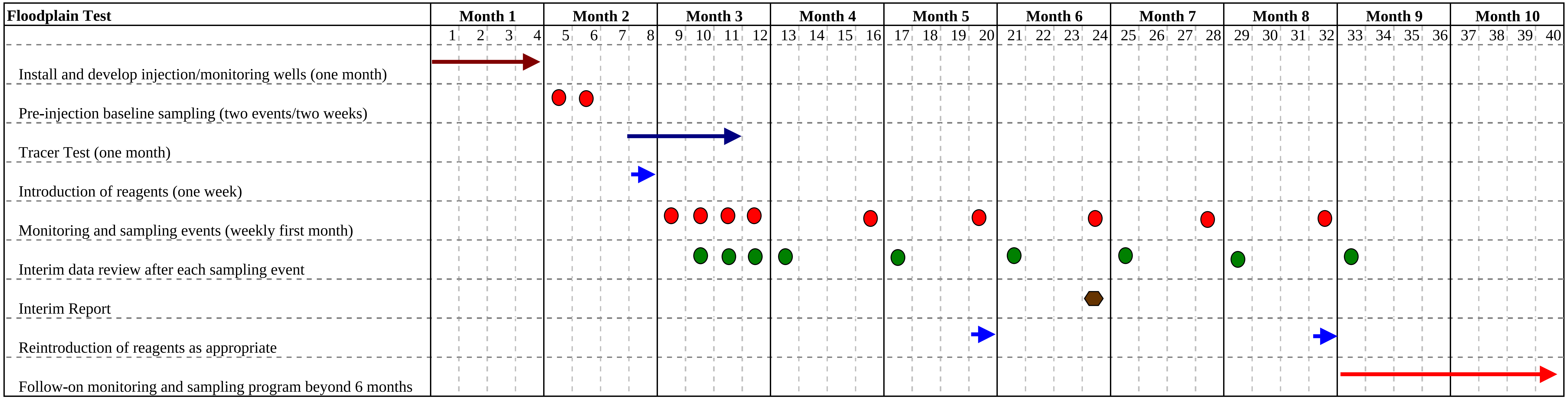

Table 1
Representative Site List
In-Situ Chromium Treatment

Project Location	Key Elements	Regulatory Oversight	Description
Coast Wood Ukiah, CA	▪ Full scale above ground and in situ treatment using calcium polysulfide ▪ Extraction, infiltration and injection ▪ Significant plume decrease, additional remediation will be required after plant closure	DTSC North Coast RWQCB U.S. EPA, Region IX	Groundwater extraction and aboveground electrochemical treatment for remediation of calcium polysulfide and molasses for clean-up of impacted soils. Hexavalent chromium concentrations decreased an order of magnitude over the first two years after reductant was introduced. The injections also caused temporary mobilization of iron, manganese and arsenic, and elevated sulfate concentrations in groundwater.
Valley Wood Superfund site, Turlock, CA	▪ In-Situ remediation in a mile-long plume with injection of calcium polysulfide ▪ Aboveground treatment of groundwater using ferrous-ion reduction ▪ Ongoing groundwater monitoring MNA closure requested	U.S. EPA, Region IX DTSC Central Valley RWQCB	Geochemical fixation was performed to control hexavalent chromium at this Federal Superfund site. The *in-situ* fixation treatment included groundwater extraction, aboveground treatment using the existing ferrous-ion reduction system, dosing the treated water with calcium polysulfide , and re-injection. Closure monitoring is currently being discussed with U.S. EPA. Because of low ambient carbon concentrations and not introducing additional carbon source, there was a temporary increase in sulfate concentrations in the groundwater for approximately one year.
Ecodyne Superfund Site Windsor, CA	▪ Full Scale Treatment of groundwater and vadose soil using calcium polysulfide ▪ Limited monitoring and agency discussion underway	North Coast RWQCB DTSC	Full-scale treatment of hexavalent chromium-impacted groundwater via *in-situ* geochemical fixation using calcium polysulfide was completed in 2004. This process expedited the cleanup by approximately 10 years, when compared with ongoing pump and treat operations which have now been discontinued. Source area soil treatment has now been accomplished.
Marley Cooling Tower Stockton, CA	▪ Pilot Studies using calcium polysulfide amended with ethanol Direct-push injection through temporary bores ▪ Ongoing monitoring	Central Valley RWQCB DTSC	First phase of a pilot test for *in-situ* chemical reduction of groundwater impacted by hexavalent chromium was completed using calcium polysulfide and ethanol. Hexavalent chromium levels were reduced from 10^{+}ppm to non-detect in less than 100 days. A second phase of pilot study to remediate the upgradient portion of the hexavalent chromium plume has also been completed with calcium polysulfide and ethanol and is now being monitored. Temporary mobilization of iron, manganese, and arsenic has been noted in proximity to injection points, but this is not long-lasting in the subsurface. *In-situ* treatment is estimated to reduce the time to closure by 25 years.

Table 1
Representative Site List
In-Situ Chromium Treatment

Project Location	**Key Elements**	**Regulatory Oversight**	**Description**
Former Aerospace Facility Long Beach, CA	▪ Pilot Study using CaSx and corn syrup ▪ Full scale implementation using injection via direct push rods. ▪ Ongoing infiltration and injection of reductant. ▪ Ongoing monitoring	Los Angeles RWQCB	The pilot test resulted in complete reduction of the hexavalent chromium in groundwater throughout the test area, and the effect of the reductant placement persisted for more than 200 days despite the flushing of the tracer by groundwater flow. The program reduced concentrations from greater than 50 mg/L to non-detectable levels. Full-scale implementation involved the injection of approximately 1,000,000 gallons of calcium polysulfide reductant solution amended with corn syrup, into the groundwater through direct-push rods. Reductant solution continues to be infiltrated through a basin to reduce hexavalent chromium concentrations in soil. Tight soil conditions hindered full contact with all impacted areas. Limited remedial efforts are underway in these areas
Carter Holt Harvey, Forwood Products, Mt Gambier, So Australia	▪ CaSx and molasses delivery via injection wells, infiltration trenches and basin. ▪ Extraction, treatment, and reinjection. ▪ Wells used to form reactive barrier across toe of plume. ▪ Clean closure achieved.	South Australian Environmental Protection Agency	This site was over a cavernous limestone aquifer, used as the water supply for a city of 25,000 people, and a major tourist attraction, “Blue Lake”. Initial remediation involved pumping from within the plume under the active water supply plant, treating with calcium polysulfide reductant amended with molasses and injecting around the plume margin. Later, the plant was decommissioned and an infiltration basin installed at the former plant site. Remediation was accomplished in approximately 2 years after basin construction. The site is now certified as remediated by the SA EPA. Because of high calcium carbonate content of the groundwater, injection wells tended to plug, requiring greater reliance on infiltration trenches and basins.
Universal Forest Products Granger, IN	▪ In situ treatment using calcium polysulfide and sodium metabisulfite in drinking water aquifer ▪ Achieved closure under a Voluntary Cleanup Program	Indiana Voluntary Remediation Program	An *in_situ* program to remediate four separate hexavalent chromium plumes was performed in a highly permeable sand aquifer. Two different reductants (calcium polysulfide and sodium metabisulfite) and delivery systems (injection wells and infiltration basin) were used, depending on plume conditions. One plume was cleaned to non-detect levels within 6 weeks of initiation of *in-situ* activities. All four plumes have now received Notices of Completion under the Indiana Voluntary Remediation Program. No mobilization of other metals was noted.
Shieldalloy Metallurgical Corporation Newfield, NJ	▪ Pilot Test using calcium polysulfide ▪ Successful reduction under challenging geochemical conditions		A pilot study was conducted to evaluate the feasibility of using *in-situ* hexavalent chromium reduction to supplement an existing pump-and-treat system. Calcium polysulfide was injected into an existing monitoring well. Even under challenging geochemical conditions – groundwater at a pH of 12 and total dissolved solids several times that of seawater – hexavalent chromium concentrations were reduced from 39 mg/L to below detection limits. The geochemical conditions at this site have resulted in the formation of a dense brine layer at the base of the aquifer, and investigations are ongoing to determine its extent and potential effects on full-scale *in-situ* remediation efforts.

Table 1
Representative Site List
In-Situ Chromium Treatment

Project Location	Key Elements	Regulatory Oversight	Description
Kaydon Ring and Seal Baltimore, MD	▪ Field-scale demonstration using calcium polysulfide ▪ Successful treatment of unsaturated and unsaturated soil using infiltration basin currently underway by other consultant group		Chromium contamination exists in the unsaturated fill, and saturated soil and bedrock under this chromium plating plant as a result of leaks dating back to World War II. A field-scale demonstration was completed under one of the plating lines by breaking up the floor, installing an infiltration bed, and percolating calcium polysulfide reductant solution through the fill into the groundwater. The feasibility of this approach was proven.
Power Engineering Denver, CO	▪ Saturated zone reactive barrier adjacent a river, using calcium polysulfide ▪ Vadose soil treatment		Chromium plating operations at this plant resulted in a hexavalent chromium plume that extended from the facility to the South Platte River. As an interim control measure, borehole placement of calcium polysulfide reductant solution was used to form a reactive barrier across the toe of the plume. *In-situ* reduction of hexavalent chromium in the vadose zone was also initiated by injecting reductant solution through a series of horizontal boreholes beneath the floor slab of the facility. No other metals were noted during monitoring, and the site is not considered as remediated.
Foremost Environmental Solutions Glenwood Springs, CO	▪ Full-scale remediation implementation using calcium polysulfide adjacent to a river ▪ Treatment of vadose and saturated soil using infiltration basin ▪ Site closure obtained	Colorado Health Department	This former plating facility is located on the shore of the Colorado River in an area popular for recreational fishing and rafting. An infiltration basin was constructed in which calcium polysulfide reductant and a carbon source? (to aid in bacterial growth) were infiltrated, resulting in reduction of the hexavalent chromium to the trivalent state and the precipitation of the chromium as a hydroxide. This site is considered complete by the Colorado Health Department. No other metals were mobilized, and sulfate concentrations decreased during remediation.
REMCO Industries Willits, CA	▪ Two pilot test completed using calcium polysulfide and molasses and injection via direct push rods ▪ Full scale remediation ongoing	North Coast Regional Water Quality Control Board	This former chromium plating site is underlain by low-permeability silts and clays that have prevented remediation via conventional pump-and-treat methods. Pilot tests were performed to demonstrate that the direct-push hydrofracturing approach is appropriate at this site, and that the molasses reductant solution used will not only reduce the hexavalent chromium to the trivalent form, but will also achieve reductive dechlorination of TCE. Full-scale remediation design and implementation is ongoing by other consulting group.
Ordnance Facility Hollister, CA	▪ Pilot test completed using HRC®		This pilot test was performed to evaluate the effectiveness of Regenesis Hydrogen Release Compound (HRC®, composed of polylactate ester) for the *in-situ* reduction of hexavalent chromium and perchlorate, as well as the reductive dechlorination of Freon-113 in an aquifer composed of medium to fine silty sand. Hexavalent chromium, perchlorate, and Freon-113 concentrations in the study area were reduced by 99 percent, 88 percent, and 92 percent, respectively.

Table 1
Representative Site List
In-Situ Chromium Treatment

Project Location	Key Elements	Regulatory Oversight	Description
Berkey Street Site Grand Rapids, MI	▪ Large-scale pilot test using HRC®. ▪ Full scale remediation under way.	Michigan Department of Environmental Quality	A large-scale pilot study was performed to evaluate the effectiveness of Regenesis Hydrogen Release Compound (HRC®) for *in-situ* remediation of groundwater exhibiting hexavalent chromium concentration of 49 mg/L in the test area. One hundred pounds of HRC were injected at each of 60 locations using direct-push methods. The reduction in hexavalent chromium concentration within the test area was greater than 90 percent.. Full-scale remediation design is under way.
Plating and Engraving Facility Berkeley, CA	▪ Pilot test using MRC® ▪ Injection via direct push rods ▪ Barrier configuration		A pilot test was performed to evaluate the effectiveness of *in-situ* hexavalent chromium reduction using Regenesis Metals Remediation Compound (MRC®). Fifteen direct-push injection points were used to create a barrier across a preferential groundwater flow path. Hexavalent chromium concentrations within the affected study area were reduced to below detection limits.
Industrial Plating Facility Odessa, TX	▪ Full-scale remediation of groundwater using MRC® ▪ Multiple barrier configuration ▪ Vadose soil treatment under investigation	U.S. EPA [CERCLA (Superfund)] Texas Commission on Environmental Quality	Both pilot-scale and full-scale applications of Regenesis Metals Remediation Compound (MRC®) were completed for the *in-situ* reduction of hexavalent chromium in groundwater beneath the site. A total of 18,720 pounds of MRC® were applied within a treatment area of 350,000 square feet. The success of the pilot- and full-scale MRC applications allowed the existing pump-and-treat system to be shut down. Application of this technology to the untreated portions of the source area is being investigated.

TABLE 2

EVALUATION OF POTENTIAL IN-SITU PILOT TEST LOCATIONS
FLOODPLAIN AREA

Evaluation Criteria	PTA-1	PTA-2	PTA-3	PTA-4
Proximity and Orientation to Well TW-2	G	E	F	P
Susceptibility to Influence from Extraction Well PE-1	E	G	P	P
Knowledge and Suitability of Stratigraphy and Groundwater Chemistry	P	G	E	U
Implications for Future Plume Monitoring	E	E	U	F
Topography	G	G	G	G
Potential Biological Impacts	G	G	F	P
Proximity to Potential Cultural Resources	E	E	E	E

E = excellent
G = good
F = fair
P = poor
U = unacceptable
PTA-1 = Potential Pilot Test Area 1
PTA-2 = Potential Pilot Test Area 2
PTA-3 = Potential Pilot Test Area 3
PTA-4 = Potential Pilot Test Area 4

Table 3

Preliminary Schedule of Analyses

Floodplain Test Area

Analyte	Analytical Method	Number of Samples: Baseline Monitoring Wells[1]	Baseline Extraction Wells[2]	Test Monitoring[4] Monitoring Wells[3]	Test Monitoring[4] Extraction Wells[2]	QA/QC Samples[5]	Total Analyses
Laboratory							
CrVI	EPA 7199	40	4	90	6	8	148
Cr(total)	EPA 6010B	40	4	90	6	8	148
Arsenic	EPA 6010B	40	4	90	6	8	148
Calcium	EPA 6010B	40	4	90	6	8	148
Iron (ferric)	EPA 6010B	40	4	90	6	8	148
Iron (ferrous)	EPA 6010B	40	4	90	6	8	148
Magnesium	EPA 6010B	40	4	90	6	8	148
Manganese	EPA 6010B	40	4	90	6	8	148
Potassium	EPA 6010B	40	4	90	6	8	148
Sodium	EPA 6010B	40	4	90	6	8	148
Bromide	EPA 300.0	40	4	90	6	8	148
Chloride	EPA 300.0	40	4	90	6	8	148
Nitrate	EPA 300.0	40	4	90	6	8	148
Nitrite	EPA 300.0	40	4	90	6	8	148
Phosphorus (as phosphate)	EPA 300.0	40	4	90	6	8	148
Sulfate	EPA 300.0	40	4	90	6	8	148
Sulfide	EPA 376.1	40	4	90	6	8	148
Volatile fatty acids[6]	EPA300.M	40	4	90	6	8	148
Ammonia	EPA 350.2	40	4	90	6	8	148
Carbonate/bicarbonate alkalinity	SM 2320	40	4	90	6	8	148
Methane	RSK 175	40	4	90	6	8	148
Total organic carbon	EPA 415.1	40	4	90	6	8	148
Field Instrument							
CrVI	HACH Kit	40	4	217	12	n/a	273
Bromide	kit/meter	40	4	217	12	n/a	273
pH	meter	40	4	217	12	n/a	273
Temperature	meter	40	4	217	12	n/a	273
Dissolved oxygen	meter	40	4	217	12	n/a	273
Oxidation-reduction potential (ORP)	meter	40	4	217	12	n/a	273
Specific conductance	meter	40	4	217	12	n/a	273

NOTES:

1. Wells PT-1 to PT-6, and PTI-1S/D; assumes three casings for each PT well
2. Wells TW-2D and PE-1
3. Wells PT-1 to PT-6; assumes three casings for each PT well
4. Assumes six sampling events with laboratory analysis
5. Assumes one Equipment Blank per sampling event
6. Includes lactic acid (lactate), acetate, pyruvate, propionate, and butyrate

Pacific Gas and Electric Company

Yvonne J. Meeks
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July 21, 2005

Cathy Wolff-White
Bureau of Land Management
Program Director
2610 Sweetwater Avenue
Lake Havasu City, AZ 86406

Subject: Request for BLM Approval, Field Activity Summary for In-Situ Chromium Reduction Pilot Tests on BLM-Managed Land
Pacific Gas and Electric Company, Topock Project

Dear Ms. Wolff-White:

Pacific Gas and Electric Company (PG&E) requests the Bureau of Land Management's (BLM) approval to conduct *in situ* chromium reduction pilot testing on BLM-managed land as part of the remediation technologies evaluation at PG&E's Topock Compressor Station. On March 3, 2004, BLM issued a signed Action Memorandum approving the time-critical interim measures activities at the site to facilitate and streamline PG&E's efforts to continue to protect the Colorado River. It is our understanding that the proposed pilot test activities are classified as site-specified activities under the Action Memorandum and require only the approval by the BLM Lake Havasu Field Office prior to implementation.

Transmitted with this letter is a Technical Memorandum describing the proposed pilot study activities. Subject to approval by BLM and other permitting agencies, the pilot tests are scheduled to begin in October 2005. Thank you for your attention in this matter. Please do not hesitate to call if you have any questions. I can be reached at (805) 546-5243.

Sincerely,

Julie Eakins for Yvonne Meeks

Cc: Sally Murray, BLM
Mark Howell, BLM
Norman Shopay, DTSC

Field Activity Summary for In-Situ Chromium Reduction Pilot Tests on BLM-Managed Land
Pacific Gas and Electric Company, Topock Project

Prepared for the Bureau of Land Management

July 21, 2005

INTRODUCTION

This memorandum has been prepared for the U.S. Bureau of Land Management (BLM) in support of Pacific Gas and Electric Company (PG&E's) request to conduct in situ chromium reduction pilot testing on BLM-managed land as part of the remediation technologies evaluation at 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.

The purpose of this memorandum is to provide a detailed description of proposed activities on BLM-managed land. These activities are understood to be previously authorized by the March 2004 Action Memorandum issued by BLM, which notes that additional wells may be authorized subject to BLM review and approval prior to implementation.

PG&E is addressing chromium in groundwater at the Topock Compressor Station under the oversight of the California Environmental Protection Agency, Department of Toxic Substances Control (DTSC). Assisting DTSC and PG&E with the planning and review of site investigation and remediation activities are the members of the Topock Consultative Workgroup (CWG) consisting of representatives of DTSC, BLM, the Colorado River Basin Regional Water Quality Control Board, Metropolitan Water District (MWD), and other regional, state, and federal agencies.

Pending approval by other permitting agencies, PG&E requests permission from BLM to conduct the pilot tests in selected areas of BLM land. The pilot tests are proposed at two discrete locations – one in a "floodplain" area and another in an "upland" area. These proposed locations are shown on Figures 1 and 2, respectively. At each of the two locations, the proposed pilot tests will consist of the following activities:

- Installation of one injection well cluster and four to six monitoring well nests
- Well development and pre-injection sampling
- Performance of a short-duration tracer test using a non-toxic tracer (potassium bromide)
- Reagent injection required for Cr(VI) in situ treatment
- Groundwater monitoring and sampling

These activities are described in more detail below. The pilot tests will be conducted on PG&E's behalf by Montgomery Watson Harza (MWH). Throughout all intrusive field investigation activities, every effort will be made to minimize disturbance to BLM lands.

FIELD INVESTIGATION ACTIVITIES

Locations and Pre-Mobilization Activities

The proposed pilot test well locations and access routes are shown on Figure 1 (floodplain area) and Figure 2 (upland area). In the floodplain area, one injection well cluster (PTI-1S/D) and six monitoring well nests (PT-1 through PT-6) are proposed. In the upland area, one injection well cluster (PTI-2 S/M/D) and four monitoring well nests (PT-7 through PT-10) are proposed.

Prior to equipment mobilization, the proposed drilling sites and access routes will be staked and surveyed for biological and cultural resources. The proposed access routes have been used previously for other well installations. Pre-construction surveys of cultural and natural resources will be conducted in consultation with BLM. All proposed drilling sites and associated equipment access routes will be surveyed. Results of the cultural and biological resource surveys will be confirmed and documented with DTSC and BLM prior to drilling equipment mobilization.

PG&E will conduct all field investigation activities in a manner that protects and avoids impacts to cultural and natural resources. Equipment mobilization is scheduled to occur subsequent to the breeding season for nesting bird species. However, if deemed necessary based on the results of pre-construction surveys, biological and/or cultural resource monitors will be present during well installation and operational activities.

Well drilling permits from San Bernardino County will be obtained and the drilling locations will be cleared of underground utilities prior to equipment mobilization.

Drilling and Well Installation

The wells in the floodplain will be drilled using an all-terrain rotosonic drilling rig; the wells in the upland area will be drilled using a truck-mounted rotosonic drilling rig. The rigs will be equipped with a 8 5/8-inch outside diameter drill casing and a 8 7/8-inch diameter drill bit. In the floodplain area, injection well cluster PTI-1 S/D will be constructed within two separate borings, and each of the six monitoring well nests will be constructed with three wells nested within a single boring. In the upland area, injection well cluster PTI-2 S/M/D will be constructed within three separate borings, and each of the four monitoring well nests will be constructed with three wells nested within a single boring. All wells will be installed during one mobilization, if possible. Well installation activities will occur over an approximately one-month period of time. Table 1 summarizes the proposed drilling depths and well construction plan for the injection well clusters and monitoring well nests at the floodplain and upland locations.

Figure 3 includes a photograph of a typical a drilling rig planned for this work. Two rigs will be mobilized at the same time. Figure 4 shows typical above-ground and flush-mounted well monument surface completions. The floodplain wells will be completed above-ground, and the upland wells will be completed with traffic-rated flush-mounted well monuments to limit the visibility of the well heads.

Table 1 Construction Plan for Phase 2 Wells on BLM Land

Drilling Area	Well Identifications	Maximum Estimated Drilling Depth	Estimated Depth(s) of Screen Interval (s)	Well Diameter and Type	Surface Well Completion
Floodplain	PTI-1S	70 feet	30-70 feet	4” PVC	Above-ground monument
	PTI-1D	120 feet	75-115 feet	4” PVC	Above-ground monument
	PT-1	120 feet	40-50 feet, 65-75 feet, 100-110 feet	2” PVC	Above-ground monument
	PT-2	120 feet	40-50 feet, 65-75 feet, 100-110 feet	2” PVC	Above-ground monument
	PT-3	120 feet	40-50 feet, 65-75 feet, 100-110 feet	2” PVC	Above-ground monument
	PT-4	120 feet	40-50 feet, 65-75 feet, 100-110 feet	2” PVC	Above-ground monument
	PT-5	120 feet	40-50 feet, 65-75 feet, 100-110 feet	2” PVC	Above-ground monument
	PT-6	120 feet	40-50 feet, 65-75 feet, 100-110 feet	2” PVC	Above-ground monument
Upland	PTI-2S	130 feet	90-130 feet	4” PVC	Above-ground monument
	PTI-2M	170 feet	130-170 feet	4” PVC	Above-ground monument
	PTI-2D	220 feet	170-210 feet	4” PVC	Above-ground monument
	PT-7	220 feet	100-120 feet, 140-160 feet, 180-200 feet	2” PVC	Above-ground monument
	PT-8	220 feet	100-120 feet, 140-160 feet, 180-200 feet	2” PVC	Above-ground monument
	PT-9	220 feet	100-120 feet, 140-160 feet, 180-200 feet	2” PVC	Above-ground monument
	PT-10	220 feet	105-125 feet, 145-165 feet, 185-205 feet	2” PVC	Above-ground monument

An all-terrain forklift will be used for equipment and material transfer to the drill sites. Short-term material storage in the drill site area will be necessary to accommodate the drilling operations. Materials to be temporarily stored at the well sites include drilling equipment and well construction materials (casing, sand, bentonite, cement grout, etc).

Continuous core will be collected during drilling of each boring for geologic logging. The cuttings generated from drilling in the floodplain and upland areas will be transferred by forklift to lined steel roll-off soil bins temporarily staged at MW-20 bench. A 20-cubic yard soil bin will be required for approximately every 240 feet drilled, so approximately 10 soil bins will be required for this well installation effort. The minimal water produced from rotosonic drilling will be temporarily stored in 55-gallon steel drums placed on pallets or portable storage tanks at each drill site. Disposal procedures for the investigation-derived waste (IDW) is discussed below under Waste Management.

Well Development and Pre-Injection Sampling

After installation, the injection and monitoring wells will be developed by a combination of surging, bailing, and pumping to remove sediment from the well casing. A Smeal® development rig or the all-terrain drilling rig outfitted with development equipment will be used for the development activity. The wastewater produced from these activities will be temporarily stored in 55-gallon steel drums placed on pallets or portable storage tanks at each test site.

Following well development, the new injection and monitoring wells will be purged and sampled at least twice to establish baseline conditions. The sampling activities will follow the procedures, plans, and methods used for the Topock groundwater monitoring program. Samples from the new monitoring wells will be submitted to a laboratory to be analyzed for hexavalent chromium and total chromium, total organic carbon, volatile fatty acids, ammonia, methane, and other selected general chemistry parameters.

Tracer Tests

Short-duration tracer tests will be performed over an approximately one-month period concurrent with the reagent injection and groundwater monitoring and sampling activities described below. Potassium bromide, a non-toxic tracer, will be injected into the injection wells PTI-1 S/D and PTI-2 S/M/D as a one-time batch at the same time as the reagent injection. Samples collected during the groundwater monitoring and sampling activities described below will be used to determine when the tracer arrives at the monitoring well nest locations. The tracer tests will help confirm the groundwater gradient and to refine estimates of aquifer parameters in the pilot test areas.

Reagent Injection

Different reagents will be used at the two pilot test locations. In the floodplain test area, approximately 1,700 gallons of prepared emulsified vegetable oil and sodium lactate solution followed by 4,300 gallons of clean treated groundwater will be injected into each of wells PTI-1 S/D. In the upland area, approximately 82,000 gallons of solution consisting of 29 percent strength calcium polysulfide diluted to 3 percent by volume with clean treated groundwater, and 1 percent by volume of emulsified vegetable oil, will be injected into each of wells PTI-2 S/M/D.

The reagent solution (along with the tracer) will be injected in batches from 21,000-gallon portable containers trucked into the site (approximately 2 to 3 trucks per day over a one-week period). The solutions will be allowed to gravity feed if possible, but depending on the rate of flow, a pump may be used to assist in injection. The injection pressures will be kept below 50 pounds per square inch. No permanent aboveground equipment will be employed. Portable tanks containing the solutions will be temporarily staged on the MW-20 bench for the floodplain test and on the IM-3 access road for the upland test; the solutions will be conveyed via hoses to the injection wells. The tanks and hoses will be removed from the test areas following the injection.

Reagent injection activities will occur over an approximately one-week time period. The reagent injection will be performed once at the beginning of the pilot tests; however, depending on the results of the first injection, the reagents may be reinjected as necessary a few months after the first injection.

Groundwater Monitoring and Sampling

Groundwater monitoring and sampling will be conducted immediately following injection, and then daily for the first week, weekly for the first month, and monthly thereafter. The monitoring/sampling activities will follow the procedures, plans, and methods used for the Topock groundwater monitoring program. Samples from the monitoring wells will be analyzed for hexavalent chromium and total chromium, total organic carbon, volatile fatty acids, ammonia, methane, and other selected general chemistry parameters by a combination of laboratory and field methods.

Purged groundwater generated during the sampling activities will be temporarily stored in 55-gallon steel drums placed on pallets or portable storage tanks at each test site.

WASTE MANAGEMENT AND EQUIPMENT DECONTAMINATION

Several types of waste materials will be generated during the drilling, development, and sampling of the proposed pilot test wells. Investigation-derived waste (IDW) materials will include groundwater, drill cuttings, decontaminant rinsate, and incidental trash.

Drill cuttings potentially may contain chromium, although during previous drilling operations at the Topock site these materials had non-detectable concentrations of chromium. The cuttings and mud will be contained in lined roll-off bins staged on the MW-20 bench during the drilling activities. After sampling and characterization, all cuttings bins will be removed from the staging area for ultimate disposition by PG&E at an appropriate licensed facility. The cuttings will be screened for chromium, the main chemical of concern for the site. If the cuttings are characterized as a hazardous waste, they will be transported offsite for disposal at a permitted hazardous waste disposal facility. It is estimated that the soil investigation-derived waste bins temporarily staged on BLM land (MW-20 bench) will not remain in excess of 45 days.

Water generated during drilling, monitoring well development, and sampling activity will be temporarily stored in 55-gallon steel drums placed on pallets or portable storage tanks at each drill site. As part of demobilization at each location, the temporarily stored water will be removed from the well site and transferred to storage tanks on the MW-20 bench for characterization and ultimate disposal or treatment at a permitted waste disposal facility.

Decontamination of drilling and development materials will be performed on a decontamination pad such that all rinsate can be contained and collected. Decontamination rinsate will be transferred to the cuttings bin or water storage tank that contains material from the borehole last drilled.

The incidental trash, consisting of empty paper and plastic bags, cardboard boxes, wooden pallets, and miscellaneous debris, will be collected at the end of each drilling shift and hauled off the drill site to an appropriate disposal facility.

EMERGENCY RESPONSE PLAN

Spill containment equipment (e.g., sorbent materials, shovels, etc.) will be maintained onsite at all times that there is groundwater in the storage containers. For any minor leaks, such as dripping from a valve or pump, the water will be contained in a pail and added to the storage tank. As a contingency in the event of a significant leak (more than a drip), equipment (vacuum trucks, pumps, etc.) and trained spill response personnel will be on call 24 hours per day for every day that the tanks contain liquid. BLM and other notifications would occur per the procedures established in the Topock Emergency Notification Binder.

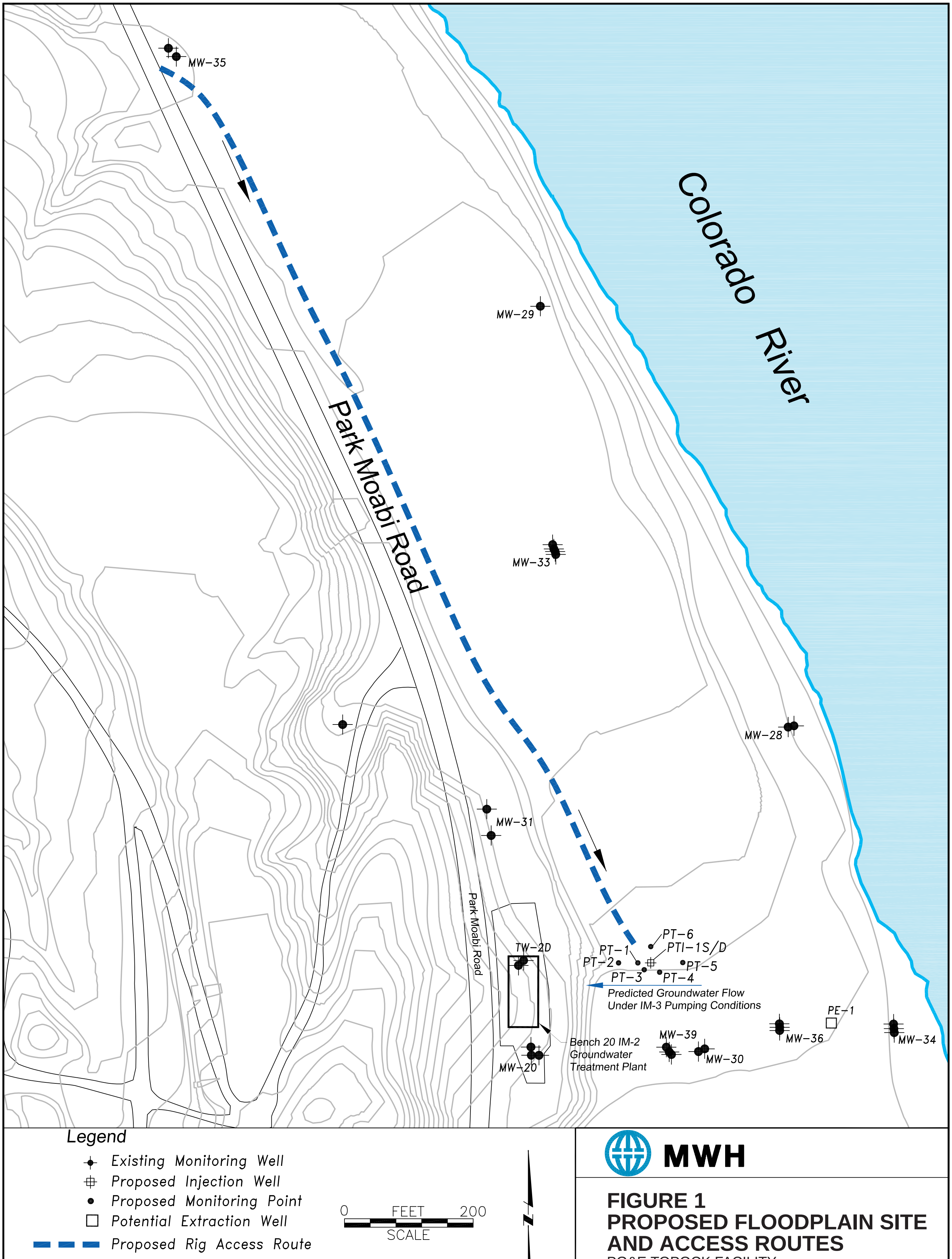
SCHEDULE

The chromium reduction pilot tests are tentatively scheduled to begin in October 2005, subject to approval by BLM and DTSC, permitting, and drill rig availability. All activities will be performed during daylight hours. The duration of specific activities on BLM land are summarized below.

Duration of Field Activities

Field Activities	**Approximate Duration**
Drilling and installation of injection/monitoring wells	1 month (2 to 5 days at each well)
Well development and pre-injection baseline sampling	2 weeks
Tracer testing	1 month (tracer injection concurrent with reagent injection)
Introduction of reagents (Phase 1)	1 week
Monitoring and sampling	1-5 days for each event; frequency will be daily for first week during injection, weekly for first month after injection, monthly or bimonthly for six to eight months
Re-injection of reagents if appropriate	1 week each
Follow-on monitoring and sampling beyond 6 months	1-5 days for each event
Storage of water and drill cuttings (IDW) for disposal	14 to 45 days per bin or per tank

Figures



MWH

FIGURE 1
PROPOSED FLOODPLAIN SITE AND ACCESS ROUTES
PG&E TOPOCK FACILITY
NEEDLES, CALIFORNIA

CH2MHILL

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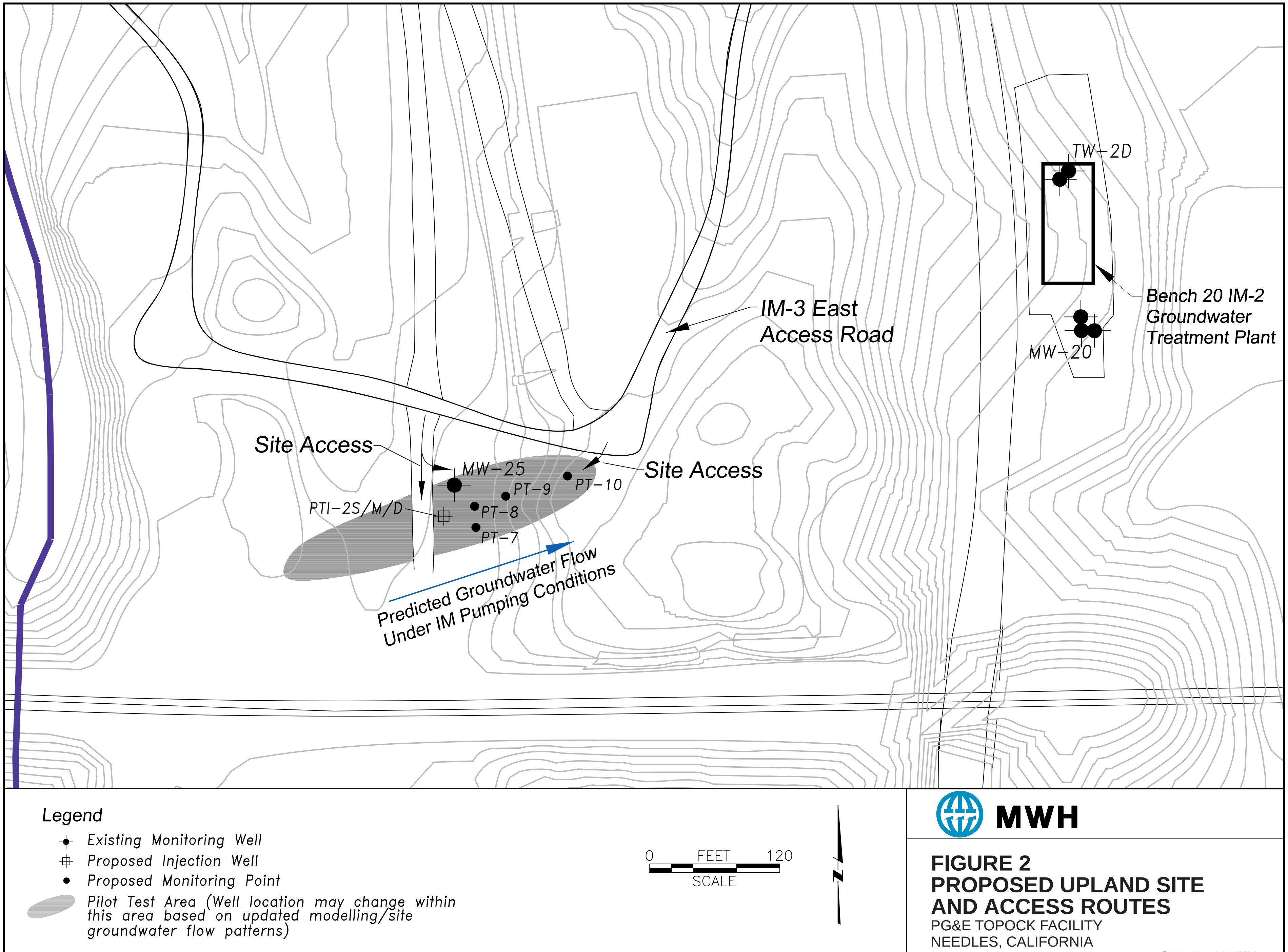


MWH

FIGURE 2
PROPOSED UPLAND SITE AND ACCESS ROUTES
PG&E TOPOCK FACILITY
NEEDLES, CALIFORNIA

CH2MHILL

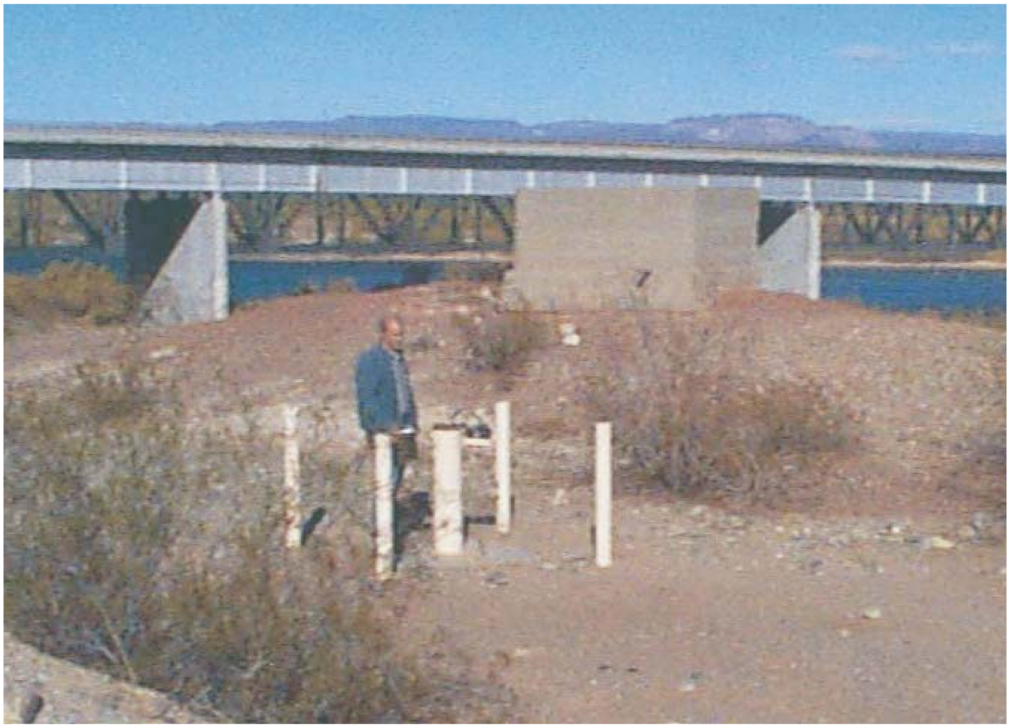
331736.IS.04.00_Figure 2_07-18-05_ez_sfo

A. Typical Limited Access Sonic Drill Rig

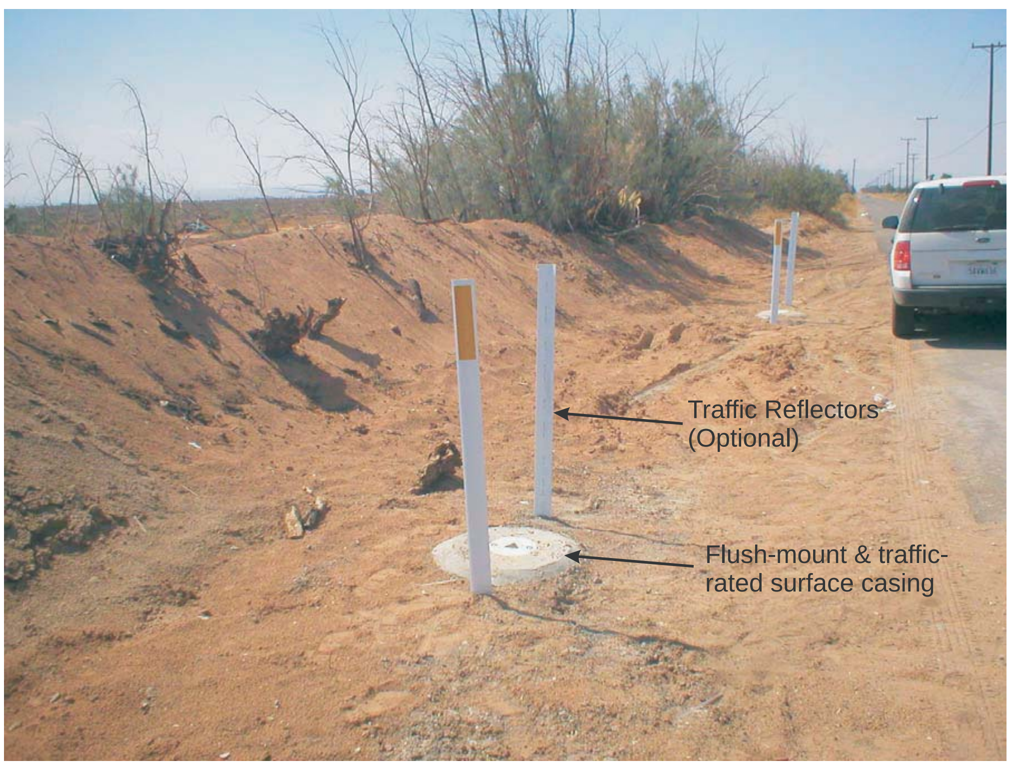
B. Typical Well Development/Pump Service Truck

FIGURE 3
TYPICAL DRILLING AND SERVICE VEHICLES
PG&E TOPOCK FACILITY
NEEDLES, CALIFORNIA

CH2MHILL



Representative above ground well completion for Floodplain site.



Representative flush mounted well completion for Upland site.

FIGURE 4
TYPICAL WELL COMPLETION
PG&E TOPOCK FACILITY
NEEDLES, CALIFORNIA

CH2MHILL

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