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October 19, 2006

Mr. Aaron Yue
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Subject: Work Plan for Additional Groundwater Characterization Beneath the Colorado River by Slant Boring in California
PG&E Topock Compressor Station, Needles, California

Dear Mr. Yue:

This letter transmits the *Work Plan for Additional Groundwater Characterization Beneath the Colorado River by Slant Boring in California*. The work plan is submitted in conformance with DTSC's September 29, 2006 letter.

If you have any questions, please do not hesitate to contact me. I can be reached at (805) 234-2257.

Sincerely,

Julie Eakins for Yvonne Meeks

cc. Karen Baker/DTSC
Chris Guerre/ DTSC
John Earle/HNWR
Casey Padgett/DOI

Enclosure

# Work Plan for Additional Groundwater Characterization Beneath the Colorado River by Slant Boring in California

## PG&E Topock Compressor Station
## Needles, California

Prepared for

## California Department of Toxic Substances Control

On Behalf of

## Pacific Gas and Electric Company

October 19, 2006

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# Work Plan for Additional Groundwater Characterization Beneath the Colorado River by Slant Boring in California

## PG&E Topock Compressor Station
## Needles, California

**Prepared for**
**California Department of Toxic Substances Control**

**on behalf of**
**Pacific Gas and Electric Company**

**October 19, 2006**

**This work plan was prepared under supervision of a California Certified Engineering Geologist:**

Paul Bertucci, C.E.G.
Project Hydrogeologist

# Contents

**Acronyms and Abbreviations** ..... **v**

**1.0 Introduction** ..... **1-1**
1.1 Project Background ..... 1-1
1.2 Current Site Characterization and Monitoring ..... 1-2
1.3 Purpose and Objectives ..... 1-3

**2.0 Field Investigation and Drilling Activities** ..... **2-1**
2.1 Drill Site Selection ..... 2-1
2.2 Site Preparation, Access, and Equipment Staging ..... 2-1
2.3 Drilling Method and Requirements ..... 2-3
2.3.1 Rotosonic Drilling Method ..... 2-3
2.3.2 All-Terrain Rig with Rotosonic Method ..... 2-4
2.3.3 Core Logging ..... 2-4
2.4 Depth-Specific Groundwater Sampling ..... 2-5
2.4.1 Water Level Measurements during Borehole Groundwater Sampling ..... 2-5
2.5 Multilevel Well Installation ..... 2-6
2.5.1 Design and Specifications ..... 2-6
2.5.2 Surface Completion Requirements ..... 2-7
2.5.3 Well Development ..... 2-8
2.5.4 Well Surveying and Completion Diagram ..... 2-8
2.6 Groundwater Sampling of Multilevel wells ..... 2-8
2.7 Site Restoration Plan ..... 2-9

**3.0 Waste Management and Decontamination** ..... **3-1**
3.1 Investigation Derived Waste Management ..... 3-1
3.2 Equipment Decontamination ..... 3-1

**4.0 Approvals and Authorizations** ..... **4-1**
4.1 Drilling Approvals ..... 4-1
4.2 Biological Surveys and Authorizations ..... 4-1
4.3 Cultural Resource Surveys, Reviews, and Consultations ..... 4-2

**5.0 Schedule and Reporting** ..... **5-1**
5.1 Project Schedule ..... 5-1
5.2 Reporting ..... 5-1

**6.0 References** ..... **6-1**

**Tables**

1 Drilling and Well Installation Plan

2 Groundwater Sampling and Analysis Plan

3 Approvals and Authorizations for Drilling

4 Planning and Implementation Schedule

**Figures**

1 Site Location Map

2 Proposed Locations for Colorado Drilling Investigations

3 Estimated Depth to Bedrock Below River Level

4 Cross-Sections of Proposed Slant Borings and Wells Beneath the Colorado River

5 Slant Boring Multilevel Monitoring Well Schematic

**Appendices**

A Barcad™ Groundwater Sampling System

B Caltrans I-40 Bridge Boring Logs

# Acronyms and Abbreviations

| | |
|---|---|
| ADEQ | Arizona Department of Environmental Quality |
| ATV | all terrain vehicles |
| BLM | U.S. Bureau of Land Management |
| BOR | Bureau of Reclamation |
| CACA | Corrective Action Consent Agreement |
| Caltrans | California Department of Transportation |
| CEQA | California Environmental Quality Act |
| CERCLA | Comprehensive Environmental Response, Compensation and Liability Act |
| Cr(T) | total chromium |
| Cr(VI) | hexavalent chromium |
| CDFG | California Department of Fish and Game |
| DOI | Department of the Interior |
| DTSC | California Department of Toxic Substances Control |
| ESA | Endangered Species Act |
| GPS | Global Positioning System |
| HNWR | Havasu National Wildlife Refuge |
| IDW | investigation-derived waste |
| IM | Interim Measure |
| IM-3 | Interim Measure No. 3 |
| MW | monitoring well |
| NCP | National Oil and Hazardous Substances Pollution Contingency Plan |
| NHPA | National Historic Preservation Act |
| PBA | Programmatic Biological Assessment |
| PG&E | Pacific Gas and Electric Company |
| PVC | polyvinyl chloride |
| RCRA | Resource Conservation and Recover Act |
| RFI | RCRA Facility Investigation |

| | |
|---|---|
| RI | Remedial Investigation |
| ROW | right-of-way |
| SHPO | State Historic Preservation Office |
| TCS | PG&E Topock Compressor Station |
| USFWS | United States Fish and Wildlife Service |

# 1.0 Introduction

Pacific Gas and Electric Company (PG&E) is addressing chromium in groundwater at the Topock Compressor Station near Needles, California, under the oversight of the California Department of Toxic Substances Control (DTSC). On September 29, 2006, DTSC issued a letter entitled "Workplan for Additional Groundwater Plume Investigation by Slant Boring in California, Pacific Gas and Electric Company, Topock Compressor Station" to PG&E (DTSC, 2006). In that letter, DTSC required that PG&E submit a work plan for conducting additional groundwater investigation using slant boring and well installation at a selected drilling site on the California shoreline of the Colorado River near the PG&E Topock Compressor Station.

This work plan has been prepared in response to DTSC's September 29 letter and describes the objectives, technical approach, and proposed field investigations for additional groundwater characterization beneath the Colorado River using slant drilling methods. The activities described in this work plan address the planning and associated authorizations and approvals for the proposed slant drilling groundwater investigation to be conducted on the California shoreline of the Colorado River at the Topock site.

## 1.1 Project Background

The Topock Compressor Station is located in San Bernardino County, approximately 15 miles to the southeast of Needles, California (Figure 1). Investigative and remedial activities are being performed under the Resource Conservation and Recover Act (RCRA) Corrective Action as well as the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). In February 1996, PG&E and the California Environmental Protection Agency DTSC entered into a Corrective Action Consent Agreement (CACA) pursuant to Section 25187 of the California Health and Safety Code (DTSC, 1996). Under the terms of the CACA, PG&E agreed to conduct a RCRA facility investigation (RFI) to identify and evaluate the nature and extent of hazardous waste and constituent releases at the compressor station. The United States Department of the Interior (DOI) is the lead Federal agency, on land under its jurisdiction, custody or control, and is responsible for oversight of response actions being conducted by PG&E pursuant to the CERCLA. Portions of the site where hazardous substances from the Topock compressor station have come to be located are on or under land managed by BLM, USFWS, and the Bureau of Reclamation (BOR) (collectively the "federal agencies"). In July 2005, PG&E and the federal agencies entered into an Administrative Consent Agreement to implement response actions at the site as set forth in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (DOI, 2005a).

Under the terms of the CACA and Administrative consent agreement, PG&E is conducting the RCRA Facility Investigation/Remedial Investigation (RFI/RI) at the compressor station. The purpose of the RFI/RI is to identify and evaluate the nature and extent of hazardous waste and constituent releases at the compressor station. Since 1996 there have been six phases of investigation at the Topock site to collect data to complete the RFI/RI. Figure 2

shows the locations of existing groundwater monitoring wells installed for groundwater characterization in the floodplain area of the Topock site. Information obtained through the implementation of this work plan is intended to be combined with the existing data and included in the Final Groundwater RFI/RI for the site.

On September 21, 2006, a site visit to evaluate potential drilling sites for this investigation was attended by representatives from DTSC, the Arizona Department of Environmental Quality (ADEQ), the Havasu National Wildlife Refuge (HNWR), the U.S. Bureau of Land Management (BLM), and PG&E. During the site reconnaissance, one shoreline drilling site, south of and adjacent to Interstate Highway I-40 on the HNWR was identified as the most favorable location for the slant drilling groundwater investigation. The location of the selected drilling site, designated AB-1, is shown on Figure 2. The other potential drilling sites on the California shoreline were not deemed feasible due to field conditions (terrain limitations and underground utilities).

DTSC and federal agency representatives noted that access to the AB-1 drilling site on the HNWR is limited due to biological impact restrictions for the migratory bird nesting season, which begins in mid-March and extends through September 30 of each year. Accordingly, DTSC has specified that the goal is to complete the slant drilling groundwater investigation at the AB-1 site before March 15, 2007. This work plan describes the required federal and state agency planning, consultation, and approval actions and provides a schedule to complete the proposed slant drilling and investigation activities before March 15, 2007.

## 1.2 Current Site Characterization and Monitoring

Under DTSC oversight, PG&E has conducted hydrogeologic investigations and groundwater characterization in the floodplain area of the Topock site between 2000 and 2006 in support of the RFI/RI. Groundwater characterization activities in 2004, 2005, and 2006 were also implemented for Interim Measure (IM) performance monitoring. The results of the more recent groundwater investigations in the floodplain area of the site are presented in the IM Phase 2 and IM 2006 well drilling investigation reports (CH2M HILL, 2005a, 2006a). The hydrogeology of the floodplain and shoreline area in the central floodplain and AB-1 drilling site consists of approximately 100 feet of fluvial sand and gravel deposits (comprising the Alluvial Aquifer) that overlie bedrock. Available information on the bedrock depth and thickness of the fluvial deposits beneath the river are inferred from limited drilling information (California Department of Transportation [Caltrans] I-40 bridge borings) and a reconnaissance seismic survey conducted in 2004 on the Colorado River in support of the RFI/RI.

Since March 2004, PG&E has additionally conducted routine monitoring of groundwater quality and hydraulic gradients in the floodplain area of the Topock site for evaluating the performance of the IM. PG&E's IM performance monitoring reports summarize the results of site monitoring and operation of the IM groundwater extraction system activities and present the inferred distribution of hexavalent chromium [Cr(VI)] in the Alluvial Aquifer in the floodplain area (CH2M HILL, 2006b, c).

## 1.3 Purpose and Objectives

While the extent of the chromium plume is defined in the majority of the California floodplain, recent groundwater monitoring data indicate that the plume extends within the lower portion of the Alluvial Aquifer some distance to the east of monitoring well MW-34-100 (MW-34 cluster on Figure 2). The extent of the plume east of MW-34 is not certain but is inferred to extend some distance south (downgradient) of this well location. Because there are no existing wells to define the maximum downgradient limit of the plume, additional groundwater investigation and water quality characterization in this area beneath the river is recommended. The proposed slant drilling investigation at Site AB-1 is proposed to provide the additional groundwater characterization data needed for the final RFI/RI and corrective measures planning for the Topock site.

The primary objectives of the proposed slant drilling and groundwater investigation from the California shoreline are to:

1. Assess chromium concentrations in the fluvial sediments beneath the Colorado River downgradient of the chromium plume observed in the floodplain.
2. Characterize the natural geochemical groundwater conditions, specifically the extent of reducing water chemistry, in the fluvial sediments beneath the Colorado River and assess whether geochemical conditions in the sediments beneath the river favor chromium reduction.
3. Install permanent multilevel monitoring points in the slant borings at site AB-1 to serve as ongoing water quality and hydraulic monitoring points beneath the river, downgradient of the floodplain area of the Topock site.

The work plan is organized as follows:

- Section 2 describes the proposed field investigation activities proposed for the slant drilling investigation at the California shoreline AB-1 site, including site preparation, well installation, sampling, and site restoration.
- Section 3 describes the procedures for managing investigation-derived waste (IDW) and equipment decontamination associated with the field investigation.
- Section 4 outlines the approvals and authorizations from various agencies for the proposed drilling investigation and field work.
- Section 5 presents the schedule for the planning, review, and implementation of the proposed slant drilling and groundwater investigation and describes the reporting activity for this project.

# 2.0 Field Investigation and Drilling Activities

The groundwater investigation will be conducted at one drilling site, designated Site AB-1, which is located on the California shoreline of the Colorado River, south of Interstate Highway I-40. Figure 2 shows the proposed location of the AB-1 drilling site and surface features and existing groundwater monitoring and IM extraction wells at the Topock site. This section describes drill site selection; site preparation, access and staging; drilling method and requirements; depth-specific groundwater sampling; multilevel well installation; groundwater sampling of multilevel wells; and restoration activities for the AB-1 drilling site.

## 2.1 Drill Site Selection

The selected drilling location AB-1 is located in the southern portion of the floodplain of the Colorado River adjacent to the Topock site (Figure 2). Site AB-1 is located immediately south of the I-40 bridge on HNWR property that is managed by the U.S. Fish and Wildlife Service (USFWS). Site AB-1 is part of an east-west investigation transect across the Colorado River, which includes a corresponding drill site, designated Site AB-2, on the Arizona shoreline (Figure 2). The slant drilling and investigation activities to be proposed at Site AB-2 are under the jurisdiction of the ADEQ and will be presented in a separate work plan.

Figure 3 shows the location of the AB-1 drilling site on a bedrock structure map of the investigation area at the Topock site, showing inferred depth contours in feet below the river level. The depth to bedrock map is based on data collected in PG&E's completed drilling investigations in the California floodplain area, a reconnaissance seismic reflection survey conducted on the Colorado River (U. S. Geological Survey [USGS] 2005), and exploration borings completed in 1962 by Caltrans for construction of the I-40 bridge crossing at Topock, Arizona (see Appendix B). As noted on Figure 3, Miocene bedrock outcrops on the California shoreline immediately south of AB-1 site and at the abutment for the BN& SF railroad track on the Arizona shoreline. The inferred bedrock structure underneath the river at the I-40 bridge is a bedrock structural "saddle"or rise. Based on the results of the seismic survey, the fluvial deposits beneath the river increase in thickness to the north and south as the bedrock dips away from the rise under the I-40 bridge. Hence, the area immediately south of the I-40 bridge has been selected as a preferred location for drilling slant exploratory borings and groundwater characterization beneath the Colorado River.

## 2.2 Site Preparation, Access, and Equipment Staging

The drilling equipment access routes on the floodplain are based on the approved access routes described in the April 2006 Technical Memorandum addressing access routes for site monitoring activities (CH2M HILL, 2006d). The Technical Memorandum summarizes

sampling access routes and proposed mitigation measures for the floodplain that were approved in May 2006 by BLM (BLM, 2006) and HNWR (HNWR, 2006).

For the proposed AB-1 drilling site shown on Figure 2, it is anticipated that clearing of vegetation will be needed to allow access for drilling equipment. A drilling area approximately 50 feet wide (north to south) by 80 feet long (east to west) will be cleared at this location. The drilling work area will be set above (west of) a cut bank located near the easternmost I-40 bridge pier. To reach the drilling work area, a 12-foot wide path for the drilling rig and support equipment will be cleared from the present location of existing groundwater wells at MW-43 under the I-40 bridge to the work area (Figure 2). The area is primarily vegetated with tamarisk (also known as salt cedar), a non-native species which has invaded riparian habitat in the Colorado River basin over the last century. Native trees such as mesquite, palo verde or acacia may also be present. Native vegetation will not be cleared if the access can be routed around the native trees and their branches temporarily tied back to allow passage. A site restoration plan, similar to that implemented after MW-43 drilling activities, and further detailed in Section 2.7, will be prepared to plan for establishing native vegetation in areas cleared of tamarisk for access to location AB-1.

The proposed access routes and drilling sites will be field-checked and clearly delineated by HNWR, PG&E, and CH2M HILL. If modifications to the access routes are needed, additional surveys will be conducted to ensure that no sensitive habitat will be impacted and that native vegetation is protected. All field activities associated with the equipment access and well drilling for this project will be coordinated with HNWR to ensure the protection of cultural and biological resources.

Site preparation shall take place prior to equipment mobilization. Site preparation shall include identifying biologically and/or culturally sensitive areas and site hazards and laying out access routes and work areas to minimize impacts to these areas to the extent possible. The drill rig shall be cleaned before mobilization to the site and following completion of drilling at the site if visible grease, oil, or other contamination is evident on the equipment. After the drill rig has mobilized into place, a short-term staging area will be established in the drilling work area. Plastic sheeting will be laid on the ground surface in the staging areas to keep the drilling materials and equipment clean and to minimize impacts to the ground surface from the drilling materials and equipment. Materials to be stored at the well site include drilling equipment and well construction materials (e.g., casing and grout).

The proposed locations of drilling equipment staging areas are shown on Figure 2. The PG&E Topock Compressor Station (TCS) will be the primary staging area for drilling activities, including IDW storage. The MW-20 bench will be used, with BLM permission, as a secondary staging area, located closer to the access to HNWR and the drilling location. Shorter term staging of drilling supplies a few days at a time is planned for a previously disturbed area indicated on Figure 2 that is located west of existing monitoring well cluster MW-32.

Drilling and well installations shall conform to state and local regulations. CH2M HILL will obtain authorizations and applications required for drilling and well installation. Utility clearances will also be obtained prior to commencement of drilling.

# 2.3 Drilling Method and Requirements

The drilling, core/borehole logging, and well construction will be performed under the supervision of a California Professional Geologist. The drilling and well installation activities will be conducted in accordance with this work plan and modified methods and standard operating procedures from the *Topock Program Sampling, Analysis and Field Procedures Manual* (CH2M HILL, 2005b).

Figure 4 presents an east-west cross section of the slant borings and wells beneath the Colorado River proposed for the AB transect drilling sites. Two slant borings are proposed at the California shoreline AB-1 site that will extend approximately 150 feet and 250 feet eastward underneath the Colorado River. Boring 1 and Boring 2 will be drilled at two different angles, estimated at approximately 30° and 40° from horizontal. The initially proposed target drilling parameters for the AB-1 slant borings are summarized in Table 1.

Drilling will be conducted in the unconsolidated Holocene and younger fluvial deposits of the Colorado River. The final angle from horizontal, and the bearing (or azimuth direction) for each of the borings will be determined in consultation with DTSC based on subsurface information available at the time of drilling and field conditions at the drill site. The slant borings will be advanced until consolidated Miocene bedrock is encountered or until refusal.

The methods, equipment, and procedures for drilling, logging, and depth specific groundwater sampling are described below. The methods and procedures are based on the successful implementation and experience from the prior drilling programs conducted in the floodplain area in 2005 and 2006 (CH2M HILL, 2005a, c, 2006a).

## 2.3.1 Rotosonic Drilling Method

Drilling will be accomplished using the rotosonic drilling technique, which involves advancing a rotating and vibrating drill head or core barrel through the subsurface. This method produces a continuous core from the land surface to the target drilling depths (angled borings that are drilled up to 300 feet of slant borehole length), generates minimal drilling wastes, and typically can drill through gravel, cobble, and softer bedrock formations.

Water sometimes needs to be added to the borehole during drilling activities, although the addition of water will be kept to an absolute minimum. Because the angle borings will be completed as small diameter wells that are likely to pump only small volumes of water, there is some concern that water added during drilling might not be flushed out of the monitoring interval during well development. It is therefore desirable to use drilling water of a different chemical signature than the groundwater in the monitoring intervals so that it will be possible to determine if samples from the completed wells have been affected by water added during drilling. Because the angle borings are meant to detect hexavalent chromium and hexavalent chromium is not present in shallow groundwater where reducing conditions exist, we anticipate that these wells in the angle borings will be screened in the deeper portion of the aquifer, below the reducing zone. The Colorado River water has a different chemical signature compared to groundwater from monitoring wells completed in the deeper portion of the floodplain. It is lower in TDS and contains stable isotopes of

hydrogen and oxygen at different ratios than the deep groundwater at the Topock site. Therefore, any water added during drilling will be obtained from the Colorado River adjacent to the drill site. The volume of water added during drilling will be measured and a volume equal to twice the amount added will be pumped out of the completed wells during development. Electrical conductivity from the wells will be compared with electrical conductivity from Isoflow® samples collected from similar depths. If any significant amount of drilling water remains in the well, the electrical conductivity in the well sample would be less than in the Isoflow® samples. In that case, additional pumping would be initiated in an attempt to flush out any remaining drilling water.

### 2.3.2 All-Terrain Rig with Rotosonic Method

The drilling activities planned for the AB-1 site will require the use of track-mounted all-terrain rotosonic drilling equipment. This type of drilling equipment was previously used by PG&E groundwater investigations and well installation on the floodplain in 2004, 2005, and 2006 (CH2M HILL, 2005a, c, 2006a).

To support the all-terrain drilling rig, a tracked or balloon-tired forklift and one or more all-terrain vehicles (ATVs) will be used to transport crew, equipment, and materials from the staging area to the drill site on the floodplain. The forklift will also be used to transport cuttings and excess core generated from drilling the soil borings to lined, steel roll-off soil bins that will be temporarily stored, with permission of the HNWR, at the staging area west of MW-32, the TCS, or the MW-20 bench. Disposal procedures for the IDW are discussed in Section 3.

### 2.3.3 Core Logging

Lithologic descriptions will be logged of each soil boring based on visual inspection of the retrieved core under the supervision of a California Professional Geologist. The field log will document the following information for each soil boring:

- Unique soil boring or well identification
- Purpose of the soil boring (e.g., monitoring well)
- Location in relation to an easily identifiable landmark
- Names of the drilling subcontractor and logger
- Start and finish dates and times
- Drilling method
- If applicable, types of drilling fluids and depths at which they were used
- Diameters of surface casing, casing type, and methods of installation
- Depth at which saturated conditions were first encountered
- Lithologic descriptions (based on the Unified Soil Classification System)
- Sampling-interval depths
- Zones of caving or heaving
- Depth at which drilling fluid was lost and the volume lost
- Changes in drilling fluid properties
- Drilling rate
- Drilling rig reactions, such as chatter, rod drops, and bouncing

The results of the continuous core logging of the borings will be summarized in grain-size core plots for the hydrogeologic characterization and to assist in selecting well screen intervals.

## 2.4 Depth-Specific Groundwater Sampling

Groundwater samples will be collected at discrete depths from each of the two boreholes. The Isoflow® sampler or equivalent will be used for groundwater sample collection. Samples will be collected from a 10-foot open borehole, at 20-foot intervals. Where feasible, a sample will also be collected from the zone just above the bedrock. Figure 4 presents a cross section of the anticipated sampling depths for collecting borehole depth-specific groundwater samples using the Isoflow® sampling method.

Depth-specific samples will be obtained from an open section of borehole below the drive casing by pumping using the Isoflow® vertical aquifer profiling system, a special sampling system designed by the drilling contractor, Prosonic. The sampling pump incorporates a packer that is placed in the bottom of the temporary casing to isolate the open hole below the casing. Attached below the packer is a submersible pump enclosed in a short section of well screen. By using a packer to hydraulically isolate the sampling interval from the water standing in the temporary casing above, the purge volumes can be minimized and representative samples can be obtained from a discrete section of the borehole. An alternative to the hydraulic packer equipped Isoflow® tool, a mechanical "segregation-block" may be used on the Isoflow® pump assembly. The advantage of this method is that the water level response inside the sonic casing can be measured during borehole purging to assess the relative permeability of the open borehole interval (see Section 2.4.1).

Purging will involve pumping one to three borehole volumes from the open borehole interval being sampled and monitoring the field parameters (temperature, pH, specific conductance, and oxidation-reduction potential). After the field parameters have stabilized and at least one borehole volume has been removed, water quality parameters will be measured and groundwater samples will be collected for Cr(VI) and ferrous iron analyses, as presented in Table 2. The Cr(VI) and ferrous iron analyses will be conducted at the onsite field laboratory currently set up at the IM-3 treatment plant using the HACH colorimetric method. A sufficient quantity of sample will be collected and filtered in the field so that confirmation samples can be sent to a certified laboratory for total chromium [Cr(T)] analysis if Cr(VI) is detected in any of the borehole groundwater grab samples. Because the time of field sample collection and screening precludes laboratory analysis of these samples within the Cr(VI) 24-hour holding time, the confirmation samples will be run for Cr(T) only. All groundwater grab samples will be filtered in the field prior to preservation and analysis.

### 2.4.1 Water Level Measurements during Borehole Groundwater Sampling

Additional characterization of the Alluvial Aquifer is proposed as part of the depth specific sampling activity. The Isoflow® sampling system can be configured with a casing segregation-block to allow the measurement of water levels during 10-foot openhole intervals for qualitative assessment of aquifer permeability. The recording of drawdown response for each zone purged may allow for distinguishing low, medium, and higher permeability zones within the boreholes tested. Attempts will be made to measure

drawdown during pumping for Isoflow sample collection. This will be attempted by fastening a pressure transducer secured to the Isoflow sampling pipe. If the transducer is damaged by the process of pump insertion and retrieval, Isoflow samples will then be collected without these water level measurements. An estimate of specific capacity would be obtained from the purging drawdown data, would providing a relative measure of the permeability of the borehole at the depth of the sample. This is considered screening level data for use in selecting more permeable zones for well screens. It is not considered suitable for more quantitative purposes such as model calibration.

# 2.5 Multilevel Well Installation

## 2.5.1 Design and Specifications

In scoping this project, DTSC has determined that permanent multilevel monitoring wells shall be installed in the slant borings drilled at Site AB-1. The Barcad™ well sampling system is recommended as the most feasible method for installing multilevel wells in the slant borings. The Barcad™ well system consists of an integrated well screen and sampling device that is 1.5 inches in diameter and 16 inches long and can be directly embedded in open boreholes or installed within existing cased wells. The Barcad™ well screen can be buried without the use of a gravel pack. For this application, the Barcad™ screen will be constructed of polyethylene. Description and information of the Barcad™ well sampling system is included in Appendix A. Normally, a nitrogen drive system is used for sampling groundwater, however, for the AB-1 multilevel monitoring wells, a peristaltic pump would be used for purging and sampling the Barcad™ well screens due to the shallow water level.

Figure 5 presents a generalized schematic diagram for the construction of multilevel wells in the slant borings drilled for this investigation. Three Barcad™ samplers are planned for installation in each of the two borings. The Barcad™ multilevel wells will be installed after the borehole has been drilled to total depth. The individual monitoring intervals will be selected based on the slant boring core log, the results of Isoflow® sampling, and in consultation with DTSC. The multilevel wells to be installed in the two borings drilled at AB-1 will be designated as listed in Table 1 (well cluster MW-52 and MW-53).

Following well screen selection, the individual Barcad™ sampling screens would be installed on separate rigid 1-inch diameter polyvinyl chloride (PVC) risers, and bundled together as a single multilevel well assembly. A custom centralizer would be placed around the Barcad™ installation casing bundle so that it's not lying against the bottom of the borehole wall. The natural formation will be allowed to collapse in place around the Barcad™ well screen, with a completion interval of 8 to 10 feet maximum for each monitoring zone. If retraction of the sonic casing does not result in formation collapse, an attempt will be made to place coarse filter-sand (6-9 or 8-12) across the well screen interval using a tremie pipe. Depending on the angle of the borehole, it may be necessary to pump this sand into place as a slurry.

The borehole above the monitoring zone will be sealed with a minimum 20 feet of a mixture of granular bentonite (Benseal) and Monterey #3 or equivalent filter-pack sand placed in the slant borehole using a tremie pipe. The process of formation collapse surrounding the well

screen and placement of an overlying sand/granular bentonite seal would be repeated for the intermediate and shallower completion intervals as illustrated in Figure 5.

The mixture of sand and bentonite will provide a grout seal with the structural integrity to stay in place as the borehole collapses. Without the sand in the mix, bentonite slurry, which has approximately the consistency of toothpaste before it sets, could be squeezed up into the drive casing as the borehole collapses when the casing is withdrawn. Besst Incorporated (see Appendix A), the manufacturer of the Barcad™ samplers has tested this method of grout placement both in the laboratory and the field and found it to be both installable in angled boreholes and capable of providing hydraulic isolation of the sampling intervals.

### Well Screen and Casing

The Barcad™ and casing requirements are:

- All Barcad™ samplers and PVC casing will be new, unused, and decontaminated.
- Glue will not be used to join casing, and casings will be joined only with compatible threads that will not interfere with the planned use of the well.
- The Barcad™ samplers and casing will be straight.

### Borehole Bentonite Seal

The bentonite seal requirements for the construction of multilevel wells in slant borings are as follows:

- The bentonite seals between the monitoring intervals will consist of minimum of 20 feet of granular bentonite and sand mixed in equal proportions (1:1). The sand/bentonite mixture will be placed as a slurry using a tremie pipe.
- Only 100 percent sodium bentonite will be used.

The granular bentonite/sand mixture will also be used for sealing the borehole to surface (see Figure 5). Due to the possibility of borehole collapse when casing is withdrawn from the angle borings, a neat cement grout will not be feasible for the surface seal in the multilevel wells installed in the AB-1 slant borings. Cement grout could be squeezed out of the borehole in the event of a collapse prior to the setting of the cement.

## 2.5.2 Surface Completion Requirements

Surface completions for all wells installed in this program will consist of above-ground, steel, locking wellhead monument. A watertight expanding rubber seal type locking cap will be provided for each well. The Barcad™ samplers will extend to the surface at an angle inside a 6 or 8-inch steel stovepipe. The wellhead monument completion will be placed over the casing and cap and seated in approximately 4-foot by 4-foot by 4-inch thick concrete pad. The concrete pad will be sloped away from the well sleeve. The well identification will be permanently marked on the casing cap and the protective sleeve. In addition, metal tags will be attached to each of the well casings to identify the specific wells within each well monument.

All wells will be secured as soon as possible after drilling by using corrosion-resistant locks. The locks will be keyed for opening with one master key.

### 2.5.3 Well Development

Within 24 to 72 hours following well installation and annular seal placement, the individual multilevel monitoring wells will be developed by purging with a peristaltic pump. Due to the small diameter of the wells and the design of the Barcad™ well screens, conventional development of these wells by surging and bailing is neither possible nor necessary. During development pumping, temperature, pH, specific conductance, and turbidity will be measured using field instruments. Well purging of the Barcad™ wells will continue until field parameters stabilize and turbidity is reduced to less than 50 nephelometric turbidity units. The purge water produced during well development will be collected in portable tanks or drums at the drill site (with secondary containment) and transferred to cuttings bins or storage tanks in the staging area. Disposal procedures for the IDW are discussed in Section 3.

### 2.5.4 Well Surveying and Completion Diagram

Following surface completion (see Figure 5), the new monitoring wells will be surveyed for well datum elevation and location. A borehole deviation log can not be collected for the AB slant borings/wells due to the specific drilling requirements (e.g., sonic steel casing and boreholes angles ranging from 40 to 30 degrees from horizontal). The bearing (azimuth direction) and inclination of the sonic drill casing will be measured with a handheld compass and inclinometer during drilling and well installation. In addition to the lithologic core logs to be prepared for the slant borings (Section 2.3.3), a well completion diagram will be prepared for each monitoring well installed. It will include the following information:

- Well identification
- Drilling method
- Installation date(s)
- Elevations of ground surface and the measuring point
- Total boring depth
- Lengths and descriptions of the screen and casing
- Lengths and descriptions of the filter pack, bentonite seal, casing grout, and any back filled material
- Depth to groundwater in the constructed wells.

## 2.6 Groundwater Sampling of Multilevel wells

The multilevel monitoring wells will be sampled within 5 days after well development and completion using a peristaltic pump. The wells will be purged and sampled using the casing-volume method purge rates selected to obtain representative groundwater samples

from the aquifer zone and be consistent with the existing sampling procedures used for monitoring wells in the floodplain.

The groundwater samples collected from the six new monitoring wells will be analyzed for Cr(VI), dissolved Cr(T), pH, specific conductance, ferrous iron, total dissolved solids, chloride, sulfate, alkalinity, carbonate/bicarbonate, nitrate, bromide, calcium, magnesium, potassium, sodium, boron, and stable isotopes oxygen 18 and deuterium. Table 2 summarizes the groundwater sampling and analysis plan for initial sampling after development. Field water quality parameters (temperature, pH, specific conductance, oxidation-reduction potential, dissolved oxygen, and turbidity) will also be measured and recorded.

Consistent with prior IM field investigations and the groundwater monitoring program, the samples for Cr(T), metals, and cations will be filtered in the field. The Cr(VI) samples will be filtered in the laboratory before analysis. Per the 2005 Field Procedures Manual, one field duplicate is required every ten samples, at a minimum of one per event. For the initial groundwater sampling, field duplicates will be collected at one well for all analytes. One equipment blank should be collected one per day, per crew, per piece of non-dedicated equipment.

Following initial sampling, the new wells will be incorporated in the Topock groundwater monitoring program and hydraulic monitoring (pressure transducer) network used for the IM performance monitoring program.

## 2.7 Site Restoration Plan

The proposed slant drilling site AB-1 is located near MW-43 on HNWR property that is managed by the USFWS. The following restoration measures will be undertaken for the AB-1 drill site. Several of these measures are similar to the approach for MW-43.

1. The slant drill site will be revegetated with mesquite trees. The planting scheme will be similar to the MW-43 restoration effort, which focused on ultimate re-closure of the tree canopy. The existing irrigation infrastructure will be extended to the slant drill site.
2. Some of the newly planted mesquite trees along the edge of the existing staging area and access/egress route may be crushed by the drill rig and other support equipment. Those trees that do not survive will be replaced at a 1:1 ratio.
3. Prior to vegetation removal, the project boundaries will be clearly marked with lath staking and flagging to minimize habitat impacts by the work crew. A preconstruction survey of the marked site will be performed by a qualified biologist to identify wetlands and any special status species in the area. Wetlands are known to occur nearby and the slant drill site abuts both fringe and adjacent wetlands. The biologist will ensure that boundaries are adjusted, if needed, to avoid these wetlands. Additionally, the biologist will search for active bird nests prior to vegetation removal. However, the drilling is scheduled to occur outside the bird nesting season. Therefore, active nests are not expected within the slant drilling area. The biologist will also photo document and log the Global Positioning System (GPS) coordinates of the pre-construction site conditions.

4. During vegetation removal, a biologist will be onsite monitoring activities to ensure work crews remain within the designated boundary and minimize impacts. The predominant plant species at the site that is expected to be removed is non-native tamarisk. However, native screwbean mesquite trees have been observed intermixed with tamarisk in the area. If avoidance or transplantation of native mesquite trees is not possible, then the biologist will document the number of trees removed and the replacement ratio will be 2:1. The biologist will ensure that the lath staking and flagging is correctly positioned to demarcate the slant drill site boundaries once the vegetation has been removed. Upon vegetation removal completion, the biologist will depart the site.
5. The PG&E field contact representative will be responsible for providing site orientation training to the workers and ensuring compliance with all applicable measures during slant drilling activities.
6. Once slant drilling and well installation activities are completed, the biologist will return to the site to photo document and log the GPS coordinates of the post-construction conditions. The data will be included in a brief report that will be submitted to the DTSC and the USFWS within 60 days of well installation. The report will document pre- and post-construction conditions as well as the planned restoration approach and schedule.

# 3.0 Waste Management and Decontamination

## 3.1 Investigation Derived Waste Management

Several types of waste materials will be generated during the drilling, development, and sampling of the performance monitoring wells. IDW materials that will be generated include groundwater, drill cuttings, and incidental trash.

Water generated during drilling, development, and sampling activities will be collected in bins or portable storage tanks temporarily located on the TCS or on the MW-20 bench (Figure 2). Secondary containment will be set-up at the drilling area for the portable storage tanks or bins. Water generated from the monitoring well installations will be introduced to the IM-3 treatment facility, or transported offsite to a permitted disposal facility.

Drill cuttings include the fragments of rock and soil that are removed to create the borehole. The cuttings will be contained in lined roll-off bins at the staging areas during the drilling and sampling activities. After sampling and characterization, all cuttings bins will be removed from the staging areas for disposal in a permitted offsite disposal facility. It is estimated that the soil IDW bins temporarily stored in the staging areas will not remain in excess of 45 days.

Incidental trash will be collected at the end of each drilling shift and hauled from the drill site to an appropriate offsite disposal facility.

## 3.2 Equipment Decontamination

The back of the track-mounted drilling rig and all down-hole drilling tools will be decontaminated prior to arrival at the site and subsequent to finishing the well installation. Decontamination will be accomplished by steam cleaning the core barrel, drill stem, drive casing, and back of the drilling rig. The pre- and post-mobilization steam cleaning will be conducted on a temporary decontamination pad (lined plastic-sheeting). Rinsate from the decontamination operation will be collected on the containment pad and transferred to the cuttings bin or purge water tanks. The decontamination rinsate will be managed along with the cuttings or purge water. Between borings, the sonic well casing, core barrel, and down-hole tools will be steam-cleaned at the temporary decontamination pad. The TCS will be the primary decontamination area. The MW-20 bench will be used as a secondary decontamination area (Figure 2).

# 4.0 Approvals and Authorizations

Table 3 provides a listing of approvals and authorizations that have been identified as applicable to the implementation of the slant boring activity on the USFWS and HNWR lands.

## 4.1 Drilling Approvals

The anticipated approval mechanism from the HNWR is expected to be an approval letter with conditions (if applicable). Prior to issuance of the approval letter, the HNWR is first required to comply with the Section 7 of the Endangered Species Act (ESA) and Section 106 of the National Historic Preservation Act (NHPA). Compliance with Section 7 ESA may occur via completion of a Programmatic Biological Assessment (PBA) currently in-progress or via a biological assessment and consultation specific to the subject activities. Compliance with Section 106 of the NHPA is expected to involve a 30-day consultation with local Native American tribes followed by a 30-day consultation with the State Historic Preservation Office (SHPO).

Approval from the DTSC is subject to compliance with the California Environmental Quality Act (CEQA). It is anticipated that the subject activities qualify for an exemption from CEQA, pursuant to Section 15061 of the CEQA Guidelines. The project site and/or facilities are expected to fall within the existing right-of-way (ROW) of Interstate 40. This ROW has been granted to Caltrans by the USFWS HNWR. Project facilities/activities within the Interstate 40 ROW will require issuance of an encroachment approval from Caltrans. The subject activities are also within the jurisdiction of the California Department of Fish and Game (CDFG), pursuant to Section 1600 et seq. of the Fish and Game Code. Compliance with CDFG requirements will require submittal of a notification, and potentially issuance of a Streambed Alteration Agreement. Installation of the well facilities will also require the prior issuance of a well permit from the County of San Bernardino.

Underlying land ownership of the project site is currently under review. Approval by the USFWS and HNWR may require concurrence from the BOR if this review indicates an ownership interest is maintained by BOR. Approval by BLM will be needed if the MW-20 bench is used for equipment staging or decontamination.

## 4.2 Biological Surveys and Authorizations

In accordance with the conditions identified in the PBA, the following pre- and post-activity surveys and monitoring will be performed.

1. Prior to vegetation removal, the project boundaries will be clearly marked with lath staking and flagging to minimize habitat impacts by the work crew. A preconstruction survey of the marked site will be performed by a qualified biologist to identify wetlands and any special status species in the area. Wetlands are known to occur nearby and the slant drill site abuts both fringe and adjacent wetlands. The biologist will ensure that

boundaries are adjusted, if needed, to avoid these wetlands. Additionally, the biologist will search for active bird nests prior to vegetation removal. However, the drilling is scheduled to occur outside the bird nesting season. Therefore, active nests are not expected within the slant drilling area. The biologist will also photo document and GPS the pre-construction site conditions.

2. During vegetation removal, a biologist will be onsite monitoring activities to ensure work crews remain within the designated boundary and minimize impacts. The predominant plant species at the site that is expected to be removed is non-native tamarisk. However, native screwbean mesquite trees have been observed intermixed with tamarisk in the area. If avoidance or transplantation of native mesquite trees is not possible, then the biologist will document the number of trees removed and the replacement ratio will be 2:1. The biologist will ensure that the lath staking and flagging is correctly positioned to demarcate the slant drill site boundaries once the vegetation has been removed. Upon vegetation removal completion, the biologist will depart the site.

3. The PG&E field contact representative will be responsible for providing site orientation training to the workers and ensuring compliance with all applicable biological measures during slant drilling activities.

4. Once slant drilling and well installation activities are completed, the biologist will return to the site to photo document and GPS the post-construction conditions. The data will be included in a brief report that will be submitted to the DTSC, BLM, and USFWS within 60 days of well installation. The report will document pre- and post-activity conditions.

## 4.3 Cultural Resource Surveys, Reviews, and Consultations

In 2005, the nearby MW-43 staging area, access/egress route, and monitoring well site were surveyed in the past for cultural resources by a qualified archaeologist. None were found at the site. Similar to the MW-43 survey, cultural resources are not expected to be impacted at the slant drill site. However, confirmation will be made through a pre-survey by a qualified archaeologist. The PG&E field contact representative will be responsible for providing archaeological sensitivity training to the workers and ensuring compliance with all applicable archaeological measures during slant drilling activities.

Consultations with the local Native American tribes and the SHPO were discussed in Section 4.1 above.

# 5.0 Schedule and Reporting

## 5.1 Project Schedule

The schedule for the planning, review, and implementation the proposed slant drilling and groundwater investigation from the California shoreline site is provided in Table 4. The implementation schedule is subject to obtaining approvals and authorizations from DTSC, HNWR, and other agencies, as described in Section 4. DTSC and federal agency representatives have noted that access to the proposed AB-1 drilling site is limited due to the biological impact restrictions for the migratory bird nesting season, which begins in mid-March and extends through September 30 of each year. Accordingly, the project schedule was developed with the goal to complete the slant boring and well installation activities at the California shoreline drilling site before March 15, 2007.

## 5.2 Reporting

Following completion of the field work, a data summary report will be prepared to document the slant drilling, well installation, and initial sampling for this groundwater investigation. The report will include the core logs for the slant borings, depth-specific groundwater sampling data, well completion logs, and the water quality characterization sampling data and validated analytical results. The field activities summary report will be submitted approximately 4 weeks after the receipt of validated laboratory results of the initial well sampling. The drilling logs and depth-specific groundwater sampling results will also be provided to DTSC in interim data releases during the drilling, sampling, and well installation activities.

# 6.0 References


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Havasu National Wildlife Refuge (HNWR). 2006. Letter to PG&E. "Reply to: Site Access and Sampling Procedures for Groundwater Monitoring Wells Located Near Potential Southwestern Willow Flycatcher Habitat, Rev. 3." May 11

U.S. Bureau of Land Management (BLM). 2006. Letter to PG&E. "Federal Agency Consultation on Technical Memorandum April 20, 2006 Site Access and Sampling Procedures for Groundwater Monitoring Wells Located Near Potential Southwestern Willow Flycatcher Habitat, Rev. 3." May 1.

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U. S. Geological Survey (USGS). 2005. Seismic profiling methods and results from the September 2004 seismic-reflection survey on the Colorado River: summary memorandum and attachments presented to DTSC and Topock Project Technical Work Group meeting, 2005.

# Tables

**TABLE 1**
**Drilling and Well Installation Plan**
*Work Plan for Additional Groundwater Characterization by Slant Boring*
*PG&E Topock Compressor Station, Needles, California*

| Site AB-1 Characterization Borings | Drilling Parameters | | Depth-Specific Sampling | | Multilevel Monitoring Wells | |
|---|---|---|---|---|---|---|
| | Target Drilling Angle | Estimated Maximum Slant Boring Depth | Groundwater Sampling during Drilling | Potential No. of Isoflow$^{R}$ Samples | Proposed Well Designations | Monitoring Zones in Alluvial Aquifer |
| 1st Boring (AB-1a) | 40 degrees from horizontal | 200' | 10' zones at 20' intervals | 9 sample zones | MW-52D<br>MW-52M<br>MW-52S | base Alluvial Aquifer<br>to be determined<br>to be determined |
| 2nd Boring (AB-1b) | 30 degrees from horizontal | 300' | 10' zones at 20' intervals | 15 sample zones | MW-53D<br>MW-53M<br>MW-53S | base Alluvial Aquifer<br>to be determined<br>to be determined |

NOTES:

1. See Figure 2 for AB-1 drilling site location.
2. Final slant drilling angles will be determined prior to drilling based on available data and site conditions.
3. Isoflow samples collected during drilling from purged open-hole; see Figure 4 for potential sampling intervals.
4 See Figure 5 for proposed multilevel monitoring wells for Borings AB-1a and AB-1b.

**TABLE 2**
**Groundwater Sampling and Analysis Plan**
*Work Plan for Additional Groundwater Characterization by Slant Boring*
*PG&E Topock Compressor Station, Needles, California*

| Analyte | Analytical Method | Standard Reporting Limit | Potential Number Samples this Investigation |
|---|---|---|---|
| **Depth-Specific Groundwater Samples from Borings (AB-1a and AB-1b)** | | | |
| Hexavalent chromium | Hach, IM3 field lab | 10 μg/L | 24 |
| Dissolved total chromium (field filtered) | Method SW 6010B | 1 μg/L | analyze if Cr(VI) detected |
| Specific conductance | field instrument | NA | 24 |
| Oxidation reduction potential | field instrument | NA | 24 |
| Dissolved oxygen | field instrument | NA | 24 |
| pH | field instrument | NA | 24 |
| Temperature | field instrument | NA | 24 |
| Ferrous iron | Hach, IM3 field lab | 50 μg/L | 24 |
| **Groundwater Samples from Multilevel Monitoring Wells (MW-52 and MW-53)** | | | |
| Hexavalent chromium | Method SW 7199 | 0.2 μg/L | 6 |
| Dissolved total chromium (field filtered) | Method SW 6010B | 1 μg/L | 6 |
| Specific conductance | field instrument | NA | 6 |
| Oxidation reduction potential | field instrument | NA | 6 |
| Dissolved oxygen | field instrument | NA | 24 |
| pH | field instrument | NA | 6 |
| Temperature | field instrument | NA | 6 |
| Ferrous iron | Hach, IM3 field lab | 50 μg/L | 6 |
| Iron (dissolved) | Method SW 6010B | 0.5 mg/L | 6 |
| Total dissolved solids | EPA 160.1 | 10 mg/L | 6 |
| Chloride, Sulfate, Nitrate | EPA 300.0 | 0.5 mg/L | 6 |
| General minerals (Ca, Mg, K, Na) (dissolved) | Method SW 6010B | 1 mg/L | 6 |
| Alkalinity | EPA 310.1 | 5 mg/L | 6 |
| Total Kjeldahl Nitrogen (TKN) | EPA 351.4/3 | 0.5 mg/L | 6 |
| Ammonia | EPA 350.2 | 0.5 mg/L | 6 |
| Manganese (dissolved) | Method SW 6010B | 0.5 mg/L | 6 |
| Total Organic Carbon (TOC) | EPA 415.1/2 | 0.5 mg/L | 6 |
| Oxygen 18 | CF-IRMS | NA | 6 |
| Deuterium | CF-IRMS | NA | 6 |

NOTES:

1. See Figure 4 for anticipated borehole depth-specific sampling by the Isoflow$^{R}$ method and multilevel wells.
2. One equipment blank to be collected per day, per crew, per non-dedicated equipment.
3. Samples analyzed with Method SW 6010B may also be analyzed with Methods SW6020A, EPA 200.7 and EPA2 00.8.
4. Not applicable (NA)
5. Continuous flow isotope ratio mass spectrometry (CF-IRMS)
6. Micrograms per liter (μg/L), milligrams per liter (mg/L)

TABLE 3
Approvals and Authorizations for Drilling
*Work Plan for Additional Groundwater Characterization by Slant Boring*
*PG&E Topock Compressor Station, Needles, California*

| Agency | Approvals and Authorizations |
|---|---|
| U.S. Bureau of Land Management | Approval letter from USFWS HNWR required. Approval subject to NHPA Section 106 and ESA Section 7 consultations (see below). |
| California DTSC | As state lead agency, approval letter from DTSC is required.<br><br>CEQA compliance anticipated to occur via a Categorical Exemption. |
| California Department of Fish and Game | Streambed Alteration Agreement required pursuant to Fish and Game Code Section 1600 et seq. |
| U. S. Fish and Wildlife Service | USFWS HNWR approval subject to completion of a required Section 7 ESA consultation addressing sensitive biological species. |
| State Historic Preservation Office | USFWS HNWR approval subject to NHPA Section 106 process involving a 30-day Tribal consultation followed by a 30-day SHPO consultation. |
| San Bernardino County | Well drilling permit required |
| California Department of Transportation | Encroachment permit required from Caltrans if project activities and/or facilities are located with the right-of-way of Interstate 40. |
| Bureau of Reclamation | Subject to review of underlying land ownership of the project site, approval from the HNWR may require concurrence from the BOR. |
| Bureau of Land Management | Approval from BLM needed if MW-20 bench to be used for equipment staging and/or decontamination. |

**TABLE 4**
**Planning and Implementation Schedule**
*Work Plan for Additional Groundwater Characterization by Slant Boring*
*PG&E Topock Compressor Station, Needles, California*

| | Task / Activity | Estimated Duration | Estimated Completion Date | Remarks |
|---|---|---|---|---|
| **1.0** | **Work Plan & Project Planning** | | | |
| | Scoping Meeting | | | Conducted 11-Oct-06 |
| | Preparation of Draft Work Plan | 8 days | 19-Oct-06 | |
| | DTSC Review & Approval of Work Plan | 7days | 30-Oct-06 | includes DTSC teleconference for finalizing Work Plan |
| **2.0** | **Authorizations & Permitting** | | | |
| | Submit Final Work Plan | | 1-Nov-06 | |
| | Consultation & Approvals/Authorization | 75 days | 19-Jan-07 | Anticipated critical path is 30-day tribal consultation followed by 30-day SHPO consultation. Assumption: CEQA exemption applied by DTSC. |
| | Drilling Approvals | 45 days | 17-Jan-07 | Approvals to be obtained during 60 day SHPO/Tribal consultation period |
| **3.0** | **Drilling Field Investigation** | | | |
| | Site Preparation & Staging | 5 days | 26-Jan-07 | AB-1 drill site, California shoreline south of I-40 bridge (Figure 2) |
| | Drilling Equipment Mobilization | 2 days | 30-Jan-07 | |
| | Drilling/Sampling & Well Installation - 1st Boring | 8 days | 9-Feb-07 | target $40^{o}$ angle boring to 200' (bedrock est.), install multilevel well |
| | Drilling/Sampling & Well Installation - 2nd Boring | 12 days | 1-Mar-07 | target $30^{o}$ angle boring to 300' (bedrock est.), install multilevel well |
| | Equipment Demobilization | 2 days | 8-Mar-07 | |
| | Monitoring Well Development and Sampling | 2 days | 9-Mar-07 | |
| | Site Restoration | 14 days | | site restoration schedule to be determined after drilling completed |
| **4.0** | **Analysis, Evaluation & Reporting** | | | |
| | Analysis, Review & Reporting (drilling & sampling) | 20 days | 10-Mar-07 | includes interim reporting to DTSC of drilling and sampling results |
| | Analysis, Review & Validation (well sampling) | 4 weeks | 30-Mar-07 | assume standard lab analysis / turn around time for initial well samples |
| | Preparation of Draft Field Summary Report | 4 weeks | 30-Apr-07 | |

# Figures

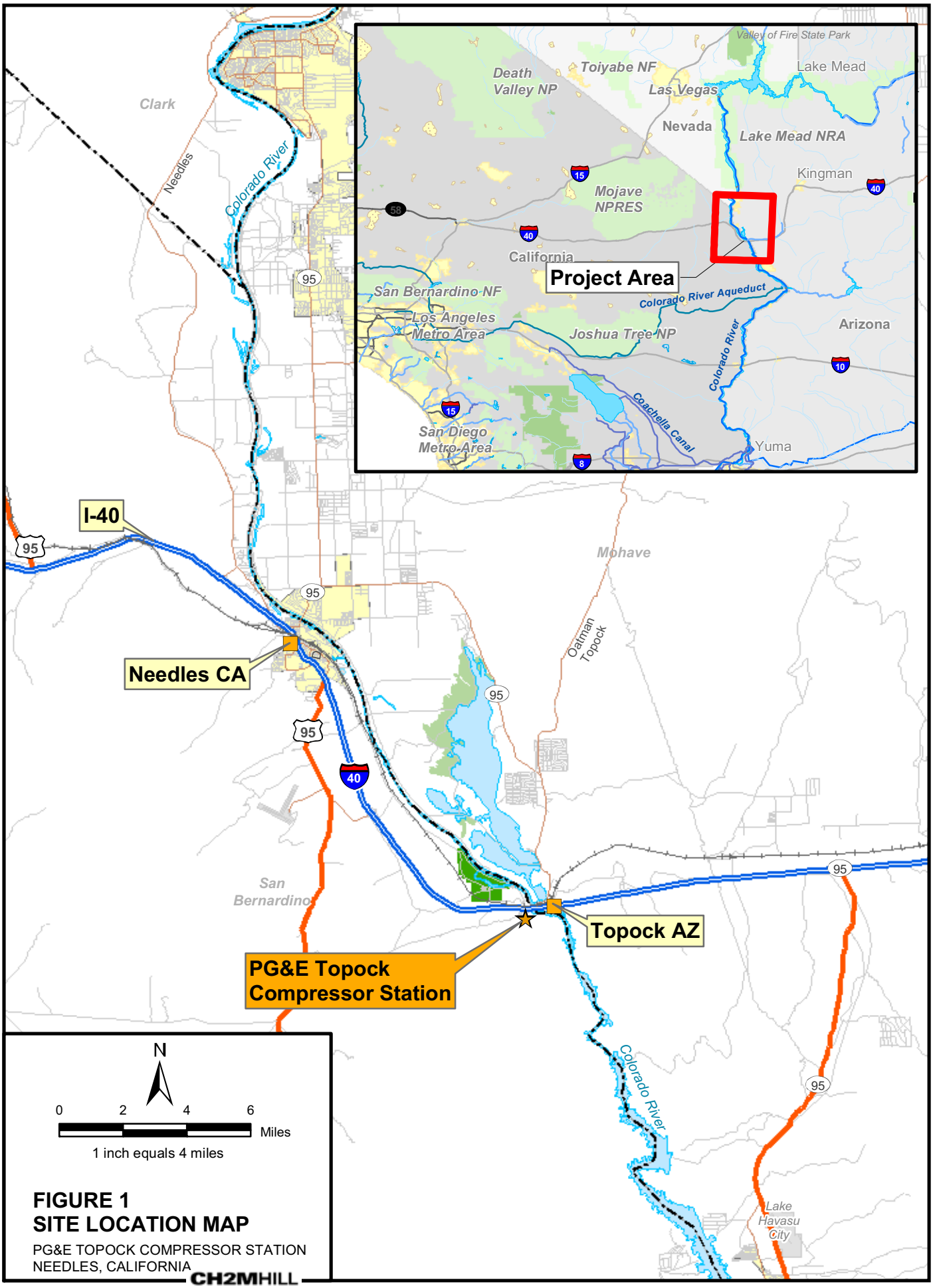


**FIGURE 1**
**SITE LOCATION MAP**

PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

RDD \\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MXD\2005\LOCATION_MAP_PORTRAIT.MXD 12/13/2005 16:33:49


**FIGURE 2**
**PROPOSED LOCATIONS FOR COLORADO RIVER DRILLING INVESTIGATION**
WORK PLAN FOR ADDITIONAL GROUNDWATER CHARACTERIZATION BY SLANT BORING
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

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N

0 300 600
Feet

Park Moabi Road

Colorado River

MW-49

MW-47

MW-33

MW-50

MW-46

MW-20
Bench

TW-2D
TW-3D

MW-44
109

MW-36-100

PE-1
77

MW-34-100
94

MW-39-100

MW-27-85
83

Miocene Bedrock
Outcrop

BN & SF Railroad

MW-32
31

MW-51

CB-14

MW-43
84

CB-07

CB-09

CB-10

CB-12

AB-1

AB-2

Hydrogeologic Cross
Section Figure 4

Interstate 40

MW-22
9

MW-48

MW-23

PGE-9
100

PG&E

Miocene Bedrock
Outcrop

PG&E Topock
Compressor Station

420 400 380 340 320 300 280 260 240 220 200 180 160 140 120 100 80 60 40 20

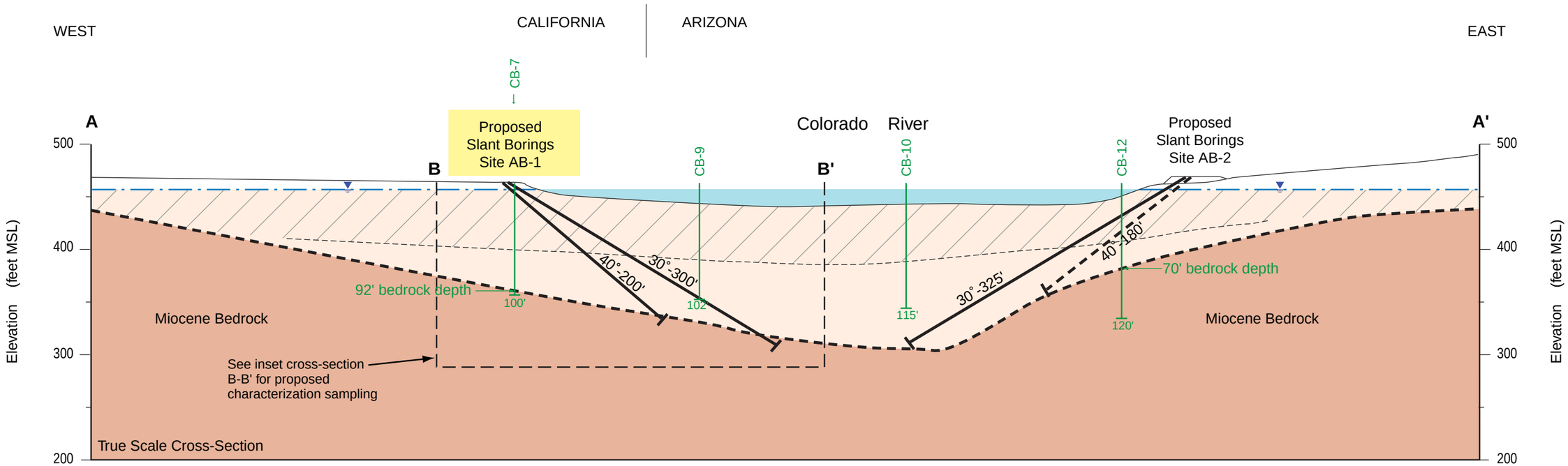
- Groundwater well/boring that encountered bedrock
- 1962 Caltrans I-40 bridge boring
- 100 — Drilled depth to bedrock feet below average river level (MSL)
- (est) 92 — Estimated depth to bedrock feet below average river level (MSL)
- 20 — Inferred depth to bedrock contour, feet below average river level (455 ft. MSL)
- AB-1 — Proposed angle boring drill site
- Approximate Location of September 2004 USGS Seismic Survey

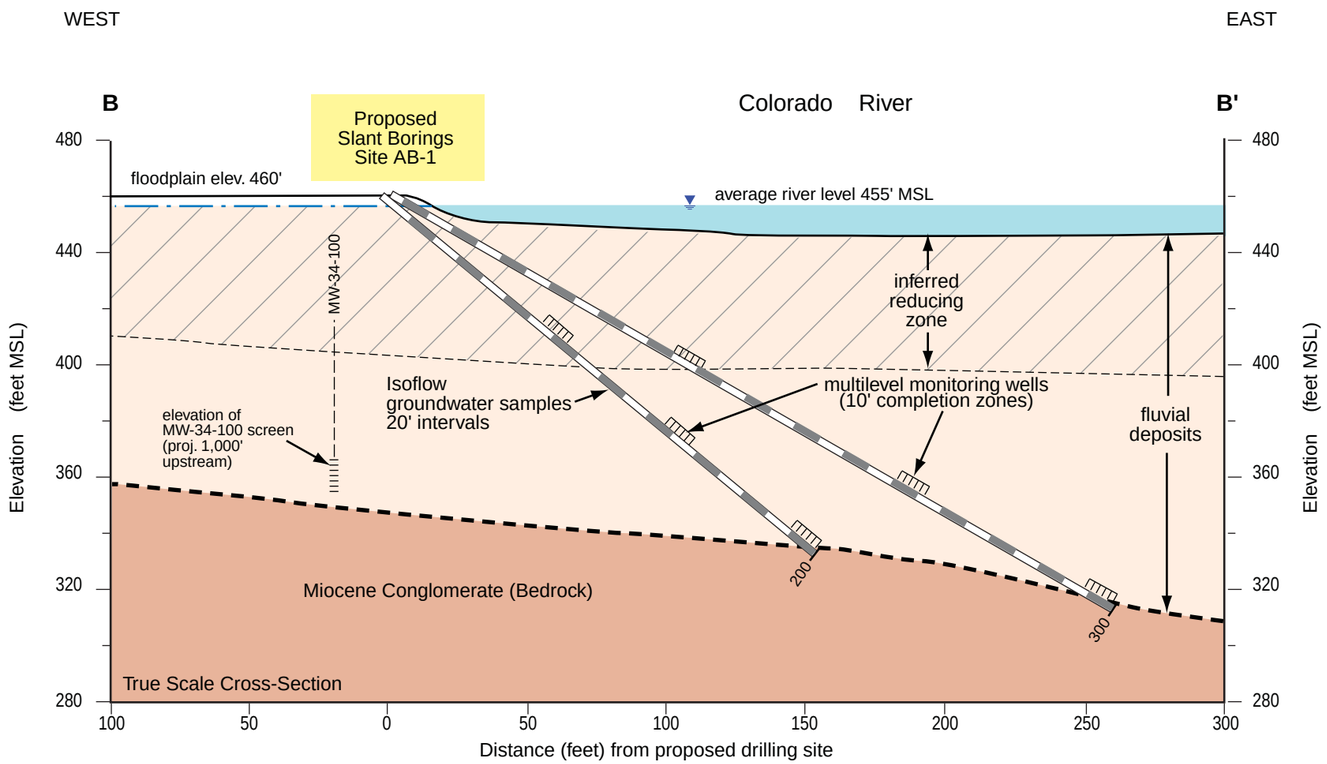
# FIGURE 3
# ESTIMATED DEPTH TO BEDROCK BELOW RIVER LEVEL

WORK PLAN FOR ADDITIONAL GROUNDWATER CHARACTERIZATION BY SLANT DRILLING
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

BAO \\ZINFANDEL\PROJ\PACIFICGASELECTRICCO\TOPOCKPROGRAM\GIS\MXD\2006\SlantDrilling_BEDROCK_ELEV_MAP_v4.MXD




LEGEND

- Saturated Fluvial deposits of Colorado River
- Natural reducing groundwater zone
- Bedrock (cemented Miocene Conglomerate)
- CB-7: Approximate location of 1962 Caltrans boring for I-40 bridge projected approximately 100' to 200' north of cross section
- 70': Approximate bedrock depth, feet below river
- 100': Approximate boring depth, feet below average river stage (455' MSL)

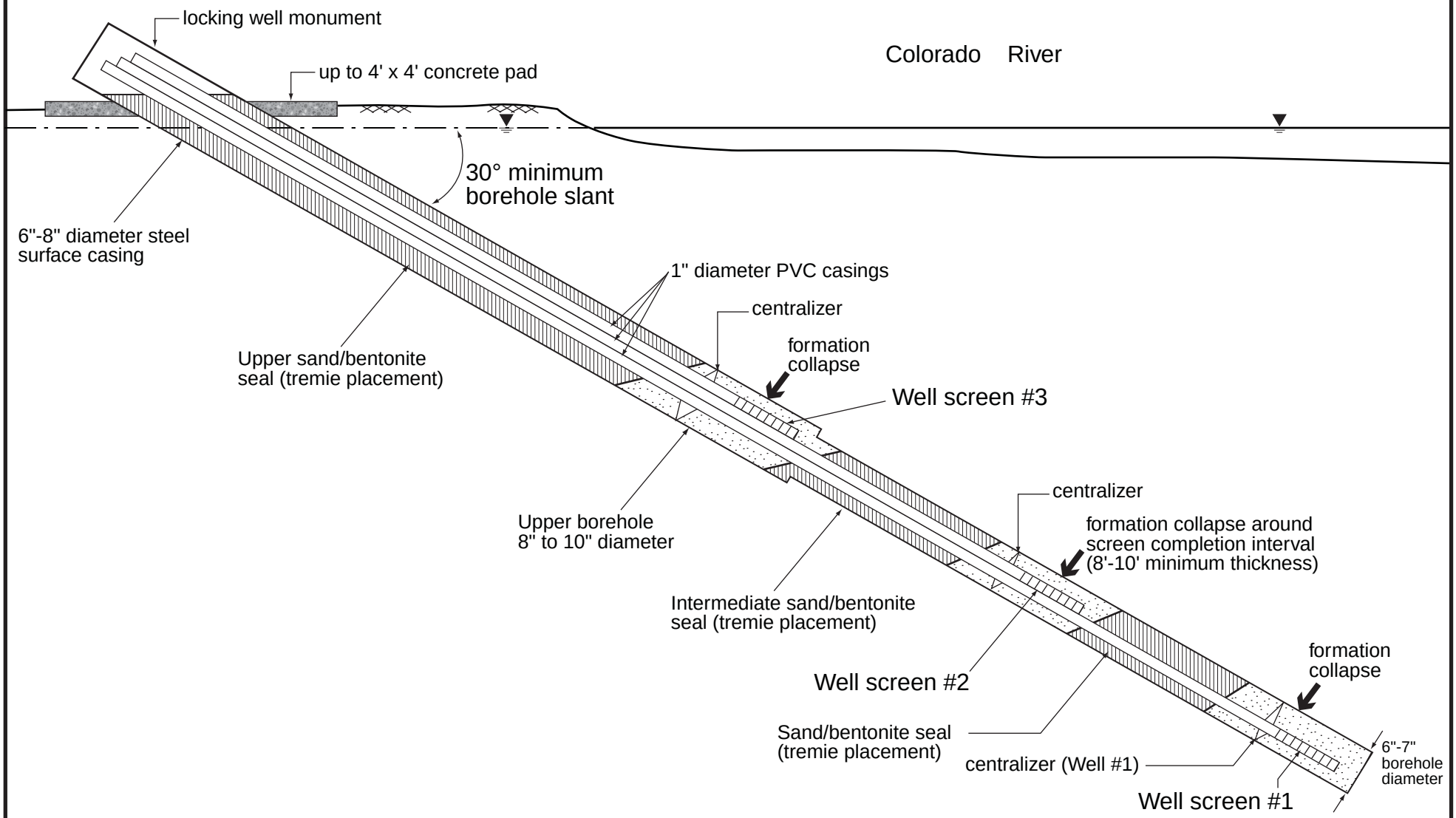
NOTES:

This Work Plan addresses the proposed slant borings/wells at the California shoreline Site AB-1.

The drilling and installation of slant borings/wells at Site AB-2 on the Arizona shoreline will be addressed in a separate work plan.

The 40˚ slant boring shown at Site AB-2 may be drilled if field conditions allow and additional characterization is required.

**FIGURE 4**
**CROSS-SECTIONS OF PROPOSED SLANT BORINGS AND WELLS BENEATH THE COLORADO RIVER**
WORK PLAN FOR ADDITIONAL GROUNDWATER CHARACTERIZATION BY SLANT BORING
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA




## Proposed Monitoring Well Equipment

Barcad® sampling screen installed on rigid PVC casing risers.

Completion intervals to be determined based on core log, Isoflow® sampling, and consultation with DTSC.

SCHEMATIC DIAGRAM – NOT TO SCALE

**FIGURE 5**
**SLANT BORING MULTILEVEL MONITORING WELL SCHEMATIC**
WORK PLAN FOR ADDITIONAL GROUNDWATER CHARACTERIZATION BY SLANT BORING
PG&E TOPOCK COMPRESSOR STATION
NEEDLES, CALIFORNIA

CH2MHILL

ES102006003BAO topock_fig_5.ai 10-19-06 dash

# Appendix A
# Barcad® Groundwater Sampling System

# BESST INC.

## GLOBAL SUBSURFACE TECHNOLOGIES

# Products and Services

BESST INC.
GLOBAL SUBSURFACE TECHNOLOGIES

BESST Inc. is the leader in advanced systems for the environmental and water resources industries around the world. We provide a comprehensive range of subsurface monitoring and sampling technologies and services:

- **Barcad Pumps**
  – Single Barcad Pump for Groundwater Monitoring

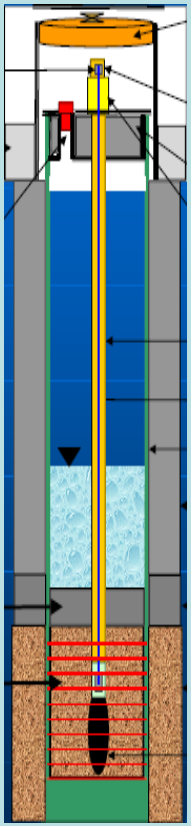
- **Barcad Multilevel Pump Systems**
  – Multilevel Barcad Pump System for Groundwater Monitoring

- **Fiber Optic Sensors**
  – Pressure, Temperature, and Refractive Index Applications in Wells of Every Depth and Diameter

# Barcad Pumps – Single Wells

BESST INC.
GLOBAL SUBSURFACE TECHNOLOGIES

Barcad Pumps are the most durable, reliable, efficient and cost-effective purging and sampling system available for monitoring wells with one zone. Barcads are driven by BESST's gas displacement technology, and have been in operation in North America in all environmental conditions – **in deep burials, running rivers, landfills, and many others** – since the 1980s.

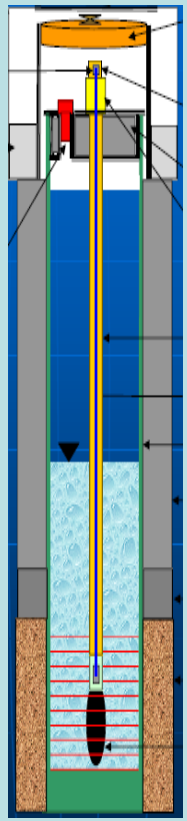


Single Barcad pumps are **embedded or suspended** in open bores and cased wells.

Embedding Barcads in annular materials reduces the purge volume at each screened interval.

A bentonite layer above and below a sand layer at the screen eliminates the stagnant water interface.

Barcads are also suspended with or without packers.



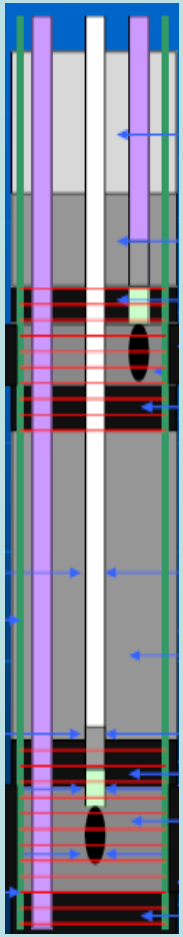
# Barcad Pumps – Multilevel Wells

BESST INC.
GLOBAL SUBSURFACE TECHNOLOGIES

Multilevel Barcads provide **simultaneous purging and sampling capability of up to 10 zones per well**. Installed in nested configurations, Barcad Pumps are the most **durable, reliable, efficient and cost-effective purging and sampling system** available for monitoring wells with multiple zones.

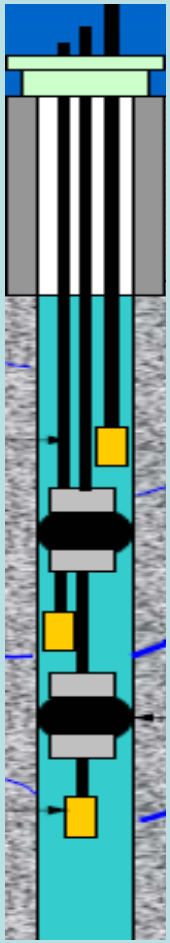
Multilevel Barcad systems are embedded or suspended in monitoring wells under all geologic and climatic conditions. Similar to single Barcad installations, multilevel Barcads can be embedded in sand and bentonite. In suspended systems, up to 10 zones can be installed with the packer system BESST developed for tunnel projects in Japan.

Integrated Fiber Optic Sensors allow for simultaneous water level, temperature, or refractive index parameter measuring.



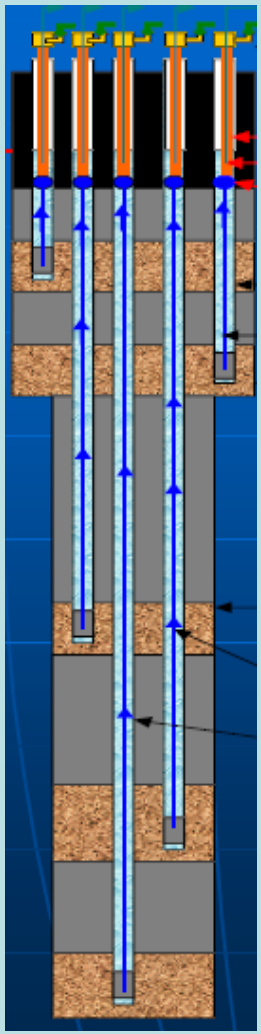
Multilevel Barcad systems are installed with straddle-packer assemblies within competent bedrock boreholes, or within encased boreholes with multilevel screens.

With Mud Rotary Drilling to install Multilevel Barcads, a multilevel screen is installed to support the borehole. After developing each screened zone, Multilevel Barcads are installed with annular materials or packers. As shown on the next page, other drilling methods may be used.



# Barcad Pumps – Multilevel Wells
## (continued)

BESST INC.
GLOBAL SUBSURFACE TECHNOLOGIES



**Examples of Barcad project types and drilling methods:**

- Direct burial of Nested Multilevel Barcad pumps within a borehole with temporary casing
  - Hollow stem auger, air rotary casing hammer, dual wall percussion / Becker rig, sonic and other casing advance methods
- Direct burial of Nested Multilevel Barcad pumps within a permanent multilevel screened casing
  - Mud rotary, air rotary
- Direct burial of Nested Multilevel Barcads within a continuous screened casing
  - Mud rotary, air rotary
  - Within existing monitoring well or water production well
- Multilevel Barcads with straddle packers within open bedrock boreholes
  - Mud rotary, air rotary, diamond core, sonic
- Multilevel Barcads with straddle packers within a permanent multilevel screened casing
  - Mud rotary, air rotary
- Barcads retrofitted within existing multilevel piezometer nests
- Multilevel Nested Barcads installed within angled boreholes in either direct burial or straddle packer configurations
  - Hollow stem auger, sonic, diamond core drilling, mud rotary

# Barcad Pumps – Multilevel Wells (continued)

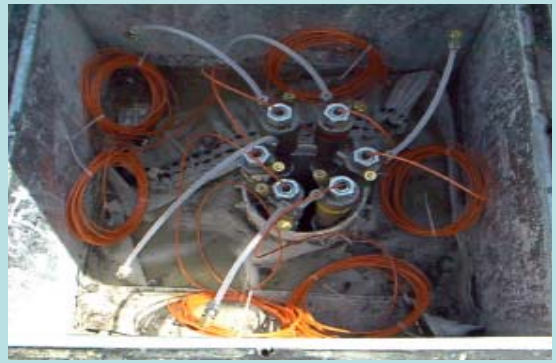
BESST INC.
GLOBAL SUBSURFACE TECHNOLOGIES

Below **6 Barcad zones are installed to 600 ft.** BGS inside a 6-inch diameter multilevel screened casing.

**BESST's 6-way Barcad Control Unit** is used for simultaneous groundwater purging and sampling of all zones.

Nitrogen gas drives the **Barcad gas displacement technology**. A 66 gallon liquid nitrogen gas tank produces 4,800 cubic feet of nitrogen gas.

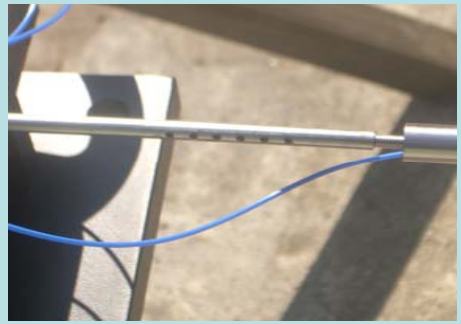
**Fiber Optic Pressure Sensors** are resistant to EMI and RFI. Our data loggers can track 1 to 256 channels simultaneously. **An 8-channel data logger is used for this 6-zone Barcad installation**.



# Fiber Optic Sensors

BESST integrates Fiber Optic Sensor technologies into Barcad Pump systems and infrastructure monitoring systems. Pressure, temperature and refractive index parameters are measured remotely and data is logged continuously.

Integrating Pressure Sensors into Barcad systems allows continuous water level measuring and data collection. Sensors are less than 2 mm in diameter – ideal for most monitoring environments. **This Multilevel Barcad well under construction has Sensors at each level to determine the extent of an upward groundwater gradient.**



BESST has a patented process and apparatus for **installing Multilevel Barcads at any angle with integrated Fiber Optic Sensors for monitoring water pressure and sampling groundwater.** Originally developed for nuclear waste and liquefied gas storage applications in Japan, BESST is now applying the technology in other applications in the U.S. and elsewhere.

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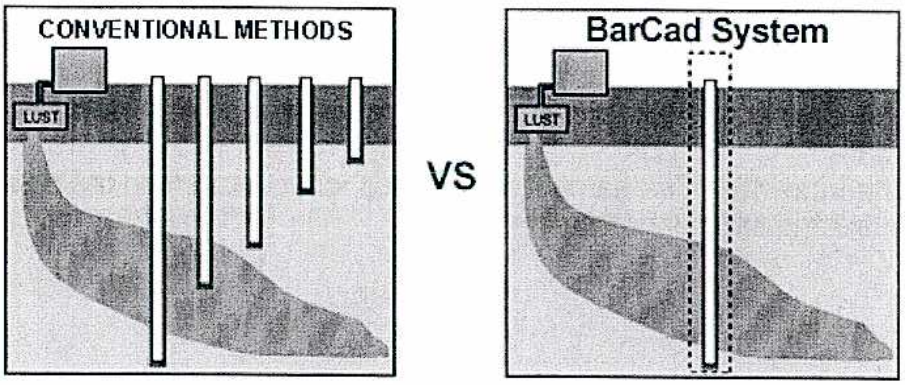
# BARCAD

## SYSTEMS, INC.

The **BarCad® System** offers an alternative monitoring well system for singular or multi-level well installations. The **BarCad® System** utilizes inert gas (i.e. nitrogen or helium) to retrieve groundwater samples - **eliminating the need for pumps or bailers**.

**For information on the operation of the BarCad System in PDF format, please click here.**

**BarCad assembly diagrams available here.**




The **BarCad** System is a simple, economical and accurate multiport monitoring well system that requires a single well installation for sampling multiple horizons. A conventional well cluster requries the installation of multiple wells. Other multilevel monitoring devices in the the industry are expensive or complicated to use, install and maintain.

# Advantages of the BarCad System

### Performance and Cost Savings

- **No pumps** - Pumps are expensive instruments that require maintenance and repair. No pump is needed for BarCad System to operate
- **Ease of use** - Field assmebly entails two easy quick-connect SwageLok connections between sampler, continuous tubing and nitrogen tank
- **Ease of installation** - Much easier to assemble, install and simpler to operate than other multiport systems (i.e. WestBay and DirectPush Multilevel Monitoring System). The BarCad System can be installed as nests in a single borehole or as a single well installation and existing wells can be easily retrofitted. The BarCad System is also easier to abandon than other types of multiport systems.
- **Pressurized gas drive** - The use of an inert gas to obtain groundwater samples enables tubing to be run horizontally. Therefore, BarCad can easily

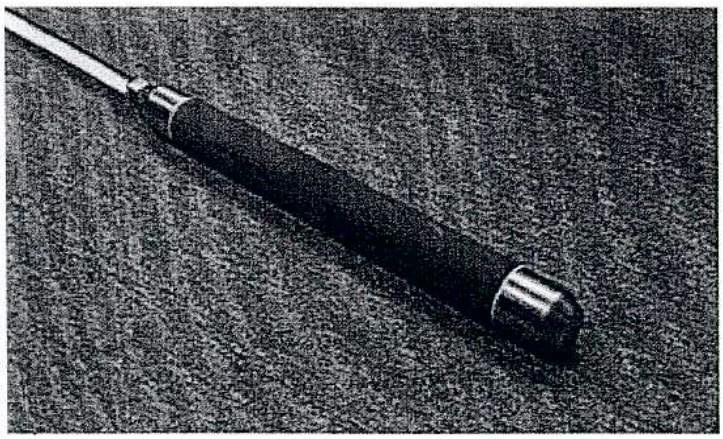
be installed below landfills, buildings and rivers.

- **Closed system operation** - Minimizes the loss of VOCs and operator contact with the sample, thus enhancing safety of the monitoring personnel
- **No depth constraints** - Gas drive sampling permits collection of samples from any depth (no pump limitations)
- **Minimal purge** - The small internal storage volume dramatically minimizes purge volume prior to sampling; in low perm formations, minimum required flushing maximizes sampling. This is typically less than a micro-purge. A smaller purge volume means less waste generated and a cost savings in disposal fees.
- **Upfront cost savings** - With the BarCad System, there is minimal upfront instrumental cost. No software, no spools, no vials and no transducers are needed to obtain a groundwater sample. All that is needed is a nitrogen tank and a regulator.
- **Versatility** - The BarCad System can be easily installed in fractured bedrock as well as semi-consolidated basin materials. It can also serve as a piezometer and be used for soil vapor monitoring wells.

## Accuracy

- **Gas-Drive Sampling** - Maintains water quality better than other methods because the sample experiences minimum turbulence and no mixing with the drive gas.
- **Sample Integrity** - The sample only comes into contact with the BarCad, riser tube and sampling container.

## The Instrument



A **BarCad®** is a groundwater-sampling instrument designed for permanent installations at a fixed level in an uncased, backfilled borehole. The **BarCad®** itself is approximately 1.5 inches in diameter and 16 inches long. Other lengths and diameters are available and the **BarCad®** may be stacked (i.e. 2 or more 16 inch long BarCads can be connected together to give longer screen lengths). The **BarCad®** is sufficiently compact to permit emplacement at multiple depths in a single small-diameter boring. This allows for the establishment and monitoring of vertical water quality and piezometric gradients without resorting to more expensive and less efficient arrays of closely spaced wells.

The sampler contains an instrument grade check valve and porous filter through which water can be extracted from the formation and conducted to the surface via a small diameter riser tube. The design of the **BarCad®** sampler allows use of a wide range of materials in its construction. Most plastics, metals and some ceramics can be employed to tailor the sampler to the geochemical environment in which it is installed.

## Construction

**BarCad®** uses various metals and thermo/fluoro plastics to custom tailor equipment to analytic requirements and characteristics of the geochemical environment. Components are laboratory cleaned, then assembled using only mechanical connections.

## Installation

Permanent installation of the **BarCad®** allows the sampling system to equilibrate with the formation water it is placed in, thereby reducing changes during sampling. Backfilled holes, with no casing left in place, further reduce disturbance of the existing geochemical regime and increase representability of the samples obtained. Self contained, in place equipment also minimizes cross-contamination between sampling locations.

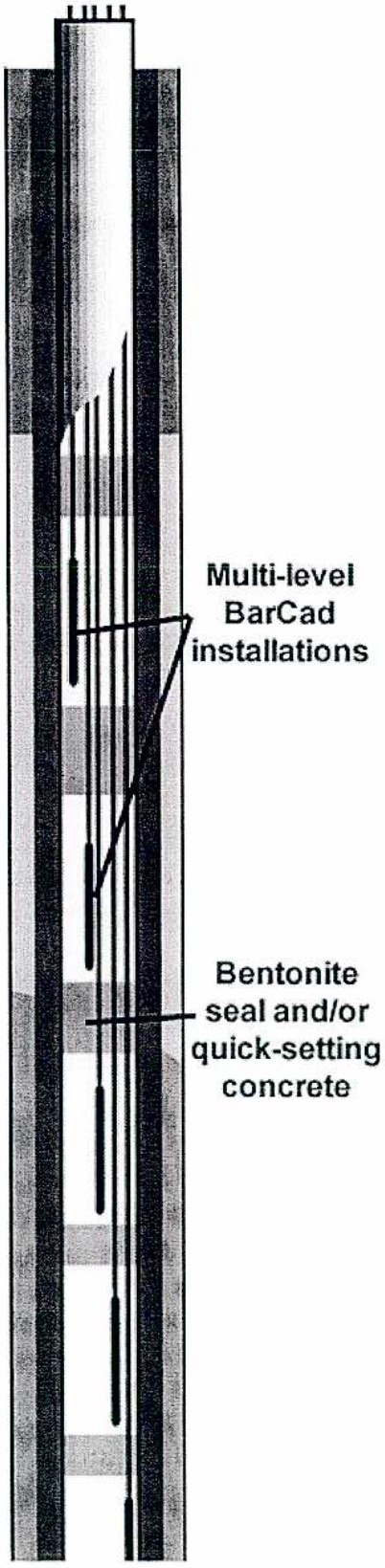
Field assembly entails one easy **SwageLok®** connection between sampler and continuous tubing. Pressurized, gas-drive (nitrogen or helium) enables tubing to be run horizontally. Therefore, **BarCad®** installations bellows landfills allow monitoring of liner integrity without penetration of the liner.

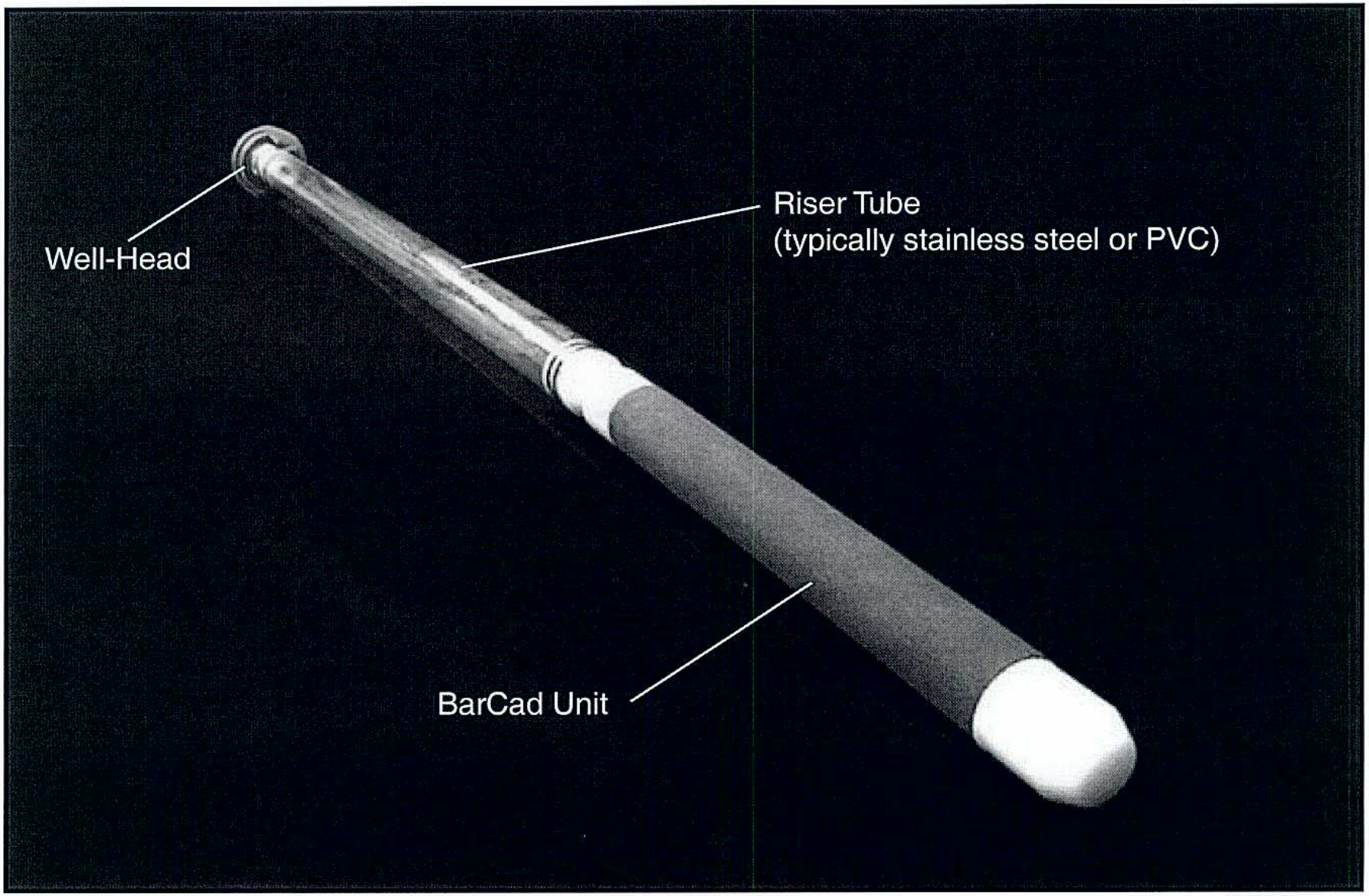
## Operation

Gas-drive sampling maintains water quality better than other methods because the sample experiences minimum turbulence and no mixing with the drive gas. Closed system operation minimizes the loss of VOCs and operator contact with the sample thus enhancing safety of monitoring personnel.

Gas drive sampling permits collection of samples from any depth. The instrument grade check valve prevents introduction of external contaminants into the formation via the sampling system. Small internal storage volume allows complete flushing and collection of only fresh formation water. In low perm formations, minimum required flushing maximizes sampling efficiency.

The **BarCad®** System operates with pressure from a portable tank of compressed inert gas (nitrogen or helium). Drive pressure can be adjusted to allow rapid, direct in-line flitering of inorganic samples without exposure to air. In-line filtration minimizes changes in sample quality by avoiding open transfer to a filter and thus resulting in aeration and/or pH changes.






# BarCad System

# Appendix B
# Caltrans I-40 Bridge Boring Logs

| | | | | | |
|---|---|---|---|---|---|
| VIII | 580 | 40 | 14.1/72.2 | 54 | 54 |

July 1, 1964

BENCH MARKS

+73-A-56 ELEV. 504.32
Set rivet with ¼ cross on top and stamped B.M. 1956 12 Ft. of 728-726

+AR-Z-507.14 ELEV. 507.15
For ARIZ. Hwy. Dept. sta. Brass Plug in PCC @ East of Motel Sign Post stanced 507+16, 14.3' Rt. 55 E produced Ely 2+4 measured from Expansion Joint @ Pavement. Set

COLORADO RIVER

E IMPROVEMENT

B-1 B-5 B-6 B-8 B-13 B-14 B-7 B-9 B-10 B-11 B-12 B-2 B-4 B-3

PLAN
Scale: 1"=50'

AS BUILT PLANS
Contract No. 14-037484
Date Completed
Document No. 80000874

BRIDGE DEPARTMENT

Approx existing ground line along E face.

Very dense brown, reddish-green with mottles slightly silty angular gravel with occasional cobble size fragments.

Very dense interbedded red sandstone & conglomerate

Very dense to hard interbedded red sandstone & conglomerate.

Very dense red conglomerate.

Very dense red clay cemented conglomerate.

Slightly compact to dense, tan & grey sand & scattered small cobble gravel.

Loose to slightly compact grey very fine to medium sand & very poorly sorted arkosic sand with small gravel layers.

Slightly compact grey pebble to cobble gravel & arkosic poorly sorted arkosic sand with brown clay pods.

Compact to very dense fine to coarse gravel.

Dense red gravel in very silty sand matrix (Weathered red conglomerate)

Very loose to very soft black organic silt.

Loose grey fine sand with interbedded strata of dark grey-black organic fine sand.

Slightly compact fine to medium sand with occasional strata of fine gravel.

Dense grey sandy gravel.

Compact to dense grey interbedded sandy gravel & grey fine to medium sand.

Dense grey gravelly fine to coarse sand.

Very hard to dense grey igneous fractured bedrock.

Very loose to loose fine sharp sand.

Loose to slightly compact grey sand & fine gravel layers.

Slightly compact grey poorly sorted angular fine to very coarse sand (arkosic) & small gravel layers.

Slightly compact grey pebble gravel in poorly sorted sand matrix with some reddish-brown clay pockets.

Very dense weathered red conglomerate.

Consolidated very dense red silty sandstone & conglomerate (Clay cemented & containing pebbles to large boulders.)

Loose sand, some silt remains.

Loose, very fine to coarse sand.

Compact to dense, grey sand & fine to medium gravel with some boulders.

Dense sand & gravel.

Very dense coarse gravel.

Very dense poorly sorted, sand & coarse gravel.

Qro

117'

Dens: brown sandy boulder gravel (Fill)

Compact to dense light grey & medium sand with occasional cobbles & boulders (Fill)

Very dense dark grey boulder gravel

Loose to slightly compact sand.

Compact sand & fine gravel layers with some coarse gravel

Dense coarse gravel, compact gravelly sand.

Very dense gravel.

Consolidated, very dense, poor, silty sandstone & conglomerate. (Clay cemented)

Tmc

PROFILE
Scale: Horiz. 1"=50'
Vert. 1"=20'

INFORMATION ON ACTUAL FOUNDATION CONDITIONS ENCOUNTERED IS ON FILE IN BRIDGE GEOLOGY SECTION

CLASSIFICATION OF MATERIAL BASED ON STANDARD GRADE SIZE LIMITS

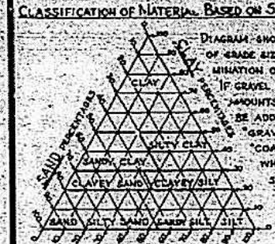



DIAGRAM SHOWING THE BASIS FOR ESTIMATES OF GRADE SIZE DISTRIBUTION USED IN DETERMINATION OF CLASS NAMES.

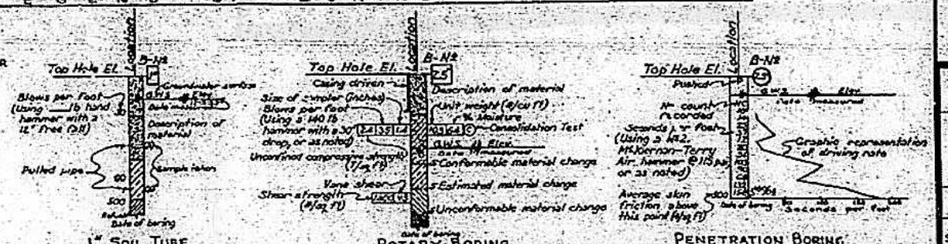
IF GRAVEL IS PRESENT IN APPRECIABLE AMOUNTS THE TERM "GRAVELLY" MAY BE ADDED TO THE CLASS NAME, VIZ. "GRAVELLY SAND". THE TERMS "COARSE", "MEDIUM" AND "FINE" WHEN USED TO DESCRIBE SAND, SILT AND GRAVEL REFER TO STANDARD GRADE SIZE LIMITS.

LEGEND OF EARTH MATERIALS

- GRAVEL
- SAND
- SILT
- CLAY
- SANDY CLAY OR CLAYEY SAND
- SANDY SILT OR SILTY SAND
- SILTY CLAY OR CLAYEY SILT
- PEAT AND/OR ORGANIC MATTER
- FILL MATERIAL
- IGNEOUS ROCK
- SEDIMENTARY ROCK
- METAMORPHIC ROCK

LEGEND OF BORING OPERATIONS

- PENETROMETER
- 2½" CONE PENETROMETER
- SAMPLER BORING (DRY)
- ROTARY BORING (WET)
- AUGER BORING (DRY)
- JET BORING
- CORE BORING
- TEST PIT




NOTE

Classification of earth material as shown on this sheet is based upon field inspection and is not to be construed to imply mechanical analysis.

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

SHEET 1 OF 20 20

BRIDGE ACROSS COLORADO RIVER AT TOPOCK

LOG OF TEST BORINGS

SCALE As Noted. | BRIDGE 54-415 | FILE | DRAWING

FHWL DRAWING NO. P-54415-A

54

I HEREBY CERTIFY THAT THIS IS A TRUE AND ACCURATE COPY OF THE ABOVE DOCUMENT TAKEN

Approx. existing ground line along ℄ Imp.

4' Lt. Sta. 560+68 ℄ Imp.

11' Lt. Sta. 562+31 ℄ Imp.

4' Lt. Sta. 562+54 ℄ Imp.

11' Rt. Sta. 563+44 ℄ Imp.

11' Rt. Sta. 564+25 ℄ Imp.

On Line Sta. 564+29 ℄ Imp.

On Line Sta. 566+44 ℄ Imp.

B-1 3" — 471.3

B-5 3" — 460.2

B-6 3" — 460.2

B-8 3" — 459.5

B-13 3" — 458.2

B-14 3" — 458.2

B-7 3" — 459.3

470

450

430

410

390

370

350

330

Very dense brown, reddish-greenish mottled slightly silty angular gravel with occasional cobble size fragments.

Very dense interbedded red sandstone & conglomerate.

3-6-62

GWS Elev 457.2 Water 3-8-62

Loose to slightly compact black organic silty fine sand interbeds of tan clean fine sand.

Dense dark red sandstone & conglomerate (Weathered)

Very dense to hard interbedded red sandstone & conglomerate.

3-30-62

Water.

Loose muddy silty sand.

Slightly compact to dense gravelly sand.

Dense red cemented conglomerate.

3-31-62

Very dense red cemented conglomerate.

Water.

Very loose brown very fine sand & silt.

Very dense red clay cemented conglomerate.

4-10-62

Loose to slightly compact, clean, fine to medium sand.

Slightly compact to dense, tan & grey sand & scattered small pebble gravel.

Loose to slightly compact grey very fine to medium sand & very poorly sorted arkosic sand with small gravel layers.

Slightly compact grey pebble to cobble gravel & matrix of poorly sorted arkosic sand with brown clay pods.

Compact to very dense fine to coarse gravel.

Dense red gravel in very silty sand matrix. (Weathered red conglomerate)

5-10-62

Loose to slightly compact grey sand & fine gravel layers.

Slightly compact grey poorly sorted angular fine to very coarse sand (arkosic) & small gravel layers.

Slightly compact grey pebble gravel in poorly sorted sand matrix with some reddish-brown clay pockets.

Very dense weathered red conglomerate.

Consolidated very dense red silty sandstone & conglomerate (Clay cemented & containing pebbles to large boulders.)

5-16-62

Water.

Very loose to very soft black organic silt.

Loose grey fine sharp sand.

Very loose to loose tan fine sharp sand.

Loose grey fine sand with interbedded strata of dark grey-black organic fine sand.

Slightly compact fine to medium sand with occasional strata of fine gravel.

Dense grey sandy gravel.

Compact to dense grey interbedded sandy gravel & grey fine to medium sand.

Dense grey gravelly fine to coarse sand.

Very hard to dense grey igneous fractured bedrock.

4-4-62

1 2 3 4 5 6 7

20' Rt. Sta. 573+60 ℄ Imp.

9' Rt. Sta. 573+85 ℄ Imp.

4' Lt. Sta. 574+05 ℄ Imp.

B-2 — 499.2 — 3" — B-4 — 503.1 — B-3 — 504.4

Dense brown sandy boulder gravel. (Fill)

Compact to dense light brown medium sand with occasional cobbles & boulders (Fill)

Very dense dark grey boulder gravel.

3-7-62

100 — 100 — 100

C 78 5/12"

3-9-62

C 60 3/12"

3-9-62

On Line Sta. 568+12 ℄ Imp.

B-9 — 460.5 — 3"

Water.

very soft ilt.

sharp sand.

loose tan

ne sand d strata lack organic

ct fine to th occasional gravel.

sandy gravel.

dense grey ndy gravel medium

ravelly sand.

dense grey ed bedrock.

Loose sand, some plant remains.

Loose to slightly compact dark grey coarse sand & fine gravel.

Compact grey sand, fine gravel.

Compact to dense, grey sand & fine to medium gravel with some boulders.

Dense sand & gravel.

AX

Very dense coarse gravel.

4-17-62

7' Lt. Sta. 570+04 ℄ Imp.

B-10 — 458.2 — 3"

Water.

Loose, very fine to coarse sand.

Slightly compact to compact poorly sorted sand & pebble to cobble gravel.

Interbedded slightly compact sand & dense gravel layers.

Dense sand & fine to coarse gravel.

Dense sand & medium to coarse gravel.

AX

Very dense poorly sorted sand & coarse gravel.

4-29-62

2' Lt. Sta. 571+98 ℄ Imp.

B-11 — 458.5 — 3"

Water.

Very loose medium sand.

Loose medium sand.

Slightly compact dark grey poorly sorted sand & granules.

Slightly compact to compact grey fine to medium sand & scattered fine gravel.

Compact to dense sand & gravel.

5-2-62

11' Lt. Sta. 572+10 ℄ Imp.

B-12 — 458.1 — 3"

Water.

Loose to slightly compact sand.

Compact sand & fine gravel layers with some coarse gravel.

Dense coarse gravel.

Compact gravelly sand.

Very dense gravel.

AX

Consolidated, very dense, red, silty sandstone & conglomerate (Clay cemented)

5-6-62

490

470

450

430

410

390

370

350

330

PROFILE

Scale: Horiz. 1"=50'

Vert. 1"=20'