REPORT

GROUNDWATER SOURCE CONTROL
INTERIM DESIGN REPORT
NW NATURAL GASCO SITE

Prepared for

NW Natural

Prepared by

Anchor QEA, LLC

In Association with

Sevenson Environmental Services, Inc.

SS Papadopulos, Inc.

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CERTIFICATION STATEMENT

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Anchor QEA, LLC

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Date

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LIST OF ACRONYMS AND ABBREVIATIONS

Abbreviation	Definition
µg/L	microgram per liter
Anchor QEA	Anchor QEA, LLC
bgs	below ground surface
CGA	Colin Gordon and Associates
COIs	chemicals of interest
COP	City of Portland datum
CVOC	chlorinated volatile organic compound
DEQ	Oregon Department of Environmental Quality
DNAPL	dense non-aqueous phase liquid
DSL	Department of State Lands
EPA	Environmental Protection Agency
FAMM	Fuel and Marine Marketing
FEMA	Federal Emergency Management Agency
FS	feasibility study
gpm	gallons per minute
GWFFS	Groundwater Focused Feasibility Study
HAI	Hahn Associates, Inc.
LNG	liquefied natural gas
LWG	Lower Willamette Group
MFA	Maul, Foster, Alongi, Inc.
MGP	manufactured gas plant
NAPL	non-aqueous phase liquid
NPDES	National Pollutant Discharge Elimination System
NRC	National Response Coordination
ODFW	Oregon Department of Fish and Wildlife
OHW	ordinary high water
OW	observation wells
PacTerm	Pacific Terminal Services, Inc.
PAH	polycyclic aromatic hydrocarbon
PEC	Probable Effects Concentration
PGE	Portland General Electric

PLC	programmable logic control
POTW	publicly owned treatment works
QA/QC	quality assurance/quality control
RA	risk assessment
RAO	remedial action objectives
RI	remedial investigation
Siltronic	Siltronic Corporation
Site	Gasco Site in Portland, Oregon
SLOPES	Standard Local Operating Procedures for Endangered Species
SPT	Standard Penetration Test
SSPA	SS Papadopulos and Associates
SVOCs	semivolatile organic compounds
TarGOST	tar-specific green optical screening tool
TCE	trichloroethane
TCLP	toxicity characteristic leaching procedure
TRVs	Toxicity Reference Values
TZW	transition zone water
USACE	U.S. Army Corps of Engineers
VOCs	volatile organic compounds
WBZ	water bearing zone

1 INTRODUCTION

As directed by the Oregon Department of Environmental Quality (DEQ), NW Natural has completed interim design of the Groundwater/Dense Non Aqueous Phase Liquid (DNAPL) source control measure for the Gasco Site in Portland, Oregon (Site). This report presents the interim design. This source control work is being completed consistent with the requirements of: a) the Joint Order (DEQ Order No. ECVC-NWR-00-27 to NW Natural and Siltronic Corporation [Siltronic], dated October 4, 2000); and b) the Voluntary Agreement (DEQ No. WMCVM-NWR-94-13 dated August 8, 1994 as amended July 19, 2006). The Site location is shown on Figure 1-1. This interim design report incorporates the findings from numerous design studies completed over the last 18 months, as requested by DEQ under the conditions of their remedial alternative selection dated March 21, 2008 (DEQ 2008). Existing conditions are described in Section 2. The vertical barrier design is in Section 3. The groundwater extraction and treatment system design is in Section 4. Permits are described in Section 5. The source control schedule is described in Section 6.

1.1 Background

On behalf of NW Natural, Anchor Environmental, LLC, prepared and submitted the *Preliminary Design, Groundwater Source Control Report* to DEQ in June 2008. Due to a recent merger, Anchor Environmental is now known as Anchor QEA, LLC (Anchor QEA). This interim design report describes groundwater and DNAPL source control measures for Segments 1 and 2. These two shoreline segments cover the entire length of the Gasco shoreline and a portion of the Siltronic shoreline. The Site map showing the locations of source control Segments 1 and 2 is on Figure 1-2. NW Natural plans to complete final design of the Segment 1 and Segment 2 source control upon receipt of comments on this interim design, and implement the source control measures as soon as possible thereafter.

It should be noted that the following source control documents relevant to this Interim Design have been submitted to DEQ but no comments have yet been received.

- *Groundwater Flow Model and DNAPL Evaluation Supplemental Report*, October 2008.
- *Evaluation of Potential DNAPL Mobilization in Former Effluent Pond Area by Shoreline Source Control Extraction Wells*, March 18, 2009.

Consequently, this Interim Design Report describes a source control system that is consistent with the findings in those reports and follows the Anchor QEA recommendations to NW Natural for source control design elements.

Anchor QEA prepared a source control evaluation report for Segment 3 (Anchor QEA 2009) but DEQ has not yet provided comments. NW Natural submitted the upland Remedial Investigation (RI) (HAI 2007) and Risk Assessment (RA) (Anchor 2004) reports to DEQ in 2007 and 2004, respectively, and has not yet received agency comments. When DEQ comments are received on the RI and RA reports, NW Natural will proceed with development of the upland Feasibility Study (FS). NW Natural believes it is critical to initiate the upland FS.

1.2 Remedial Action Objectives

The Remedial Action Objectives (RAO) for source control were first proposed in the *Groundwater/DNAPL Source Control Focused Feasibility Study* (GWFFS) (Anchor 2007b). DEQ issued a March 21, 2008, letter commenting on the GWFFS. Source control RAOs were also described in the June 2008 Preliminary Design Report. In Section 3.1 of the Preliminary Design Report, additional language was added to address the comments in DEQ's March 21 letter. Following review of the Preliminary Design Report, DEQ provided comments on the Preliminary Design Report in an August 22, 2008 letter. The following RAOs are modified from those in the GWFFS and the Preliminary Design Report and are intended to address DEQ's comments as presented in its March 21 and August 22, 2008 comment letters.

The source control physical removal action goals for shoreline Segments 1 and 2 are as follows:

- Groundwater – Prevent discharge of upland groundwater to the Willamette River, as measured by analyzing groundwater hydrology data from Site wells and the river.
- DNAPL – Prevent the migration of upland DNAPL to the river.

At DEQ's request, the following clarifications apply to the above RAOs:

- Source control measure alternatives have been evaluated specific to mitigating migration to the Willamette River along shoreline segments 1 and 2 by DNAPL in the fill water bearing zone (WBZ) and alluvial WBZ, and contaminated groundwater in the alluvial WBZ.
- DNAPL removal will be included to the extent necessary to control and contain the potential movement of DNAPL from former effluent management areas on the NW

Natural and Siltronic properties that could result from the operation of the hydraulic containment system.

This report provides the design of a shoreline hydraulic containment system (including groundwater extraction wells and treatment system) that NW Natural intends to construct as soon as possible. As explained in Section 3 of this report; the findings of DEQ-requested design studies have shown that DNAPL containment actions, such as a vertical barrier and DNAPL removal, should not be a component of interim source control, but should be evaluated in the Site-wide Feasibility Study. This is explained further in Section 1.4 and subsequent sections.

1.3 Integration with In-River Cleanup

The issue of integration of riverbank stabilization with other Site cleanup activities was discussed in detail in Section 1.2 of the Preliminary Design Report (Anchor 2008b). That report discussed several key issues related to future riverbank stabilization work including:

1. Should riverbank stabilization work occur during or after construction of the shoreline source control measures?
2. Can source control measures be constructed so that they do not limit the riverbank stabilization options?
3. If riverbank stabilization does not occur during construction of the shoreline source control measures, should it occur during future upland cleanup activities, or during the future in-water cleanup under EPA authority?

Since submittal of the Preliminary Design Report, the above riverbank stabilization questions have been discussed at numerous meetings with DEQ and EPA. Regarding question 1, NW Natural has recommended that riverbank stabilization work occur after the interim groundwater/DNAPL source control measures have been constructed. EPA and DEQ have agreed with this approach. Regarding question 2, the details of source controls presented in this interim design report show that the construction of the extraction wells and a vertical barrier would not restrict future riverbank stabilization options. Section 3.3 of this report describes how the vertical barrier is designed to accommodate future removal of riverbank soil if necessary during the in-water dredging operation. Section 3 also describes how the top of the sheetpile wall is designed to be far enough below current grade to allow the riverbank slope to be regraded if necessary during future stabilization activities. Regarding question 3, the discussions with EPA and DEQ have concluded that the riverbank stabilization work will be conducted concurrently with the in-river cleanup directed by EPA. EPA, NW Natural, and

Siltronic have signed an Administrative Settlement Agreement and Order on Consent which includes a Statement of Work that describes how the riverbank stabilization work will be part of the in-river cleanup.

1.4 Integration with Site-Wide Upland Cleanup

At the time of the November 2007 GWFFS submittal, the overall project schedule showed that DEQ would review and approve the upland RA (Anchor 2004) by July 2007, and that NW Natural would submit the Site-wide FS to DEQ in July 2008. The 2007 schedule also showed that the Source Control Design would be finalized in August 2008. Under that schedule, NW Natural planned that the source control design would be evaluated within the context of the Site-wide FS, so that the two designs could be integrated to provide a system to protect human health and the environment using the most cost-effective technologies.

Although NW Natural and DEQ expected that construction of upland cleanup actions would be sequenced after implementation of source control to the river the project schedules at that time for the site contemplated design of source control actions in conjunction with development of the Upland FS.

To date, DEQ has not provided comments to NW Natural on the Site RA (Anchor 2004) or the Site RI Report (HAI 2007). Therefore, the preparation of the Upland FS has been delayed by two years from the date that was in the 2007 project schedule.

Operation of the shoreline source control extraction wells will prevent dissolved contaminants in upland groundwater from recontaminating sediments following the in-river cleanup action. Offshore investigations have shown that upland DNAPL is not currently discharging to river sediments via subsurface pathways. NW Natural investigations required by DEQ have shown that the distribution of upland DNAPL will not be significantly impacted by operation of the source control wells (Anchor 2008c, Anchor QEA 2009b). Because the extraction wells will cause a reversal of the groundwater gradient, operation of the extraction wells will reduce the potential for DNAPL in the shoreline area to migrate to the river. Near-term source control actions therefore do not need to include actions to block DNAPL migration to the river.

DEQ is requiring that source control actions include interim design of a vertical barrier and implementation of a DNAPL removal program. As described above, there is no current discharge of DNAPL to the river that would recontaminate sediment in the near term following

the in-water cleanup action. As further explained in Section 3, the vertical barrier and DNAPL removal technologies should be evaluated within the context of the Site-wide upland cleanup. NW Natural remains ready to prepare the Upland FS immediately upon receipt of DEQ comments on the RI and RA reports. Therefore, NW proposes to sequence final design of the barrier wall described in Section 3.3.1 to follow evaluation of DNAPL mitigation measures in the Upland FS.

2 EXISTING CONDITION

2.1 Hydrogeology and Conceptual Site Model

2.1.1 General Geology and Groundwater Occurrence

The upland hydrogeology was described in the RI Report (HAI 2007). DEQ has requested extensive additional investigations as part of source control evaluations that have provided more detail on Site hydrogeology, particularly near the Willamette River shoreline. These have included shoreline and offshore investigations, the findings of which were reported in the *Phase 1 Report and Phase 2 Field Sampling Approach, Gasco Siltronic Groundwater Source Evaluation* (Anchor 2007a) and the Offshore Investigation Report (Anchor 2008a). The findings of the offshore investigations are described in Section 4.2. DEQ also requested that TarGOST investigations be conducted to further define the nature and extent of upland DNAPL. The TarGOST investigations are described in Section 3.2.1 of this report.

Figure 2-1 shows the locations of all current monitoring wells on Segments 1 and 2, including Gasco and Siltronic properties. Table 2-1 lists the construction details of the existing and proposed monitoring wells, piezometers, and extraction wells. Figures 2-2a, b, and c, are detailed maps showing topography, well locations, pipelines, roads, and other features in the Segment 1 and Segment 2 shoreline areas. These figures also show some proposed features that are discussed later in this report.

Figures 2-3a, b, and c, 2-4, 2-5, 2-6, and 2-7 are detailed geologic cross sections that are focused in the shoreline area. The locations of these cross sections are shown in plan view in Figure 2-1. Figures 2-3a, b, and c depict three portions of the A-A' cross section that is parallel to the river shoreline covering Segments 1 and 2. The cross sections on Figures 2-4 through 2-7 are approximately perpendicular to the river shoreline and show the locations of planned extraction wells and the vertical barrier. These cross sections were constructed using the geologic information from several sources, including:

- Upland remedial investigation borings and monitoring wells (HAI 2007)
- Shoreline and offshore borings (Anchor 2008a)
- Supplemental monitoring wells (Anchor 2008b)
- TarGOST Borings (HAI 2008)
- Siltronic borings and monitoring wells (MFA)

Siltronic has recently installed monitoring wells WS 20 through 27 and the well locations are shown on the Figure 2-1 map. Maul, Foster, Alongi, Inc. (MFA) recently completed the preparation of geologic logs for these wells. The geologic information from the well borings was not received in time to incorporate into the geology on Figure 2-3. The cross sections will be updated with the available new information, as needed, during finalization of this Interim Design Report.

The Site hydrogeology and conceptual site model is based on the findings described in the RI Report (HAI 2007), and in subsequent reports (Anchor, 2007b, 2008b, Anchor QEA 2009a). The three upland hydrogeologic units are the Fill WBZ, Alluvium WBZ, and the underlying Columbia River Basalt. Groundwater in the Fill WBZ and Alluvium WBZ is recharged from underflow originating in the hills west of the Site and from infiltration of incident precipitation on the Site. Figures 2-8a and b are groundwater potentiometric surface maps completed in the Fill and Alluvium WBZs. These contour maps illustrate the groundwater elevation patterns that result in groundwater discharge to the river.

Groundwater in the Fill WBZ is recharged primarily from infiltration of precipitation because much of the Site is unpaved. Near the shoreline, many of the monitoring wells screened in the Fill WBZ dry up in the summer and late fall. Groundwater in the Fill WBZ recharges the underlying alluvium and discharges to the river. Groundwater in the Alluvium WBZ discharges to the river. The basalt is considered a no-flow boundary in the MODFLOW model that has been developed by SS Papadopulos (SSPA) for the Site. The use of the MODFLOW model in designing the source control measures is described in Section 4 of this report.

2.1.2 Alluvium WBZ

As a result of the paleochannel in the basalt bedrock shown on Figures 2-3a, b, and c, the depth of the Alluvium WBZ ranges from about 50 to 200 feet below ground surface (bgs) at the river shoreline. The alluvium is thinnest near the north (downstream) property line with the U.S. Moorings site. The subsurface profiles on Figures 2-4 through 2-7 show that the interbedded silts and sands in the upland Alluvium are similar to those present in the offshore Alluvium.

Subsurface profiles in Figures 2-3 through 2-7 show that the Alluvium WBZ is comprised of two sand units. The upper unit is fine sand with numerous discontinuous silt layers, indicated on the profiles with a green color. The lower unit is primarily medium sand with fewer silt beds, indicated on the profiles with a green diagonal hatch pattern. Figures 2-3a, b, and c show that

the thickness of both sand units increases from north to south along the shoreline as the depth to bedrock increases. Aquifer tests at wells PW-3-85 and PW-3-118 and calibration of the Site MODFLOW model indicate that the hydraulic conductivity of the upper fine sand unit is about 10 feet/day and about 300 feet/day for the lower medium sand unit.

In some areas an alluvial gravel layer is present at the contact between the base of the Alluvium WBZ and the basalt bedrock.

2.1.2.1 Alluvium WBZ Aquitard

During interim design of source controls the Site geologic cross sections (Figures 2-3 through 2-7) were revised based on the new geologic information obtained from the TarGOST borings and new monitoring well borings. It was determined that an aquitard is present within the Alluvium WBZ. The aquitard is a silt unit that is present within the lower medium sand unit of the Alluvium WBZ between elevations -100 and -120 feet. As shown on Figure 2-3a, the aquitard is composed of a single silt bed on the north portion of the shoreline, and in that area, the aquitard is generally more than 10 feet thick. In the southern portion of the shoreline, the aquitard is somewhat lower in elevation and consists of either a single silt bed or multiple closely spaced silt interbeds. The aquitard silt is likely a geomorphic overbank deposit that was placed during historic river flood events when the floodplain was at a lower elevation.

Figure 2-9 is an isopach map showing the thickness of the aquitard. The Site geologic information indicates that the aquitard is thickest on the north portion of the Gasco Site and the north portion of the Siltronic site. These were likely historic floodplain areas at lower elevation that accumulated more silt during flood events. New geologic information from the ongoing Siltronic RI may modify the dimensions of the aquitard. Table 1 in Appendix N provides the geologic data used at each upland boring location to map the presence of the aquitard. The geologic data in Table 1 was also used by SSPA to add the aquitard layer to the Site MODFLOW model.

Review of the Site groundwater quality data shows that the aquitard has a significant effect on groundwater quality in the Alluvium WBZ. Table 2-2 shows a comparison of the concentrations of benzene, naphthalene, free cyanide, and total cyanide in monitoring wells screened in the Alluvium WBZ above and below the aquitard. The concentrations of each of the four analytes are also shown on Figure 2-10, shoreline subsurface profile A-A′. The data shown

on Figure 2-10 is from the September 2008 sampling event, which is generally representative of the data in Table 2-2.

The monitoring wells used for comparison are wells clustered at the same location on Site, but screened above and below the aquitard. With few exceptions, the concentrations of benzene and naphthalene in wells screened below the aquitard are less than 1 microgram per liter (μg/L), which is typically an order of magnitude or more lower than the concentration in wells screened above the aquitard. The average benzene concentration from the September 2008 sampling event was 99.5 percent lower in samples taken from below the aquitard than samples taken from above the aquitard. The average naphthalene concentration from the September 2008 sampling event was 99 percent lower in samples from below the aquitard than samples taken from above the aquitard. Free cyanide concentrations are generally present at trace concentrations in the alluvium and are even lower below the aquitard. The average free cyanide concentration from the September 2008 sampling event was 94 percent lower in samples from below the aquitard than samples taken from above the aquitard. For total cyanide there is also a substantial decrease in concentration below the aquitard. Total cyanide concentrations are generally at least an order of magnitude higher above the aquitard than below the aquitard. The average total cyanide concentration from the September 2008 sampling event was 85 percent lower in samples from below the aquitard than in samples taken from above the aquitard. The groundwater quality data shows that more than 99 percent of the mass of manufactured gas plant (MGP-) related contamination is located above the aquitard.

2.1.3 Offshore Groundwater

The offshore investigation found that a groundwater plume of dissolved MGP-related chemicals of interest (COIs) extends from upland source areas into the river channel sediments. The 3D subsurface profiles on Figures 2-11a, b, and c, show that the MGP-related groundwater plume is present in the upland Alluvium WBZ and extends into the alluvium under the river channel. These 3D profiles of the shoreline show the offshore extent of cyanide, benzene, toluene, benzo-a-pyrene, and naphthalene in groundwater (Anchor 2008a). A seepage evaluation conducted in the late summer and fall of 2007 estimated that the range of groundwater seepage from Site upland Segments 1 and 2 into the river ranged from about 225 to 253 gallons per minute (gpm) at the time of the investigation (Anchor 2008a). The seepage study was conducted during the late summer and fall, when river levels are at their seasonal low level. Because the low seasonal river level results in a higher head difference between upland groundwater and the river, it is expected that the measured seepage amount is near the

maximum that is expected to occur on a seasonal basis. The findings from the offshore investigations were considered in establishing the source control RAO of preventing discharge of upland groundwater into the river.

The offshore investigations included a detailed assessment of the nature and extent of DNAPL in the river sediments. Figures 2-12a and b are two of many subsurface profiles presented in the *Offshore Investigation Report* (Anchor 2008a). These two figures show the extent of dissolved free cyanide and total cyanide in groundwater as measured in groundwater grab samples obtained in river shoreline borings drilled in river sediments along the base of the riverbank in 2007. The borings were extended from the river sediment mudline to basalt bedrock. Sonic drilling methods were used to obtain continuous sediment cores which were screened for NAPL using several screening techniques. The profiles on Figures 2-12a and b also show that DNAPL was detected in shallow river sediment in several of the borings. DNAPL was not detected in any of the borings below an elevation of about -17 feet City of Portland (COP) datum. However, DNAPL has been detected in the upland alluvial WBZ at elevations down to -70 feet COP datum. The offshore investigation findings indicate that DNAPL has not migrated from the upland alluvium into river sediments. The investigations also found that DNAPL in river sediments shown on Figures 2.12a and b is sourced from direct discharge of MGP residuals from upland waste management areas into the river, not from DNAPL migration from the upland Alluvium WBZ.

A release or releases of trichloroethane (TCE) on the Siltronic property have resulted in groundwater contamination. Siltronic has defined the nature and extent of the chlorinated volatile organic compound (CVOC) plumes (MFA 2007). Figure 2-13 shows the approximate width of the combined CVOC plume at the riverbank. Siltronic is currently implementing an in situ source removal action (MFA 2007).

2.2 Current Land Use

The entire Site is zoned industrial, and a detailed description of historic and current industrial operations is in Section 2 of the RI Report (HAI 2007). This description of current land use is summarized from the RI Report. The industrial facilities are shown on Figure 1-2. Shoreline Segment 1 extends across the NW Natural and Siltronic property line and includes about 400 feet of the northern end of the Siltronic property. Shoreline Segment 2 is all on NW Natural property and extends from Segment 1 to the northern boundary of the NW Natural property.

The Fuel and Marine Marketing (FAMM) terminal and NW Natural Liquified Natural Gas (LNG) storage and distribution facility are upland of Shoreline Segment 1.

Koppers Inc., leases the southwestern portion of the NW Natural property at 7540 NW St. Helens Road. The Koppers plant location is outside of the footprint of the source control activities that are proposed in this report. However, the Koppers coal tar pitch pipeline does cross the shoreline in Segment 1, so a description of the Koppers operation is included herein. Koppers operates a coal tar pitch distillation plant. The Koppers plant imports coal tar pitch and related products via rail tank cars and bulk cargo ships. Koppers either stores or remanufactures these products prior to distribution. As of 2005, the management of solid pencil pitch has reportedly been primarily phased out. Liquid coal tar pitch is received by Koppers at the NW Natural dock where it is pumped from the vessel, through an above-ground heated pipeline to a storage tank on the Koppers lease area (HAI 2007). The location of the Koppers pipeline is shown on the maps in Figures 1-2 and 2-1.

Pacific Terminal Services, Inc. (PacTerm), under contract with FAMM, operates a fuel storage and distribution facility at the northern portion of the NW Natural property. The terminal receives, stores, blends, and ships marine fuels and lubricants, utilizing both barge and truck for shipment (HAI 2007).

Siltronic operates a silicon wafer manufacturing plant adjacent to the NW Natural property.

3 VERTICAL BARRIER DESIGN

3.1 Basis of Design

The process and rationale for DEQ's selection of source control components are documented in the 2007 GWFFS report and the 2008 Preliminary Design Report. The primary source control component is a groundwater containment system using shoreline extraction wells. The approximate locations of the planned extraction wells as they were known at the time of the Preliminary Design Report are shown on Figure 3-1. The design of the extraction well and treatment system is presented in Section 4.

In past meetings and letters DEQ has directed that a vertical barrier be designed to block DNAPL migration to the river (DEQ letter, September 24, 2009). This section of the design report provides a design for the vertical barrier, although NW Natural does not believe that a vertical barrier is needed to block DNAPL migration, as explained further below and in Section 3.2.

The sources and distribution of DNAPL at the Site are described in detail in the RI Report (HAI 2007). Table 3-1 is a summary of DNAPL physical and chemical properties in the Fill and Alluvium WBZs. The RI Report describes root macropores in the former effluent pond area that provide a very limited method for migration of DNAPL through the silt in this area. The RI report also concludes that mobile DNAPL is now largely absent in the fill in the former effluent pond area. DNAPL recovery efforts conducted to date at Gasco and the findings from MGP sites around the United States have shown that mobile DNAPL oil migrates very slowly (Gerhard 2007), while the solid tar does not migrate at all. The results from TarGOST borings completed in 2008 showed that the RI did a good job of defining the extent of DNAPL in the former effluent pond area.

Although DEQ has stated in past correspondence that there is a high potential for DNAPL to migrate into the Willamette River (March 21, 2008 letter from DEQ to NW Natural), evidence of subsurface migration into the river has not been found. The DNAPL detected in offshore investigations in nearshore river sediments is shown on Figures 2-12a and b. As described in Section 2.1, the extensive offshore investigations completed in 2007 (Anchor 2008a) indicated that the only DNAPL present in shoreline sediments is very shallow and is the result of historic direct discharge of effluent into the river, not the result of subsurface migration of DNAPL from the former effluent pond area into river sediments. This was conclusively demonstrated in

shoreline borings GS-01 through GS-12, where DNAPL was absent in deep sediments, thereby showing that DNAPL detected in upland nearshore alluvium has not migrated into nearshore sediments. Therefore, subsurface DNAPL has not migrated from upland Site areas into river sediment more than fifty years after the MGP operation ceased. Since these Site investigations have shown that DNAPL from upland source areas has not migrated in the subsurface to river sediments, there is no evidence of a complete DNAPL subsurface pathway.

With the source control extraction wells in place, the river sediments will be protected from recontamination from adjacent upland sources following the in-water cleanup. The DEQ requested investigations described in Section 2 and 3.2.2 have shown that DNAPL will not migrate to the river at least in the near term, i.e., several years. There would be no additional environmental risk associated with operating the extraction wells to allow time for the vertical barrier to be evaluated in the context of the Site-wide FS. As stated in Section 1.4, it is recommended that the vertical barrier design presented in this section be evaluated in the Site-wide FS rather than carried forward to final design prior to the FS.

Although DEQ has directed NW Natural to complete interim design of a sheetpile vertical barrier as generally described in the Preliminary Design Report, the agency deferred selection of the barrier materials, location, and dimensions. In order to help resolve the issues of barrier materials, location, and dimensions, DEQ requested that NW Natural conduct several design studies prior to completion of this Interim Design Report. The requested studies related to the vertical barrier design have been completed and the findings are described in Section 3.2. The locations of the extraction wells and a vertical barrier based on this interim design are shown on the Figure 2-2b map and the Figure 2-3b cross section. Section 3.3 describes how the findings of the design studies were used to evaluate the preliminary design of the vertical barrier.

3.2 Completed Design Studies

3.2.1 TarGOST DNAPL Evaluations

The nature and extent of DNAPL at the Site was presented in the RI Report (HAI 2007). DEQ requested further delineation of the extent of DNAPL using TarGOST technology. On behalf of NW Natural, Hahn Associates, Inc. (HAI) conducted TarGOST investigations in 2007 and 2008. For the Gasco project, the term DNAPL is defined to include tar, mobile oil, and residual oil. DEQ requested this information to help evaluate the design of near-shore source control

alternatives and to refine the delineation of DNAPL in the former effluent pond area and on Siltronic property.

The TarGOST exploration technology uses a cone penetrometer drill tool equipped with a detector that is pushed to selected subsurface sampling depths. The detector measures the fluorescent signature and magnitude to identify the presence of various petroleum compounds. The device was specifically calibrated to respond to DNAPL tar and oil at the Gasco Site by conducting test borings at locations where the DNAPL occurrence was known from previous investigations. The technology is reliable for the detection of the presence of tar and oil, but cannot differentiate between tar and oil or determine if the material is mobile. The cone penetrometer measures the change in earth resistance as it is pushed in the ground, and the magnitude of resistance is correlated to soil types, such as sand, silt, clay. Thus the penetrometer logs are used to determine soil type.

Figure 3-2a shows the nature and extent of DNAPL (tar and oil) in the Fill. Figure 3-2b shows the areal extent of tar and oil detected in the Alluvium above the depth of 100 feet bgs. Figure 3-2c shows the areal extent of tar and oil detected in the Alluvium below 100 feet. The TarGOST investigation generally confirmed the findings of the previous RI investigation, but did refine the DNAPL boundaries in some areas of the Site. The detections of DNAPL and the thickness of geologic materials detected in the TarGOST borings were used to refine the geologic profiles in Figures 2-3 through 2-7. The TarGOST boring logs are provided in Appendix H.

Section 3.3 describes how the nature and extent of DNAPL is accounted for in design of the vertical barrier.

3.2.2 DNAPL Migration Evaluation

In comments on the Preliminary Design Report, DEQ requested evaluation of DNAPL mobility as it relates to design of the vertical barrier. To answer this question, SSPA and Anchor prepared the *Groundwater Flow Model and DNAPL Evaluation Supplemental Report* (Anchor and SSPA 2008). That report is provided in Appendix I. The October 2008 report also addresses several of DEQ's groundwater flow questions related to design of the groundwater extraction well system. Those model findings are described in Section 4.2.1.3.

The objective of the DNAPL mobility evaluation was to determine if there is a potential for upward vertical migration of free-phase DNAPL product into the riverbed sediments and/or surface water as a result of the implementation of the proposed source control measures at the Gasco Site. Specifically, DEQ asked if the installation of the proposed vertical barrier and associated pumping of groundwater extraction wells on the landward side of the barrier could induce DNAPL migration beneath the wall that could subsequently discharge into the Willamette River. The following discussion is summarized from the October 2008 report.

Fundamentally, the flow of DNAPL is not coincident with groundwater flow in magnitude or direction in saturated environments because of density/specific gravity differences between the two media. The three driving forces that act concurrently on subsurface DNAPL include the gravity gradient (weight of the fluids), the capillary pressure gradient (surface tension of the fluids), and the hydraulic gradient (Cohen and Mercer 1993). It is normally assumed that upward vertical hydraulic gradients associated with groundwater flow can prevent or slow the downward movement of DNAPL. For example, shallow recovery wells and drains can be used to create or increase vertical (upward) hydraulic gradients, particularly across an aquitard that separates two aquifers, and this mechanism has been considered to contain sinking DNAPL at several sites. However, reversing DNAPL flow for recovery is very difficult because of capillary effects between the fluid and surrounding aquifer matrix materials.

The DEQ approved, site specific MODFLOW model was used to generate vertical hydraulic gradients projected under multiple pumping scenarios, both with and without the vertical barrier. The analyses were conducted with the barrier bottom at -60 foot elevation, COP datum. The -60 foot barrier bottom elevation was evaluated based on DEQ recommendations in its March 21, 2008 letter commenting on the GWFFS. The resulting vertical hydraulic gradients were examined at the bottom of the proposed vertical barrier to assess if upward hydraulic gradients could potentially overcome gravitational forces associated with the downward migration of DNAPL.

The following conclusions were derived from the above analysis:

- None of the modeled conditions have upward hydraulic gradients that could draw DNAPL upward towards the river on the river side of the barrier wall. The vertical

gradients in this area are near zero, and mobile DNAPL in the area would tend to migrate in a downward direction since gravitational forces greatly exceed the hydraulic gradient.

- Based on differences between hydraulic and gravitational gradients, there is a potential that downward migration of DNAPL in the immediate vicinity of the pumping wells could be retarded or contained. This effect decreases rapidly moving away from extraction wells. Capillary effects may prevent the complete reversal of downward DNAPL migration in these areas, and heterogeneities in the aquifer matrix would play an important role in determining the magnitude of these effects.

During subsequent interim design evaluation, the gradient analyses were conducted with the bottom of the vertical barrier at -40 foot elevation. These analyses were conducted to allow comparison with the previous model results generated assuming a bottom barrier elevation of -60 feet. The -40 foot barrier bottom elevation was described in the GWFFS and Preliminary Design report to achieve DEQ's request to block DNAPL migration to the river navigation channel. Figures 3-3a and 3-3b show the modeled gradient distribution with a total extraction system flow of 250 gpm for barriers having bottom elevations of -40 feet and -60 feet, respectively. For comparison, Figure 3-3c shows the modeled gradient distribution with a total extraction system flow of 250 gpm and no barrier. The model results show that the distribution and magnitude of gradients for the -40 foot elevation option are similar to those resulting from analysis of a -60 foot bottom barrier elevation. Figure 3-3c shows that the magnitude of gradient reversal between the wells and river is actually higher without the barrier present. This demonstrates that the blocking effect of the barrier reduces the magnitude of the gradient reversal between the wells and the river.

On behalf of NW Natural, Anchor QEA and SSPA also completed a DEQ-requested modeling evaluation of the potential effect on DNAPL migration in the former effluent pond area from anticipated groundwater gradient increases induced by planned shoreline source control extraction wells (Anchor QEA 2009b). The findings from that evaluation are also described in Section 4.2.1.4. The evaluation concluded that changes in gradient in the former effluent pond area due to shallow and intermediate depth extraction well pumping would cause maximum distances traveled by DNAPL over a 3-year period to range between approximately 5 to 10 feet using shallow extraction wells, and 0.5 to 1.0 feet using intermediate depth extraction wells.

From that analysis, enhanced groundwater movement in the former effluent pond area due to shoreline extraction wells is minimal and would not substantially change DNAPL distribution over time. The model findings are conservative approximations of the potential distances that DNAPL could travel. The true estimate would be less if the capillary term were factored into the calculation (Anchor QEA 2009b).

3.2.3 Geotechnical Investigation

To provide information for design of the sheetpile barrier, eight borings were drilled at the locations shown on Figure 3-4. Data from this investigation was provided to Glynn Geotechnical Engineering to assist in its design of the vertical barrier.

The borings were drilled between February 18 and February 29, 2008, using hollow-stem auger techniques by Cascade Drilling Inc. In the event of auger refusal, mud-rotary techniques were employed. Four of the borings were drilled to a depth of 120 feet, and four were drilled to a depth of 40 feet. The borings were logged in the field by an on-site Anchor QEA geologist. Copies of the field boring logs are presented in Appendix D. The borings were sampled continuously in the first 10 feet with a 1½-foot split-spoon sampler, and in 5-foot intervals below 10 feet. As the split-spoon sampler was advanced, blow counts of the hammer driving the split-spoon were tallied by the on-site geologist and recorded on the field boring log for the Standard Penetration Test (SPT) analysis. Soil samples were then collected from the split-spoon and submitted for geotechnical analysis to Analytical Resources Inc., laboratories. The samples were analyzed for Atterberg Limits, moisture content, grain size, specific gravity, and reactivity. Copies of the field boring logs including sample intervals and SPT blow counts are presented in Appendix D. Laboratory results of the geotechnical analysis are presented in Table 1 of Appendix D.

Additionally, samples were collected with a 2½-foot Shelby tube at discrete intervals from selected borings and analyzed for vertical hydraulic conductivity, grain size, and moisture content. The sample intervals were selected in the field by the on-site geologist. The samples were collected at depth intervals containing fine-grained low permeability material. Depth intervals of the Shelby tube samples are included on the boring logs in Appendix D. Laboratory results of the Shelby tube sample analysis are presented in Table 2 of Appendix D.

3.2.4 Vibration Study

On behalf of NW Natural, Anchor QEA, Colin Gordon and Associates (CGA), Stephen Dickenson, PhD (Dickenson), and Sevenson prepared a Work Plan entitled *Work Plan – Gasco Siltronic Construction Vibration Study* (Anchor et al. 2008) to evaluate construction induced vibrations at the Siltronic facility that might be generated during construction of a vertical barrier wall. The Work Plan was developed in collaboration with Siltronic and was designed to understand the potential impacts of construction-induced vibrations on Siltronic's facility and accommodate Siltronic's production restrictions, process analysis, and feedback schedule during the testing. The Work Plan was approved by DEQ in a letter dated September 12, 2008; however, following comments made by EPA, DEQ suspended its approval of the study for approximately three months while the EPA issues were resolved.

Siltronic recommended protocols for vibration testing to determine the potential effects of the proposed activities on manufacturing processes, in the *Wafer Test Outline, for Potential Effects from Vibrations (December 6, 2007 revision)* and the *Wafer Test Results Summary (Sample)* (attached to the Work Plan). Additional details related to Siltronic's specifications for scheduling and sequencing the vibration testing, the "wafer test feedback" schedule, and reporting of results are provided in the correspondence (appended to the Work Plan) to NW Natural regarding wafer process monitoring for vibration impacts.

During field testing, comprehensive vibration monitoring was conducted to evaluate potential construction activities, including heavy equipment movement, backhoe pre-trenching, sheetpile driving, and pile removal on the Gasco portion of the site. The primary goals of the construction simulation and ground motion monitoring investigation were two-fold: 1) to develop site-specific relationships for the attenuation of ground motions from the source of vibrations, and 2) to bracket the anticipated range of ground vibrations that would be generated by various construction techniques. Given the number of available alternative types of barrier walls and associated construction methods, it was not considered practicable to evaluate all possible methods at the Site. The monitoring program outlined in the Work Plan was intended to characterize the range of motions that could be expected during construction options being evaluated by Anchor QEA and DEQ. The findings of the study were summarized in the *Vibration Study Data Report* (Anchor QEA 2009c) and provided to the DEQ to assist in its selection of a groundwater DNAPL source control design for the Site.

The monitoring program was successfully executed to establish the vibration characteristics from construction activities; including equipment transport, trenching, and pile driving using three different hammers. All work was conducted in coordination with, and with full approval by Siltronic. In addition, the attenuation characteristics of the soils at the northernmost portion of the Gasco Site and the northwestern portion of the Siltronic site were quantified, including the influence of the Siltronic building on the free-field ground vibrations. Ground vibrations generated during the investigation effectively bracketed the range of motions that could be expected during full scale construction using similar equipment and procedures. Additionally, the results of this construction simulation program were used to bracket the likely range of ground motions that could be expected during construction of other barrier technologies that were evaluated in the GWFSS by Anchor QEA and DEQ. The findings from the monitoring were used to quantitatively estimate the vibrations that would be expected to result from multiple barrier types.

The following is a summary of findings from the vibration study:

- The Gasco Site shows a significant attenuation of ground surface vibration due to construction activities. At the Siltronic site, the vibrations were also observed to attenuate with distance from the source, but at a much lower rate.
- The pile driving methods generate peak vibrations at different frequencies. The APE 200-6 vibratory driver tended to create vibration at a consistent 16 Hz on the Gasco Site, while generating more vibration at 20 Hz on the Siltronic site.
- The Model 250V Variable Moment vibratory driver changed frequencies throughout its operation but tended to stay between 10 and 20 Hz, particularly at the Siltronic site.
- The Junttan HHK 5A Hydraulic Impact Hammer induced motions across a broader portion of the spectrum, specifically between 5 and 20 Hz. The motions were lower in amplitude than those generated by the vibratory hammers and therefore had much less influence on building vibration levels than the other two methods.
- Vibrations associated with moving heavy equipment and pre-trenching were negligible.
- The processes of sheetpile extraction done with the Model 250V Variable Moment vibratory driver and the ramping up and down of the pile drivers tended to create the most vibration within the building structures, although such events were intermittent. However, sheetpile extraction would be a rare occurrence during actual construction.
- Warning limits were established for each 1/3 octave band at each building accelerometer. As pile-driving activity and non-project related local vibration impacts exceeded warning limits, these limits were adjusted upwards by mutual agreement between NW

Natural and Siltronic after it was determined that there were no immediate impacts to the plant processes. The final warning limits were compiled and will be used to assist in future construction.

- Some warning limits were exceeded during ambient monitoring and during times when construction simulations were not taking place. Consequently, this type of information will be factored into design and implementation of construction activities.

In addition, as stated in the Siltronic Vibration Testing Summary Report (*Vibration Study Data Report*, Appendix E; Anchor QEA 2009c):

> "Siltronic concludes a sheet pile barrier wall can be constructed along the GASCO shoreline up to the northwest boundary of the Siltronic property with appropriate selection of construction methods, vibration monitoring and warning alarms. Production was significantly impacted by vibration however solutions appear to be available to modify specific tool mounting or relocation of tools and a few office workers to accommodate the construction activities. Long-term effects of continuous vibration on sensitive measurement tools and connectors could not be evaluated. Construction of a sheet pile barrier wall adjacent to the operating wafering fabs also could not be evaluated. It is likely that additional testing will be necessary should it become necessary to install a barrier wall along the Siltronic shoreline."

3.3 Vertical Barrier Design

3.3.1 Barrier Schedule

As described in Section 1.2, the near-term source control actions are intended to protect the river and prevent recontamination of river sediments following the in-water cleanup.

Operation of the shoreline source control extraction wells will prevent dissolved contaminants in upland groundwater from recontaminating sediments following the in-river cleanup action. Offshore investigations have shown that upland DNAPL is not currently discharging to river sediments via subsurface pathways. Further, NW Natural investigations required by DEQ have shown that the operation of source control wells would not significantly impact the distribution of upland DNAPL (Anchor and SSPA 2008; Anchor QEA 2009b) and would cause little if any increased rate of DNAPL migration. Thus, near term source control actions do not need to include a vertical barrier to block DNAPL migration to the river. Because the extraction wells will cause a reversal of the groundwater gradient, operation of the extraction wells will reduce the potential for DNAPL in the shoreline area to migrate to the river.

DEQ is requiring that source control actions include design of a vertical barrier and a DNAPL removal program. As described above, there is no current discharge of DNAPL to the river that would recontaminate sediment in the near term following the in-water cleanup action.

There are advantages that would result from sequencing final design of a vertical barrier and DNAPL removal activities after design and construction of the hydraulic containment system, including:

- The in-river sediment remedy, which includes riverbank remediation is currently in the investigation stage, and will be much further along when the upland FS is completed. More will also be known at that time about riverbank preferred remedial needs and extent and the need for any shoreline barrier wall could be better integrated into those likely riverbank alternatives. This includes evaluating the possibility of placing a wall at the base of the riverbank slope to contain or prevent potential migration of more DNAPL in the shoreline area than a barrier at the top of the bank could provide.
- The DNAPL migration evaluation (Figures 3-3a, b, and c; Section 3.2.2) demonstrated that the presence of the barrier reduces the magnitude of horizontal gradients that are induced between the barrier and the river. If the extraction wells are operated for a few years without the vertical barrier, the mass of groundwater contaminants captured by the extraction wells would be much higher than would occur during the same period with the barrier in place.
- The vertical barrier and DNAPL removal actions could be evaluated in the Site-wide FS along with other potential upland remedial actions. An overall evaluation of upland remedial alternatives in the FS will include consideration of DNAPL removal, soil removal in both small and large scale, vertical barriers in front or and/or around existing upland DNAPL areas, and or vertical barriers up gradient of DNAPL areas. Any or all of these options either singly or in combination may make a shoreline barrier wall completely unnecessary, or at the least result in movement of the location and purpose of such a wall.
- The installation of a vertical barrier or DNAPL removal facilities in advance of the Site-wide cleanup could limit the scope or extent of future upland actions.

For the above reasons, it is recommended that the vertical barrier and DNAPL removal actions be evaluated in the Site-wide FS.

3.3.2 Barrier Dimensions

In the GWFFS, the location and depth of the vertical barrier were planned to block DNAPL in the fill and upper alluvium from migrating under gravitational forces to the river channel. In the GWFFS, the bottom elevation of the barrier was planned at -40 feet elevation, COP datum. That elevation is equivalent to the bottom elevation of the Willamette River navigation channel. At that elevation the barrier depth would range from about 65 to 70 feet due to the changing ground surface elevation along the top of the shoreline. The location of the barrier in the GWFFS was established as shown on Figure 3-1. The location was based on the known extent and depth of DNAPL as defined in the RI, and in subsequent TarGOST investigations (see Section 3.2.1).

The 2007 and 2008 TarGOST investigations did not change the defined depth or lateral extent of DNAPL in a way that requires a change in the barrier location from what was shown in the GWFFS or the Preliminary Design Report. The barrier location shown on the map in Figures 2-2b and c is based on the occurrence of DNAPL in alluvium and fill as shown in subsurface profile on Figure 2-3b. As shown on Figure 2-3b, the barrier location is designed to extend past the DNAPL detected in boring B-1 at the north end, and to extend past the DNAPL detected in boring B-4B on the south end. The barrier is not designed to extend further north or south along the shoreline because DNAPL is not present in the fill or upper alluvium in those areas.

Based on the findings of the DNAPL migration evaluation described in Section 3.2.2., the bottom barrier elevation of -40 feet will prevent DNAPL migration to the river channel, to the extent any vertical barrier is necessary. DEQ has requested that a barrier bottom elevation of -60 feet be carried into design. The vibration study found that it is possible to install the sheetpile barrier to the -60 foot elevation, but that this is the maximum constructible depth. Although such a sheetpile barrier is constructible, the additional depth is not needed to block DNAPL migration to the river. The subsurface profile on Figure 2-3b shows both the -40 foot and -60 foot bottom barrier alternatives.

The top of the barrier wall is designed to be at elevation +20 feet. This top of barrier elevation is below the elevation of current ground surface along the top of the bluff, which ranges from about +32 to +25 feet. The top of barrier elevation is designed to be above the seasonal high groundwater elevations in the Fill and Alluvium WBZs based on historic ground water hydrology data. The proposed top of barrier elevation of +20 feet provides flexibility to regrade the shoreline slope during future shoreline stabilization.

As shown on Figures 2-2b and c the barrier would be located as close to the top of the shoreline bluff as is practical, considering the constraints dictated by equipment access. Some of the monitoring wells that are currently located close to the planned barrier alignment would have to be decommissioned due to their location near the top of the shoreline bluff. Monitoring well clusters MW-4 and MW-16 are very close to the planned barrier location and there is a high probability that they would have to be decommissioned prior to wall construction. Other existing wells may also be damaged beyond repair. If that occurs these wells will not be replaced because the new wells planned to be installed for source control monitoring will provide good coverage of these shoreline areas. The proposed new monitoring wells are discussed in Section 4.2 and shown on Figures 2-1 and 2-2a, b, and c.

3.3.3 Barrier Materials

As described in the GWFFS and Section 3.3 of the Preliminary Design Report, the vertical barrier was planned to be constructed of steel sheetpile, with slurry wall as an acceptable alternative, if necessary. In the March 21 comment letter on the GWFFS, DEQ agreed with steel sheetpile as the preferred wall material, with slurry wall as an acceptable alternative.

The findings from the vibration study confirm that sheetpile technology can be used and provided feedback into what types of driving technology provides the best combination of driving efficiency and low vibrations.

Based on the need to install long sheets and the associated heavy driving forces, a steel sheet, AZ37-700, was selected for the barrier wall. The high section modulus of the selected member also affords additional resistance to bending that could accommodate some level of excavation along the riverside of the barrier. The sheetpile wall, as designed, consists of 142 welded pairs of steel sheets, each having a driving width of 4.5933 feet. The sheeting pairs will be welded off site and delivered to the project site. The use of welded pairs increases the installation rate and assists in maintaining wall alignment during installation.

3.3.3.1 Constructability Evaluation

A construction implementability evaluation was performed as part of the GWFFS. The GWFFS finding was that steel sheetpile was the preferred alternative for a barrier wall, pending the results of further DEQ-requested design studies, including the vibration study. As noted in

Section 3.2.4, both NW Natural and Siltronic have since determined that a sheetpile wall could be constructed with the appropriate construction methods, vibration monitoring, and warning alarms. There appears to be no remaining substantial unresolved constructability issues related to the implementation of a sheetpile barrier wall.

3.3.3.2 Outfall By-pass System

Sevenson will install a stormwater by-pass system during the construction of the barrier wall at the intersection of the WR-107 outfall. Prior to pre-trenching, at the outfall location, the surface water underground discharge pipe will be located to prevent damage that might be caused by the excavator digging the trench. The pipe will be exposed inland of the wall and a sump will be dug (dimensions and location to be determined while on site) to maintain storage for any stormwater runoff that enters the pipeline. The sump will be lined to prevent direct contact between the storm water and soils. Two 12-inch Godwin pumps will be stationed next to the sump with sections of HDPE pipe connected to the discharge side of the pumps and run to the river. Stormwater collected in the sump will be discharged to the river using this system. The top of the barrier wall is designed to be at +20 ft elevation, which is well below the elevation of the current stormwater discharge pipe. Upon completion of the barrier wall, the stormwater discharge pipe will be reconstructed at a depth above the finished barrier wall.

3.3.3.3 Sheetpile Seal Material Selection

On behalf of Sevenson Environmental, Glynn Geotechnical Engineering conducted bench scale testing of potential seal material for use in the steel sheetpile joints (Glynn 2008). A copy of the report is in Appendix A. The findings from the study were also intended to inform the design of the appropriate type of slurry mix to use in the event that a slurry wall was selected for a portion of the Site vertical barrier. The materials tested included bentonite clay, Portland cement, and organoclay in a range of mixture ratios and water contents. The candidate mixes were exposed to DNAPL samples obtained at the Site by HAI. The findings from these studies were used to design the sheetpile wall sealant material.

The sheetpile barrier will be installed into soils and groundwater that contain hydrocarbon based contaminants. The Site DNAPL consists of medium to light hydrocarbons which tend to negate the sealing effects of bentonite; therefore, the evaluation and testing of a recipe for the sealant consisted of a blend of bentonite and organoclay. The selected sealant mixture of 90%

bentonite/10% organoclay has a demonstrated permeability lower than the target in-place permeability of 1.0 E^{-7} cm/sec.

3.3.4 Trenching

The constructed fill along the proposed alignment of the barrier wall consists of a significant percentage of debris including wood, concrete, boulders, riprap, and brick. The debris, which extends to an average depth of 20 feet below existing grade, would preclude, or at best seriously hinder, the driving of steel sheet piling. A pre-trench operation to a depth of approximately 20 feet will be conducted in advance of the barrier wall installation. The removal and replacement of the surficial fill with a clean gravel material will have the added benefit of reducing any ground vibrations caused by the driving of sheet piling.

Sevenson will pre-trench using a CAT 325 Excavator with a bucket width of 3 to 4 feet. Therefore the trench dimensions will be approximately 4 feet wide x 20 feet deep and 660 feet long. Based on the observations from the Vibration Study, no side slope or angles will be needed for the trench to maintain sidewall stability. This activity will begin 1to 2 days prior to starting the installation of the sheets. At the end of each day, the trench will be backfilled with clean uncompacted material. Sheetpiles will be driven through the clean material to design depths. The backfilling of the trench, prior to sheetpiles being installed, will help prevent surface water from collecting in the trench, an individual from falling into the trench, or sidewalls from collapsing.

Existing borings and the Vibration Study indicate that pre-trenching may be deeper than elevation 20 (top of sheetpile wall). In-situ material and the groundwater table will determine the trench depth. The trench will be dug to a depth not greater than the groundwater table or where the strata of oversized material and undisturbed natural material transition. Soil that will be excavated during pre-trenching will be direct loaded into trucks and disposed of in an approved off-site landfill as discussed below. A small stockpile may be needed for any material that is not shipped off site at the end of each day. The material will be covered by tarps until the following day and then loaded out for disposal.

3.3.4.1 Equipment Selection

A CAT 325 Excavator (or similar) with a bucket width of 3 to 4 feet will be used for pre-trenching. Tri-axle trucks will haul the soil to a pre-approved landfill (see Section 3.3.4.3).

3.3.4.2 Sealing the Trench to Prevent DNAPL Migration during Pile Driving

DEQ has expressed concern that subsurface DNAPL that is encountered during pile driving could migrate downward along the surface of the steel sheet. Although Sevenson does not feel that such migration is likely to occur, assessment of this issue is ongoing and will be further addressed prior to submittal of a Final Design Report.

3.3.4.3 Soil Disposal

NW Natural is planning to develop an Investigation Derived Waste (IDW) Management Plan for the Gasco Site in conjunction with DEQ. Soil generated during pre-trenching activities will be managed according to the agreed upon IDW Management Plan.

3.3.4.4 Backfill Source Material

Following pre-trenching and then again after sheetpile installation (if additional settlement occurs) the trench will be backfilled with clean imported ½-inch aggregate material. The proposed source of the material will be defined in the final design but will be clean quarry-grade material.

3.3.4.5 Volumes

Approximately 3,000 tons of soil would be excavated during the pre-trenching based on trench dimensions four feet wide, 660 feet long, and 20 feet deep.

3.3.5 Pile Driving

3.3.5.1 Equipment Selection

The pile driving equipment that would be used to install the sheetpile barrier wall is an APE Model 250V Variable Moment Vibratory Driver and a Junttan HHK 5A Hydraulic Impact Hammer suspended from a 100 to 120 ton Linkbelt Crane. The selected pile driving equipment is depicted in Figure 3-5. These two types of pile driving equipment were used during the Vibration Study along with an APE 200-6 Vibratory Driver. All three types of pile driving equipment were successfully used to drive sheetpile to the design depth during the vibration study. The Junttan HHK 5A Hydraulic Impact Hammer induced the lowest amplitude vibratory motions, did not result in an impact "event" reported by Siltronic, and hence was selected for the barrier wall interim design. In addition, the APE Model 250V Variable Moment

Driver induced relatively lower amplitude vibratory motions than the APE 200-6 Vibratory Driver, and would also be used during barrier wall construction. Wall construction would begin at the farthest extent along the proposed wall alignment away from the Siltronic facility with the APE Model 250V Variable Moment Vibratory Driver because the driving efficiency of this equipment exceeds that of the Junttan HHK 5A Hydraulic Impact Hammer. In the event that vibration warning limit exceedances attributed to the construction activity occurred at the Siltronic facility, one mitigating option would be to use the Junttan HHK 5A Hydraulic Impact Hammer, which did not result in an impact "event" during the Vibration Study at the closest extent along the proposed wall alignment to the Siltronic facility.

3.3.5.2 Vibration Monitoring System and Protocols

The vibration monitoring system and protocols that would be used during the construction of the barrier wall are described in Appendix B. The vibration monitoring system and protocols are based on findings from the preconstruction vibration study which were summarized in the *Vibration Study Data Report* (Anchor QEA 2009c). A photograph of the data acquisition system, an accelerometer, and cabling is provided in Figure 3-6. The monitoring system includes eight accelerometers within the Siltronic facilities connected to a data acquisition system at a central location. The proposed locations of the monitoring stations are shown on Figure 3.7. Appendix B describes the responsibilities of the parties associated with the vibration monitoring program, monitoring locations, initial warning levels, communication protocols, warning level exceedance protocols, process monitoring and warning level adjustment protocols, and reporting requirements related to vibration monitoring.

3.3.5.3 Mitigation of Sound Impacts

To mitigate potential sound impacts at the Siltronic operations during the installation of the sheetpiles, a temporary scaffolding wall would be constructed with sound boards attached and located in front of Siltronic's office building. If the sound boards on the scaffolding wall do not sufficiently reduce interior building noise, acoustical blankets around the driving hammer may also be used. In this case, a steel "Box" would be constructed using W4x13 I beams and a three-sided "halo" will be constructed using W8x26 beams. Acoustical blankets would be hung on all sides of the two constructed sections. The box would sit on the ground and a support crane would suspend the halo. The halo would be lowered while the sheetpile was driven to final grade. Doing so would encapsulate the sheetpile with acoustical blankets during installation. The box and halo could be moved as needed along the sheetpile barrier wall.

3.3.6 Sealing of Sheet Pile Joints

The sheeting sections of the barrier wall, specifically the interlocking joints, would be augmented by the inclusion of a seal material consisting of a recipe of bentonite and organoclay. As stated in Section 3.3.2.3, Sevenson conducted bench scale testing of potential seal material for use in the steel sheetpile joints. The seal system would be either the Sevenson patented seal system or an equivalent alternate by De Neef, as depicted in Figure 3-8. The joint sealant would be installed during the barrier wall installation efforts. The joint material is placed just prior to setting and subsequent driving of a sheeting pair. Quality assurance/quality control (QA/QC) efforts are conducted as the joint sealant is installed.

3.3.7 Cathodic Protection

Due to the nature of the installation environment, methods to prevent corrosion of the steel sheetpile wall were considered. Corrosion prevention options that were considered included a steel coating or cathodic protection. Steel coatings can be compromised due to scratches caused by handling during installation or contact with abrasive objects buried in the ground. Given the potential for damage to a steel coating during installation at the Site, cathodic protection was selected for incorporation into the design. Passive cathodic protection by means of anodes will be incorporated into the design of the barrier wall during the Final Design.

3.3.8 River Sheen Monitoring

During the vibration study, Anchor QEA conducted weekly or coincidental site visit sheen monitoring events. Sheen monitoring occurred on 1 day during the ambient monitoring period before the construction simulations began (February 2, 2009), on 3 days during construction simulation (February 11, 13, and 19, 2009), and on 3 days during the ambient monitoring phase after the construction simulations were completed (February 20 and 23, 2009 and March 4, 2009). Sheen monitoring observations were noted on the Visual Observations Log Form (Attachment A).

No sheen was observed during the monitoring events noted above, with one exception which occurred after the construction simulations were completed. On February 20, 2009, Anchor QEA conducted a coincidental monitoring event from the shoreline. A spotty sheen of 10 x 20 feet was noted inside the containment system near the shoreline at 07:30. The sheen had dissipated by 09:45 and no sheen was observed during a 13:30 observation. February 20, 2009, was the first day of the ambient monitoring phase after the construction simulations were

completed. Demobilization activities took place on that day, but did not begin until after 07:30. As such, these activities (breaking down equipment and materials, cutting 90-foot sheetpiles down to 45-foot sections, loading equipment and materials on to trucks, and regrading of disturbed areas) are not correlated with the occurrence of the sheen.

Consequently, the production of substantial sheen due to construction of the vertical barrier is unlikely. Nonetheless, visual monitoring for sheen in the river water would be performed once per day during construction of the barrier wall. The planned visual sheen monitoring area is depicted in Figure 3-9. The planned construction schedule would include work Monday through Saturday, and resulting in visual sheen monitoring 6 days per week. Monitoring would be documented on the visual sheen monitoring forms currently submitted to DEQ for routine sheen monitoring. National Response Coordination (NRC) would remain on call for emergency response and boom placement in the event that a substantial sheen does occur.

3.3.9 Quality Control during Barrier Construction

During installation, Sevenson would observe the alignment of the sheetpiles, the condition of the steel piles, the conditions of the interlocks, and identify damage to the sheetpile during installation activities. The energy of the hammer used to drive the sheetpile would be in accordance with the manufacturer's recommendation based on the pile weight and subsurface conditions

Sevenson would remove and replace piles that were damaged or driven with an unacceptable deviation. Sevenson would also verify that the length of the sheetpile was appropriate for the location where the pile was being placed.

The seam in the sheetpile pair with the fabrication shop applied open angle iron would be sealed with the joint sealant selected as part of the permeability test program. (This permeability test program will demonstrate the appropriate materials for the environment of the application and characteristics of permeability not greater than $1x10^{-7}$ cm/sec. No permeability sampling or testing will be performed on the materials installed in the field.)

4 GROUNDWATER EXTRACTION AND TREATMENT SYSTEM

4.1 Basis of Design

4.1.1 Extraction Wells Performance Goals

As described in Section 1.2, the source control RAOs are:

Source control physical removal action goals for shoreline Segments 1 and 2:

- Groundwater – Prevent discharge of upland groundwater to the Willamette River, as measured by analyzing groundwater hydrology data from Site wells and the river.
- DNAPL – Prevent the migration of upland DNAPL to the river.

At DEQ's request, the following clarifications apply to the above RAOs.

- Source control measure alternatives have been evaluated specific to mitigating migration to the Willamette River along shoreline segments 1 and 2 by DNAPL in the Fill WBZ and Alluvial WBZ, and contaminated groundwater in the Alluvial WBZ.
- DNAPL removal will be included to the extent necessary to control and contain the potential movement of DNAPL from former effluent management areas on the NW Natural and Siltronic properties that could result from the operation of the hydraulic containment system.

The overall goal of these RAOs is hydraulic containment to protect the river. Procedures for assessing the performance of the source controls will follow the guidelines as described in *A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems* (EPA 2008). The EPA guidance contains recommendations for assessing system performance to achieve capture using methods that measure hydraulic containment and methods that measure water quality performance.

The methods and procedures designed for performance monitoring are described in Section 4.2.2.4. The RAOs are designed to achieve hydraulic containment; therefore, the performance monitoring methods described in Section 4.2.2.4 are primarily those that use hydrology data to confirm capture. Because the groundwater is contaminated on both the upland and the river sides of the shoreline extraction wells, there is no plume boundary that can be used to measure water quality performance. However, Section 4.2.2.4 includes plans to monitor groundwater quality for the purpose of assessing trends of specific parameters.

4.1.2 Treatment System Performance Goals

The groundwater treatment system is designed to achieve the DEQ mandated effluent criteria listed on Table 4-1. Although the effluent criteria are the key discharge permit conditions that must be met, there will be other permit conditions that must be met. When the treatment system discharge permit is provided by DEQ, all permit conditions will be assessed to determine how they affect the treatment system performance goals and operating protocols.

4.1.3 Extraction/Treatment System Shut Down

The groundwater extraction system is designed to operate continuously to achieve hydraulic containment. Individual wells would be temporarily shutdown for maintenance or repair, but the rest of the extraction wells would continue to operate for those periods. At least two replacement well pumps will be kept in inventory on site at all times. With replacement pumps available on site, the replacement of a well pump should be completed within 24 hours of shutdown. Section 4.3 addresses maintenance and repair of the treatment system.

The entire well system might experience temporary shutdown that could result from the following factors:

- Maintenance and repair of the pipeline system
- Shutdown of the treatment system
- Power outage
- River flooding above elevation 28 feet, COP datum
- Other force majeure events

Due to hydraulic gradient reversal, river level rises that cause the river elevation to be higher than the nearshore upland groundwater elevation will cause river water to temporarily recharge nearshore groundwater, thereby preventing groundwater discharge to the river. These natural gradient reversals will occur seasonally during daily river tidal fluctuation or during increases in river levels due to upstream precipitation or hydraulic damming caused by high levels in the Columbia River. Under these gradient reversal conditions, the extraction well discharge rate will be reduced accordingly. Extraction well pumping rates will be reduced and may temporarily stop during extended periods of gradient reversal, but the wells will restart to maintain capture as the river level declines.

The 100-year Federal Emergency Management Agency (FEMA) flood elevation is 28 feet, COP datum. River flooding above this level rarely occurs and is generally temporary, lasting a few hours or days at most. Under such extreme flood conditions there will be extenuating circumstances associated with Site access, Site flooding, personnel travel, and other issues that could dictate a shutdown of the source control system.

The northwest industrial area is a high Portland General Electric (PGE) priority for restoration of power in the event of an outage. Based on records from PGE, the longest historic power outage that has occurred in the northwest industrial area is less than 12 hours.

The treatment system is also designed to perform on a continuous basis concurrent with operation of the extraction wells. Potential exceptions could include temporary shutdowns caused by the following factors:

- Accidental failure of the pipeline from the extraction wells to the treatment system
- Equipment or pipeline failure in the treatment plant
- Treatment system equipment maintenance and repair
- Power outage
- Natural disasters or other emergencies

The treatment system is designed with a high degree of redundancy of pumps, filters, and other components which would minimize the occurrence or duration of a complete shutdown of the treatment plant.

DEQ has requested an evaluation of the period of time that system shutdown could occur before an unacceptable water quality impact in the river occurs. The first water quality impacts that could occur would be at the point where organisms are first exposed along the groundwater flow path. This point would be in the surface sediment where benthic organisms reside, typically the top few centimeters of sediment in freshwater systems. Therefore, evaluating the period of time that a shutdown could occur and not cause impacts to benthic sediment dwelling organisms would also be protective of surface water organisms and river impacts as well. Such an evaluation was conducted by modeling the impact of groundwater advection and chemical transport changes that would occur during shutdowns on the performance of a sediment remedial cap. Performance of a future clean cap was selected, rather than current river conditions, because a clean cap would be much more sensitive to such

chemical transport changes as compared to relatively contaminated existing sediments that are already substantially impacting benthic organisms.

The impact of groundwater extraction system shutdowns on future cap performance was modeled using the widely used Reible and Lampert (2009) cap model (version 2.13). This model was developed to be consistent with and refine U.S Army Corps Guidance (Palermo et al. 1998) on cap modeling evaluations also developed by Reible. This model estimates the long-term porewater and sediment chemical concentrations expected after the cap comes to steady state equilibrium.

Among other inputs, the model requires estimation of the long-term groundwater advection velocity through the cap. Because it takes many years to reach steady state in most caps, even for highly mobile chemicals, very short-term changes in groundwater velocity will have negligible impacts on the long-term steady state concentrations that are achieved. Therefore, for conditions where the extraction system was operating with no shutdowns, a reasonable long-term groundwater velocity in sediments was entered into the model (1 cm/yr). This velocity was then varied on an average annual basis for conditions when a certain number of days of shutdown might occur over the course of year. So, if a condition of 5 days of shutdown per year was estimated, the average of 360 days of operating system velocities and 5 days of full velocity groundwater flow was calculated and entered into the model.

The estimate of 1 cm/yr for system operation is approximate, and such a "near zero" value would be consistent with complete capture that is to be achieved with this hydraulic containment design. Also, the offshore velocities during system operation would be expected to vary spatially and be higher further away from the Site. However, the near zero assumption would be more consistent with locations closer to shore where the highest concentration groundwater plumes occur and substantial sediment remediation is expected. Maximum or near maximum offshore shallow groundwater chemical concentrations were entered into this model, consistent with these spatial assumptions about velocities. The groundwater velocities during times of shutdown were assumed to instantaneously resume to the full current groundwater velocity (a conservative assumption). The velocity used for this condition was the second highest velocity estimated from seepage meter data using the grid approach presented in the *Offshore Investigation Report* (Anchor 2008a), approximately 3 cm/day. The highest estimated velocity was assumed to be an outlier and not representative of widespread

conditions across the nearshore areas on the sediments, and the second highest velocity used is probably still very conservative in this regard.

Benzene and naphthalene were modeled because they are present in high concentrations in the shallow offshore groundwater and are highly mobile. Cyanide will also be modeled for the final design, but those results are not available at this time. For naphthalene, the third highest observed shallow groundwater concentration was entered into the model; two higher values appeared to be relatively extreme outliers and not likely indicative of broader offshore conditions. During eventual sediment remediation design, these types of locations would likely be dredged first and then capped removing sediment contamination likely contributing to these extreme concentrations in shallow groundwater. For benzene, the highest observed shallow groundwater concentration was input into the model. Other parameters were input consistent with general physical conditions at the Site. Mid-range anaerobic and aerobic biodegradation rates were input into the model based on literature detailed reviews of biodegradation rates conducted by Aronson et al. (1997 and 1999). The cap chemical isolation layer was assumed to consist of 60 cm of sand and 2 cm of activated carbon. More robust designs could be devised and are feasible, but these would only increase the number of days of allowable shutdowns as described below. Chemical concentration results in the bioactive cap layer were compared to the ORNL Tier II aquatic Toxicity Reference Values (TRVs) for benzene and naphthalene; and naphthalene was also compared to the MacDonald Probable Effects Concentration (PEC) for sediments.

The modeling results for benzene indicate that shutdown frequency would have to exceed 45 days per year before the steady state concentration in the bioactive layer of an offshore cap of this specific design would exceed the relevant TRV. However, given that this would represent a relatively significant period of time relative to the time to steady state for benzene (approximately 2.2 years), a safety factor of one half should be applied and this would yield an allowable shutdown frequency of somewhat more than 22 days per year.

The modeling results for naphthalene indicate that the shutdown frequency would need to exceed 5 days per year before the steady state concentration in the bioactive layer of a cap would exceed either the water or sediment relevant TRVs. This represents a very small amount of time relative to naphthalene's time to steady state (approximately 40 years), so no further adjustment to this allowable shutdown time is needed.

Both these results indicate that these shutdowns would have to occur consistently every year over the time to reach steady state in the caps. Given the low duration of power outages and the sporadic and infrequent nature of other items above that might shut the system down, it appears very likely that shutdown frequency could be kept well below 5 days per year on an ongoing average annual basis, thus avoiding any substantial impact to the river.

4.2 Groundwater Extraction System

4.2.1 Design Studies

4.2.1.1 Offshore Investigations

On behalf of NW Natural, Anchor QEA conducted a series of investigations in the Willamette River offshore of the Site during the period from July 2006 to October 2007. This work was required by DEQ to determine the nature and extent of contamination in offshore groundwater and river sediments. DEQ required this work to inform the source control design as it relates to the connection between upland sources and the river. The investigations included comprehensive sampling and testing of groundwater, sediments, and river water. The following summary of work completed and findings is from the Executive Summary of the *Offshore Investigation Report* (Anchor 2008a).

The primary objectives of the investigations were to assess the following issues:

- Understand how the vertical and lateral extent of chemicals in groundwater beneath the river and transition zone water (TZW) may be related to chemical concentrations measured in upland groundwater.
- Understand how groundwater and TZW concentrations may be related to direct historical deposition of materials in the river.
- Determine if the chemical concentrations in the biologically active TZW in navigation channel sediments have been directly impacted by historical deposition of waste materials in the river.
- Determine the potential variability in measured shallow sediment TZW chemical concentrations due to tidal fluctuations in the Willamette River.
- Provide additional lines of evidence for verifying groundwater discharge and providing general level estimates of groundwater discharge rates within the river sediments adjacent to the Site.
- Evaluate the potential for transport of cyanide measured in Site groundwater and TZW

to surface water and any conversion to free cyanide under select river conditions.

- Collect data that may be useful for assessing in-river risks from cyanide (i.e., low tide versus high tide conditions and/or river current velocity and direction).

Following is a summary of the work completed to achieve these objectives:

- Barge mounted drilling equipment was used to complete borings along four offshore transects: transects A, B, C, and D. Transect A is located at edge of shoreline and transect D is located approximately 550 feet from shoreline.
- One hundred six groundwater samples and 83 sediment samples were tested for cyanide species, semivolatile organic compounds (SVOCs), VOCs, and metals.
- A total of 30 borings were drilled along transects B, C, and D. One hundred five groundwater samples and 21 sediment samples were tested for cyanide species, SVOCs, VOCs, and metals.

Ultrasonic seepage meters were installed at seven offshore locations to measure seepage rates over a 5-day period. Mini-piezometers were installed at three offshore locations. A total of 30 TZW porewater samples were obtained over multiple tidal cycles. A total of 12 near bottom river water samples were obtained at the mini-piezometer locations. Willamette River water samples were collected at 20 offshore locations. A total of 180 river water samples were tested for total cyanide, amenable cyanide, free cyanide, selected metals, and conventional parameters.

For the purpose of describing the nature and extent of MGP-related COIs, this summary focuses on free cyanide, total cyanide, benzene, toluene, naphthalene, and benzo(a)pyrene. These six target analytes have a wide range of subsurface fate and transport properties, and their distribution are generally representative of the MGP-related COIs.

Free cyanide has been detected in a very small percentage of the groundwater samples, and at trace concentrations were detected. This is significant because the free cyanide compound is considered the toxic form of cyanide. The detected concentrations were generally below 10 μg/L.

Total cyanide is present in groundwater in all offshore transects at generally all depths sampled. Total cyanide is very soluble, chemically stable, and does not adsorb significantly to the sediment matrix. Therefore, total cyanide is one of the most widely distributed of the MGP-related COIs.

Benzene, toluene, and naphthalene are also widely distributed, but their plume patterns are variable, reflective of both historical direct discharge or overflow of oily effluent to the river and groundwater transport from upland sources. Consistent with a much higher tendency of benzo(a)pyrene to adsorb to organic carbon, its distribution in groundwater is quite limited compared to naphthalene (another PAH), which is much more mobile in groundwater. The presence of elevated benzo(a)pyrene concentrations in offshore groundwater is primarily associated with the occurrence of non-aqueous phase liquid (NAPL) in shallow sediments. Although trace concentrations of benzo(a)pyrene are detected in some of the deeper groundwater samples, these are likely associated with the suspended solids in the groundwater grab samples obtained in this investigation.

Seepage data from the 2005 Lower Willamette Group (LWG) investigations at Gasco and Siltronic were combined with seepage data from the 2007 Gasco Seepage investigation to estimate a range of total seepage rate from 225 to 253 gpm from the area offshore of Gasco and Siltronic. This is comparable to the extraction well pumping rate that modeling indicates would be necessary to achieve upland groundwater source control.

No free cyanide was detected in any surface water sample. There was one detection of free cyanide (unfiltered) in shallow TZW (1.5 to 2.5 feet below mudline), but all other TZW samples were non-detect for free cyanide.

4.2.1.2 Pilot Extraction Well PW-3 Testing

Pilot extraction wells PW-3-85 and PW-3-118 were installed for field testing to obtain site-specific aquifer properties to inform the MODFLOW groundwater model and, ultimately, the design of the groundwater/DNAPL source control system. In previous reports these wells were named PW-4-85, 118, but were renamed so that names of the wells were sequential according to their spacial orientation. This description of the test procedures and findings is summarized from Appendix E of the GWFFS (Anchor 2007b). The two PW-3 extraction wells are located near the Siltronic property line.

The PW-3 pump test consisted of pumping the shallow screen interval (PW-3-85) and intermediate screen interval (PW-3-118) both individually and together. The test included separate step-drawdown tests on each screen interval and a combined constant rate test on both screen intervals. The tests were conducted in July 2007 and included extensive continuous (one-

minute frequency) monitoring of water levels in the pumping wells and observations wells for extended periods before, during, and after pumping. A summary of the rate and duration of tests is provided below in Table 4-2.

Water levels during the tests were affected by river stage changes, which were primarily due to tidal fluctuations during the test period.

Analysis of the constant rate test at PW-3-85 shows two responses: an early time response and a later time response. The early time response is indicative of conditions close to the pumping well before the influence of the river boundary becomes significant. The later time response is likely influenced by the river boundary.

Analyses of the PW-3-85 and PW-3-118 step-drawdown and constant rate tests show a considerable difference in the hydraulic conductivity in the shallow and deep alluvium. In both tests, the influence of the river boundary appears to affect the pump tests as seen in the rapid equilibration of the water levels with time. These variations in aquifer properties are accounted for in the properties assigned to the MODFLOW model layers. Analysis of the pump test data provided the aquifer properties of hydraulic conductivity and storage coefficient that were used in development and calibration of the MODFLOW model.

Water level data collected by transducers after the PW-4 pump test are show below in Figure 4-1. This figure illustrates the tidal efficiencies at the various wells. Water levels at the wells follow the stage fluctuations in the river, but are attenuated and delayed in time compared to the river stage fluctuation. The attenuated fluctuation in the wells compared to the river tidal fluctuation is referred to as the tidal efficiency and is usually reported as a percentage of the river stage fluctuation. The delay in the peak water levels in the well compared to the timing in the river is referred to as the lag time.

4.2.1.3 Groundwater Flow Model

Following submittal of the Preliminary Design Report (Anchor 2008b), DEQ requested additional groundwater flow modeling as part of source control design. The additional modeling work was reported in the following documents.

- *Groundwater Flow Model and DNAPL Evaluation Supplemental Report* (Anchor and SSPA 2008)

- In 2009 DEQ requested additional figures, which required additional model runs.

Figure 4-2 is a particle track map showing the model-predicted capture zone in the Alluvium WBZ induced by the ten extraction well locations. The modeled total extraction well flow rate for this analysis was 260 gpm. The 2008 model report and 2009 figures are in Appendix I. The following findings affect source control design and they are taken directly from the October 2008 model report.

1. The Site groundwater elevation data for March 27, 2000, represents a reasonable worst case condition for future modeling and design purposes.
2. Overall, the calibration to March 2000 worst case conditions with the change in the upland boundary head, recharge rate, and adjustment of the deep alluvium hydraulic conductivity zone increases the overall groundwater flow in the model by 30 percent from the average base case condition for the period the worst case condition is in effect. This is accounted for in the particle track map on Figure 4-2.
3. Modeled source control scenarios of shallow, intermediate depth, and paired extraction wells show that the use of shallow extraction wells requires the highest pump rate to achieve capture.
4. The intermediate depth extraction well scenario results in the highest upward vertical gradients on the landward side of the vertical barrier, but these gradients decrease more rapidly with distance from the pumping well than in the shallow extraction well scenario.
5. Model runs after assumed potential post-dredge bathymetry was present showed somewhat higher pumping rates to attain capture than the current bathymetry. However, modeling the post-dredge bathymetry in addition to the March 2000 reasonable worst case flow condition is believed to be overly conservative because the assumed 20-foot dredge depth would be extreme throughout the whole shoreline area and will likely be restored with engineered fill or filled in by natural river sedimentation processes. With the addition of post-dredge engineered fill or natural river sedimentation the resulting bathymetry will be close enough to current bathymetry to make the modeled groundwater flows essentially the same. Therefore, the March 2000 reasonable worst case model described in Section 4 is recommended as the worst case scenario to be considered in future design evaluations.
6. None of the modeled scenarios have upward hydraulic gradients that could draw DNAPL upward towards the river on the river side of the barrier wall. Based on differences between hydraulic and gravitational gradients, there is a potential that

downward migration of DNAPL in the immediate vicinity of the pumping wells could be retarded or contained.

Based on the findings of the 2008 and 2009 model evaluations the groundwater extraction and treatment system are designed to handle an average total flow of 300 gpm. This accounts for the expected average flow from the ten extraction wells of 200 gpm, plus the discharge from existing LNG basin groundwater sump, plus some additional flow from potential future DNAPL extraction wells in the former tar pond area. As explained in Section 4.3 and Appendix C, the treatment system is designed to handle a temporary peak flow of 400 gpm to accommodate the March 2000 worst case modeled flow of 260 gpm described above.

4.2.1.4 DNAPL Movement

At the request of DEQ, Anchor QEA evaluated the potential for DNAPL mobilization in the former effluent pond area as a result of future source control groundwater pumping. The findings of this modeling were presented to DEQ in a March 18, 2009, technical memorandum that is summarized here and described in detail in Appendix J.

The model results, summarized in Table 4-3 below, show that changes in groundwater gradient in the former effluent pond area due to shallow and intermediate depth extraction well pumping would cause maximum distances traveled over a 3-year period to range between approximately 5.2 to 10.4 feet using shallow extraction wells, and 0.5 to 1.0 feet for intermediate depth extraction wells. The data in Table 4-3 refer to the behavior of DNAPL pools, not residual DNAPL.

From this analysis, enhanced groundwater movement in the former effluent pond area due to shoreline extraction wells is minimal and would not substantially change DNAPL distribution over time. These calculations are conservative approximations of the potential distances that DNAPL could travel and the true estimate would be less if the capillary term were factored into the calculation.

The evaluation also showed that mobilization of residual DNAPL (as opposed to pools) is not expected to occur at Gasco in the former effluent pond area because groundwater gradients that result from pumping, and the material properties of the aquifer matrix and of the DNAPL, produce a capillary number that is well below the critical value.

4.2.1.5 DNAPL Removal Pilot Plan

A *DNAPL Removal Pilot Plan* (Anchor 2008c) was submitted to DEQ in October 2008. The first objective of the plan was to conduct a field test using pilot DNAPL extraction wells to determine how pumping of shoreline source control wells would affect DNAPL migration in the former effluent pond area. This test was designed to respond to DEQ's concern about DNAPL migration under the influence of the shoreline extraction wells. The second objective of the test was to provide information to aid in future design of a DNAPL extraction system. DEQ issued a January 22, 2009 comment letter stating that it was unlikely that the first objective of the test would be met, but recommended that NW Natural proceed with the test to achieve the secondary objective. Because DEQ did not support conducting the test for its first objective, NW Natural informed DEQ in a February 10, 2009 letter of its intent to postpone implementation of DNAPL pilot testing until it can be done in the context of the upland Feasibility Study process.

Since submittal of the DNAPL Removal Pilot Plan, NW Natural conducted the evaluation of potential DNAPL mobilization that was described in Section 4.2.1.4. The predicted migration distances shown on Table 4-3 indicate that the migration of DNAPL is expected to be insignificant under the influence of the shoreline extraction wells. As described in Section 4.1, the findings of that analysis further support NW Natural's plan to evaluate DNAPL removal as part of the upland RI/FS process, not as part of shoreline source control activities.

4.2.1.6 Segment 2 Extraction Well Pilot Test Plan

On September 23, 2009 the *Segment 2 Capture Zone Field Test Plan* (Anchor QEA 2009d) was submitted to U.S. Environmental Protection Agency (EPA) for review. The plan includes the installation of three shoreline extraction wells, upland monitoring wells, and offshore piezometers in Segment 2. The extraction wells, monitoring wells, and piezometers will be equipped with electric water level transducers. The three extraction wells will be pumped at varying rates with concurrent measurement of gradient changes in the wells. The purpose of the test is to assess how operation of the extraction wells affects offshore seepage of groundwater in the river to support the development and evaluation of sediment remedial alternatives (e.g., sediment capping). The findings of the evaluation will be used for design of the in-river sediment cleanup to be conducted under the authority of EPA. Incidentally, the test findings can be used to further evaluate the model-predicted pumping rate needed for shoreline source control, but this further evaluation is not the reason for the test. To the extent that these

data are available in time for Final Design, these will be considered and incorporated into that design, but are not essential to complete the Final Design.

Some preliminary comments have been received from EPA and DEQ and the plan is being modified accordingly. A 1-month extension on the October 31, 2009, closure of the in-water fish window has been received from the Oregon Department of Fish and Wildlife (ODFW), so the offshore piezometers must be installed by the end of November 2009. Section 7 of the *Capture Zone Field Test Plan* shows that well installation, field testing, and reporting should be completed approximately 15 weeks from receiving agency approval on the plan.

4.2.2 Extraction System Design

4.2.2.1 Extraction Wells

4.2.2.1.1 Well Location and Screen Depth

The shoreline extraction wells are planned to be in the ten locations shown on Figures 2-1, 3-1 and 4-2. The well locations are numbered sequentially from south to north, starting with well location PW-1 on Siltronic property, to well location PW-10 near the north end of Segment 2. These well locations and spacing are based upon the findings of the pilot extraction well test described in Section 4.2.1.2 and the MODFLOW model work described in Section 4.2.1.3. From these ten locations, which are spaced roughly 200 feet apart along the shoreline; the extraction well system will prevent groundwater from migrating to the river, as represented on Figure 4-2. The well locations may be modified slightly from those shown on the maps in this report, due to equipment access or underground utility considerations. The well locations are spaced a suitable distance from the shoreline to accommodate the potential future installation of a vertical barrier.

At each well location the anticipated screen length will be about 20 feet. If only one extraction well is installed at that location, it will have a screen length of 20 feet. If it is necessary to install two well screens at a location due to the presence of silt/clay beds in the planned screen zone, each of the paired wells will have ten ft long screens, for a total of 20 feet. The twenty ft total screen length was selected for each location based on the need to have low entrance velocity of groundwater into the well screen. Maintaining a low entrance velocity is considered beneficial for minimizing the rate of formation of mineral deposits and bacterial slimes that will accumulate in the well screen and alluvial sands/silts outside the well screens.

The planned extraction well screen elevations are shown on the subsurface profiles in Figures 2-3a, b, and c and are listed on Table 4-4. With respect to selecting the screen elevations, two primary factors were considered: the geology of the Alluvium WBZ and groundwater quality. Figure 2-10 shows representative groundwater quality data for the entire shoreline. Figures 2-3a, b, and c show the geology of the Alluvium WBZ and the planned well screen elevations.

As described in Section 2, the Alluvium is divided into two units: an upper fine sand with a hydraulic conductivity of about 10 feet/day and a lower medium sand unit with a hydraulic conductivity of about 200 feet/day. These two units are shown on Figures 2-3a, b, and c. Where the Alluvium is thickest, it is preferred to screen the wells in the upper fine sand. If the wells were to be screened in the lower medium sand, most of the flow would come from it rather than from the upper fine sand. Wells PW-1 through PW-7 are therefore planned to be screened in the upper fine sand unit.

The exceptions are wells PW-8 through 10. Those three wells are planned to be screened in the lower medium sand unit. This is because the upper fine sand is much thinner on the north end of the shoreline. At those three locations the upper fine sand zone is much thinner, consistent with the reduced total thickness of the Alluvium WBZ. If those three wells were to be screened in the upper fine sand zone, there would not be enough available drawdown to operate the wells. Due to the overall reduced thickness of Alluvium along the north shoreline, screening the wells in the medium sand unit should provide capture for the entire Alluvium. The second reason for screening the upper fine sand, where feasible, is that most of the mass of contamination is in this portion of the Alluvium.

The potential future construction of the vertical barrier was also considered in the design of the well screen elevations. For extraction wells PW-3 through 6 located on the upland side of the vertical barrier, the MODFLOW model results and the subsurface gradient profiles shown in Appendix I indicate that the wells should be screened near the bottom of the vertical barrier. Section 3 describes how two barrier bottom elevations, -40 feet and -60 feet have been evaluated. Figure 2-3b shows the extraction well screen elevations relative to potential bottom barrier elevations. The screen elevations shown for wells PW-4, 5, and 6 are designed to be installed within the bottom section of the upper fine sand unit, which coincides with potential bottom elevations of a future vertical barrier.

Prior to finalizing the well screen elevation at all locations, the geologic logs for each boring will be examined for the presence of silt beds in the currently planned screen zones. Section 4.2.2.1.2 provides more detail on this process. As shown on Figure 2-3b, the available geologic data indicate that silt beds may be present, especially at PW-4 and 6. If a significant percentage of the planned screen zone is in silt, the entire screen may be moved up or down, or two ten ft long screens may be placed above and below the silt beds.

During construction, the drilling contractor will have the screens available in 10-foot-long sections, with threaded connections. Having 10-foot-long screens available in the field will allow the screens to be placed above or below significant silt beds. If there are no significant silt beds in the planned screen zone, the 10-foot screen sections can be threaded to create a single 20-foot-long screen.

Containment of groundwater in the Fill WBZ is also a goal of source control. Table 4-4 and Figures 2-3a, b, and c show that there will be multiple monitoring wells along the shoreline being used to assess the effect of the extraction wells on water levels in the Fill WBZ. Monitoring of these wells will show decline in groundwater levels in the Fill WBZ due to the increased downward hydraulic gradient caused by the extraction wells. It is likely that most of the upland area of the Site will be paved as part of upland cleanup and stormwater management actions. The paving should stop most of the infiltration recharge to the Fill WBZ, causing further decline in Fill WBZ groundwater levels. The current plan is to monitor the effect of the Alluvium WBZ extraction wells and the effect of future paving to evaluate the need for additional measures to control groundwater in the Fill WBZ. If sufficient decline in Fill WBZ groundwater levels is not observed, contingency measures for this WBZ would be implemented at that time.

4.2.2.1.2 Well Materials, Construction, Development

The components of the extraction wells are shown on Figure 4-3. The primary components are listed below.

- 8-inch diameter steel casing
- 8-inch diameter Johnson wire-wrapped stainless screen
- 20 feet total screen length at each location (this may be two 10-foot screens, depending upon geology)
- Screen slot size of 0.035 inch

- Gradation 10/20 annular backfill sand
- 2-foot-long stainless steel casing sump below the screen

The annular backfill sand grain size was designed based on grain size analyses done on the "GS" borings completed in 2006. The annular backfill sand recommended herein was used in the construction of extraction well PW-3 (formerly PW-4) and was determined to be appropriate based on the results of well screen development and the pump tests.

The wells are planned to be drilled using sonic drilling technology. This technology is selected because cable drilling methods are very slow, air rotary drilling can result in personnel health and safety issues due to contaminated return air, and mud rotary drilling methods generate larger volumes of contaminated drilling wastes that require off-site disposal.

The sonic drill will obtain a continuous soil core which will be examined in the field by the Anchor QEA geologist to create a complete geologic log. This log will be used to determine the extraction well screen depths. Table 4-4 lists the currently planned extraction well screen intervals.

As shown on Figure 4-3, the annulus above each screen will be sealed with bentonite grout per Oregon Water Well construction requirements. For wells PW- 4, 5, and 6, the bentonite grout will be mixed with organoclay due to the potential presence of DNAPL. The planned ratio of bentonite to organoclay is 90/10 by volume. A variance from Oregon Water Resources well construction rules will be obtained prior to initiating field work. Such a variance has previously been obtained at the Site for other borings drilled in DNAPL zones.

Appendix E describes how solid waste materials derived from well drilling, well construction, and screen development activities will be characterized and disposed. Contaminated water from drilling and development activities will be treated in the on-site carbon treatment system and discharged to the City of Portland publicly owned treatment works (POTW) under the facility Industrial Wastewater Discharge Permit.

Appendix E also describes the procedures for construction and screen development for the extraction wells, monitoring wells, and observation wells.

4.2.2.2 Conveyance and Control System

A process and instrumentation diagram of the extraction well conveyance and control system is shown on Figure 4-5. The extraction wells at all ten locations will be equipped with 5 horsepower centrifugal pumps. The centrifugal pumps will be powered by motors controlled by variable frequency drives that are directed from a panel equipped with a programmable logic control (PLC) system. The PLC system will be equipped with HMI data acquisition, programmable for alarm condition notification and capable of future expandability, if needed.

Being powered by variable frequency drive allows the pump discharge to be continuously adjusted as controlled by the PLC system. Figure 4-5 shows that water level transducers will be installed to monitor the groundwater elevation in selected wells. A water level transducer has already been installed on the FAMM dock to monitor the Willamette River elevation.

Due to river tide-induced water elevation fluctuations, it is anticipated that the well discharge rates will adjust frequently to maintain capture. Section 4.2.2.4.2 describes how water elevation data from the control wells will be used to change the extraction well discharge rates to maintain capture.

A water level transducer will be installed in each of the extraction wells. Transducers will also be installed in the new monitoring wells shown on Figures 2-2a, b, and c and 2-3a, b, and c and listed on Table 4-4. Table 4-4 indicates which of the wells will be equipped with transducers. As shown on Table 4-4, a subset of the transducers will be used to monitor groundwater elevations for the purpose of controlling the extraction well discharge rate. On Table 4-4 those wells are termed control wells.

Figure 4-5 also shows that extraction wells PW-3 through PW-6 will also be equipped with DNAPL recovery pumps. Based on existing information on DNAPL occurrence, it is possible that DNAPL will enter these wells and accumulate in the bottom sump below the screen. If DNAPL accumulates in the well sumps, the current design is to use a Blackhawk air actuated piston pump for DNAPL recovery.

The DNAPL will be pumped to holding tanks and removed for off-site recycling as is currently done for DNAPL recovered from Site monitoring wells MW-6-32 and MW-13-31.

4.2.2.3 Anti-Fouling Design and Maintenance

Under the direction of Anchor QEA, Water Systems Engineering, Inc. conducted laboratory testing of representative groundwater samples from wells MW-1-55, PW-4-85, and PW-4-118. The purpose of the testing was to determine how susceptible the wells would be to the formation of minerals and bacterial slime that would reduce the permeability of the well screens, annular backfill and aquifer formation sands. The Water Systems Engineering, Inc., study found that the aquifer chemistry suggests a moderate to high potential for fouling from the formation of mineral deposits and bacterial growth.

Until recently it was planned to use chemical treatment as recommended by Water Systems Engineering to maintain the well screens, annular and formation sands in permeable condition. However, there has been concern that the use of traditional chlorine-based, acid and caustic chemicals for this purpose at the Gasco Site could cause the formation of cyanide gas, creating a difficult worker health and safety issue to mitigate. Therefore a different method for maintaining well performance is planned to be tested at the Site.

This method is available under the trade name of Aqua Gard. The Aqua Gard method was developed by Subsurface Technologies, Inc. Information on the Aqua Gard technology is in Appendix K.

The Aqua Gard system uses a perforated injection pipe that is permanently installed in the well to inject liquid carbon dioxide into the well screen, surrounding annulus and aquifer formation materials. Since the Aqua Gard injection system is permanently installed on the well head, the well pump does not have to be removed to perform the Aqua Gard treatment. Prior to injection of the liquid carbon dioxide, the extraction well pump is turned off. The physical agitation that occurs during vaporization of the liquid carbon dioxide dislodges accumulated mineral deposits and bacterial slimes. Carbonic acid also forms during this process which dissolves some of the material. Following injection of the liquid carbon dioxide, a suitable period of time is allowed to elapse to be sure that all of the liquid carbon dioxide has vaporized, generally several hours. Then the pump in the treated well is restarted. Within a short period following restart of the well pump, the affected groundwater, dislodged minerals, and organic materials will be pumped to the facility groundwater treatment system.

The current plan is to install an Aqua Gard unit on one of the planned extraction wells to be constructed this summer as part of the Segment 2 Capture Zone test. That test is referenced in

Section 4.2.1.6. If the unit performs as expected on that well, then the Aqua Gard system would be used for all system extraction wells.

Based on the experience of Subsurface Technologies, Inc., at other sites, it is estimated that semi-annual treatment will maintain the well screens and formation sands in good condition. The frequency of maintenance required to attain efficient operation of the well system will not be certain until one or two years of well operation have been experienced.

To determine if semi-annual treatment is sufficient, the performance of the well system will be reviewed monthly during the first year of operation by preparing a specific capacity graph for each well that is updated monthly. Well specific capacity is the ratio of drawdown to discharge. If regular monitoring of specific capacity indicates that well performance is declining, that could mean that more frequent Aqua Gard treatment is needed.

Another more direct way to assess the need for treatment is to use a downhole camera to visually inspect the well screen and casing for the presence of mineral deposits and bacterial slime. A downhole camera may be used for this purpose, but only if semi-annual Aquaguard treatment does not seem to maintain well performance. It would be necessary to remove the well pump and transducer assemblies from the well casing to allow the use of a downhole camera, so this assessment method will not be used unless necessary.

4.2.2.4 Performance Monitoring

4.2.2.4.1 Monitoring Well Network

Monitoring of the performance of the extraction well system requires the installation of additional monitoring wells and piezometers. The proposed monitoring wells and piezometers are listed on Table 2-1 and shown on the Figure 2-2a, b, and c maps and Figure 2-3a, b, and c subsurface profiles. The rationale for the location and screen depth for these monitoring points are described in Section 4.2.2.4.2. Table 4-4 shows the proposed performance well monitoring network, consisting of existing and proposed wells to be used for assessing extraction system performance as described in the following sections.

4.2.2.4.2 Capture Assessment

This plan for measuring the capture performance of the source control system is designed to meet or exceed EPA guidance in *A Systematic Approach for Evaluation of Capture Zones at Pump*

and Treat Systems (EPA 2008). The extraction well system will be operated to maintain an average hydraulic condition of gradient reversal such that upland groundwater is not discharging to the river. As explained herein, the average gradient reversal will be maintained by controlling the extraction well discharge rate based on transducer monitoring of groundwater elevations at designated control wells. Site specific groundwater discharge and groundwater elevation data will also be used in the DEQ-approved site MODFLOW and PATH3D models to produce particle track maps for assessing capture.

Table 4-4 lists the existing shoreline and proposed shoreline monitoring wells, extraction wells, and piezometers. The network of existing shoreline monitoring wells was carefully evaluated to see which wells have suitable location and screen elevation to be useful to assess the capture performance of the extraction well system. As shown on Table 4-4, eleven of the existing monitoring wells were suitable for this purpose. Because the current shoreline monitoring well network was designed only to characterize the nature and extent of contamination, many of the existing well locations are not suitable for capture evaluation. Therefore Table 4-4 lists the new monitoring wells, observation wells, and piezometers that are needed to provide the necessary water level data to fully evaluate capture performance of the entire source control system.

Table 4-4 shows the wells that will be equipped with water level transducers. All of the water level transducers also measure water temperature. The transducers to be installed in the extraction wells will also measure groundwater conductance. By measuring temperature and conductance trends in the observation wells it is hoped that the influence of river water inflow to the wells can be detected.

Section 4.2.2.2 describes how groundwater elevation data from the monitoring wells is measured by the PLC system and will be used to control the extraction well discharge rate. Each of the extraction wells will be surrounded on two sides by monitoring wells containing water level transducers. The monitoring well locations are roughly equidistant between extraction wells. In some cases existing monitoring wells will be used, but in many cases new monitoring wells must be installed for this purpose. For example, extraction well PW-4 is flanked by monitoring wells OW-4, MW-27, and MW-28, as shown on Figure 2-3b and on Table 4-4. Table 4-4 shows that transducers will be installed in OW-4, MW-27-96 (proposed), MW-27-181 (proposed), MW-28-92 (proposed), and MW-28-177 (proposed). Of those five transducers, three will be control transducers, and two will be monitoring transducers. The control transducers are in the wells that are screened in approximately the same elevation of the aquifer

as the extraction well. The monitoring transducers are in wells that are screened in a deeper zone of the aquifer.

The PLC system will monitor the average elevation of groundwater in each of the control transducers compared to the average elevation of water in the Willamette River. The goal is to maintain the average groundwater elevation below the average river elevation to maintain the condition of gradient reversal. The groundwater elevation will naturally change constantly in response to river-induced tidal effects. This constant change requires the transducer controlled system to adjust the well pump discharge rate to maintain the condition of gradient reversal. Although the monitoring transducers are not used to control the well pumping rate, they are used to make sure that the gradient reversal that is measured in the control wells also occurs in the deeper portion of the aquifer. After initial startup of the system, a period of monitoring will be required to ensure that the correct wells are being used as control wells. In some cases it may be necessary to change control wells if they better reflect the gradient reversal at that location.

Review of Table 4-4 and Figure 2-3b shows that each extraction well will be flanked by a similar network of control and monitoring wells with transducers. The PLC system will monitor and control the discharge rate of each extraction well based on the three control transducers for that well. The frequency of water level measurement for the transducers will initially be set at 15-minute intervals and the PLC system will be set to maintain an average condition of gradient reversal based on a running one hour average basis. That initial setting will be pilot tested to see how well the extraction wells respond to water level changes. The frequency of water level measurement and the averaging method used by the PLC system may be modified as needed depending upon the lag time between well discharge changes and water level changes in the control wells.

Table 4-4 also lists a number of piezometers that are planned to be installed in the river. Some will be installed along the shoreline and some attached to the FAMM dock, as shown on the maps on Figures 2-2a and 2-2b. The piezometers will be installed at multiple depths below the river mudline. The subsurface profiles on Figures 2-4 and 2-5 show the depths and locations of several of the river piezometers. Many of these piezometers will be equipped with water level transducers. As described in Section 4.2.1.6 the groundwater elevation data from these river piezometers will be used to assess the effect on offshore seepage that is achieved by the

shoreline extraction wells. This information will be used for design of the in-water river sediment cleanup plan.

4.2.2.4.3 Water Quality Trend Monitoring

Groundwater quality trends will be monitored at selected wells during operation of the source control system. Because both upland and nearshore groundwater is contaminated with the same COIs at similar concentrations, there is no chemical plume boundary or water quality compliance boundary to assess. The groundwater quality data will not be used for assessing whether the source control actions are successful at achieving shoreline containment. Therefore, the water quality monitoring plan is not intended to be used to judge the success of the source control action, but rather to measure water quality changes that occur during operation of the extraction well system. A subset of the existing and proposed new wells is proposed for water quality trend monitoring. The groundwater quality data will be provided to Siltronic for their evaluation of potential hydraulic impacts to the enhanced in situ bioremediation source control measure.

Table 4-4 lists the existing and proposed shoreline monitoring wells. The table shows that the existing shoreline monitoring wells are sampled semi-annually in the current upland monitoring program. With the addition of the new wells shown in Table 4-4, it is planned that the sampling frequency for the existing wells on Table 4-4 be reduced to annual for the next 5 years. This reduction is justified because the new proposed wells provide additional spatial coverage of the shoreline zone, which makes semi-annual monitoring of the currently existing wells unnecessary. After 5 years of source control operation, the monitoring program would be evaluated to determine if continued monitoring of the existing wells is needed.

The proposed new wells on Table 4-4 are divided into those with a recommended tiered monitoring frequency, and those with a recommended annual monitoring frequency. The extraction wells at all ten locations will be on the tiered monitoring plan. As explained in the footnote on Table 4-4, the extraction wells in the tiered plan will be sampled monthly for the first year of source control operation, quarterly the second year, semi-annually in years three through five, then annually thereafter. The main purpose of the frequent monitoring in the first 5 years is to assess changes in effluent groundwater quality that could affect the operation of the treatment plant.

The proposed new monitoring wells, MW-22 through MW-29 will be sampled following well construction and development. Thereafter these wells will be sampled on an annual basis for the purpose of documenting trends in COI concentrations.

The proposed new Fill WBZ observation wells to be installed adjacent to the extraction wells will also be sampled following construction and development. The new Fill WBZ observation wells will be sampled annually as part of the continuing source control monitoring program.

The proposed new piezometers in the river will be sampled following construction and development. Thereafter selected piezometers will be sampled annually as shown on Table 4-4.

Groundwater samples obtained in the source control monitoring program will be tested using the following methods.

- EPA 8260 for VOCs
- EPA 8270 SIM for PAHs
- EPA 335.4 for total cyanide
- D-4282 for Free cyanide

4.2.2.4.4 Maintenance, Repair, and Reporting

The operation of the extraction well system will be instrumented for remote monitoring. Using a telemetry system the groundwater elevations in the control wells and the pumping rates in each extraction well will be remotely monitored. The system will have automatic alarms that will be triggered for abrupt water level changes in the control wells and extraction well pump shutdowns. When those alarm conditions occur, NW Natural will respond to make the necessary adjustments or repairs.

The final design report for the extraction well system will include a detailed plan describing the alarm conditions, response plan, operation, and maintenance of the extraction well and treatment system.

For the first 5 years of system operation quarterly reports will be prepared for submittal to DEQ. These reports will describe the system capture performance as measured using the methods described in Section 4.2.2.4.2. The reports will describe significant system operational events, including shutdowns for equipment repair, or maintenance. The reports will also

provide the groundwater quality data from the monitoring program, including updated trend graphs. After the first five years of quarterly reporting there will be an evaluation of reporting requirements and reporting frequency.

There will also be the reports required by DEQ for the discharge permit for treated groundwater. It is assumed that DEQ will specify the reporting requirements when the agency issues the permit.

4.3 Groundwater Treatment System Design

Sevenson's treatment system interim design report is in Appendix C. The interim design was prepared following the Treatment System pilot test, which was completed in September 2009. The *Wastewater Pilot Plant Testing Plan* (Pilot Plan; Sevenson 2009) was provided to DEQ on May 4, 2009. DEQ provided a preliminary comment letter on May 13 and Sevenson prepared a May 15 response letter addressing DEQ's comments. A revised pilot plan was provided to DEQ on June 29, 2009. A copy of the revised pilot plan is provided in Appendix L.

The wastewater treatment plant design and materials balance is in Attachment A within Appendix C. This mass balance is provided in Attachments A and B, for NW Natural and Siltronic, respectively. The treatment system process flow diagram is on Figure 4-6.

5 PERMITS

The source control project will require a stormwater permit, expanded consultation with the City of Portland on Greenway requirements, and access to Siltronic property. Some of the permits and authorizations have already been received; all of the regulatory requirements are described below. Permit information also summarized in Table 5-1.

The City of Portland Bureau of Development issued a Greenway Letter of Determination on June 22, 2009, related to the installation of wells and placement of access road material in the greenway setback; the determination will not expire. The City concluded that Greenway Review was exempted within the code for cleanup related activities, so a modified Greenway Review was (and will be) used for this project to address any activities within the greenway setback (i.e., wells installed in the greenway and roads installed to access those well locations) to ensure that the activities are in substantive compliance. This Letter of Determination does not cover installation of a vertical barrier wall or any work on Siltronic property. While these activities would still be considered exempt, a separate consultation and modified Greenway review will be required for activities above ordinary high water that fall under the authority of DEQ.

A National Pollutant Discharge Elimination System (NPDES) 1200-C permit will also be required for potential uplands construction-related stormwater impacts of this project. This stormwater construction permit is required for projects that disturb more than 1 acre of land on site due to any combination of clearing, grading, excavation, or stockpiling of fill material. Such disturbance of land will likely occur even in the event that the barrier wall is not installed as a near term source control measure as recommended in this design. The City of Portland issues the NPDES stormwater permits on behalf of DEQ.

Other required construction permits, if any, will be identified and described in the Final Design Report.

6 CONSTRUCTION SCHEDULE AND SEQUENCING

Figure 6-1 depicts the current working schedule for the groundwater source control design and implementation. This is termed a "working schedule" because findings of design level studies, DEQ review cycles, and DEQ decisions could impact the schedule in terms of alleviating the need for certain tasks, highlighting the need for additional design tasks, and/or causing duration changes to particular tasks. With the understanding that ongoing work could impact even major milestones within the schedule, key estimated target dates for design and construction are described below. This schedule assumes that a vertical barrier wall will be further evaluated in the Upland FS in the context of other potential upland remedial actions and will not be part this interim Source Control Design. For this reason, a reasonable anticipated timing and duration of the Upland FS is also shown on Figure 6.1 to illustrate that the time lag for any future wall determinations would be very brief. If the Upland FS concludes that a barrier wall is an appropriate part of an overall site remedy, constructing such a wall early or first in the sequence of upland remedial activities will be fully considered and would be the preferred approach, if feasible. The key dates for the Source Control Design are:

- Completion of Interim Design – November 6, 2009
- DEQ select final alternative (i.e., key design features) – January 5, 2010
- Completion of Revised Interim Design Report based on DEQ comments – March 1, 2010
- Order critical construction materials – April 26, 2010 (depending upon DEQ approval and that public comment will not impact design)
- DEQ staff report and submittal of Final Design – April 26, 2010
- DEQ issues discharge permit – April 26, 2010
- Mobilize for construction – April 5, 2010
- Complete construction – September 27, 2010

These estimated dates also illustrate key sequencing that must take place to proceed with construction including:

- DEQ must select final alternative in sufficient detail to allow ordering of critical construction materials.
- The DEQ staff report and decision document must be completed (and coordinated to be consistent with simultaneous preparation of the Final Design) so that construction mobilization can take place.
- The DEQ discharge permit must be issued (and coordinate to be consistent with the Pilot

Treatment System Testing results and simultaneous preparation of the Final Design) so that construction mobilization of the treatment system can take place.

7 REFERENCES

Aronson, D. and P.H. Howard. 1997. Anaerobic Biodegradation of Organic Chemicals in Groundwater: A Summary of Field and Laboratory Studies. Environmental Science Center, Syracuse Research Corporation, North Syracuse, New York.

Aronson, D., M. Citra, K. Shuler, H. Printup, and P.H. Howard. 1999. Aerobic Biodegradation of Organic Chemicals in Environmental Media: A Summary of Field and Laboratory Studies. Environmental Science Center, Syracuse Research Corporation, North Syracuse, New York.

Anchor. 2004. Revised Baseline Level III Ecological and Human Health Risk Assessment Report NW Natural Gasco Site. Prepared for Northwest Natural. Prepared by Anchor Environmental, L.L.C. December.

Anchor. 2007a Phase 1 Report and Phase 2 Field Sampling Approach, GASCO Siltronic Groundwater Source Evaluation. Prepared for NW Natural. May 2007.

Anchor. 2007b. Gasco/Siltronic Groundwater and NAPL Source Control Focused Feasibility Study. Prepared for NW Natural. November 2007.

Anchor. 2008a. Offshore Investigation Report. NW Natural "Gasco" Site. Prepared for NW Natural. Prepared by Anchor Environmental L.L.C. February.

Anchor. 2008b. Preliminary Design Report, Groundwater Source Control. NW Natural Gasco Site. Prepared for NW Natural. Prepared by Anchor Environmental, L.L.C. June 2008

Anchor. 2008c. DNAPL Removal Pilot Program. NW Natural Gasco Site. Prepared for NW Natural. Prepared by Anchor Environmental L.L.C. October.

Anchor Environmental, LLC and S.S. Papadopulos, Inc (SSPI). 2008. Groundwater Flow Model and DNAPL Evaluation Supplemental Report, NW Natural, Gasco Site, prepared for NW Natural, October, 2008.

Anchor et al. 2008. Work Plan – Gasco Siltronic Construction Vibration Study. Appendix A to Preliminary Design Report. Prepared for NW Natural. Prepared by Anchor Environmental, L.L.C., Colin Gordon and Associates, Stephen Dickenson, PhD, and Sevenson Environmental Services, Inc. June 2008.

Anchor QEA. 2009a. Source Control Evaluation Report. "Segment 3" Siltronic Property Related to NW Natural "Gasco" Site. Prepared for NW Natural. Prepared by Anchor QEA, LLC. February.

Anchor QEA. 2009b. Evaluation of Potential DNAPL Mobilization in Former Effluent Pond Area by Shoreline Source Control Extraction Wells Memorandum to Bob Wyatt, NW Natural From David Keith, Mike Riley, and John Edwards, Anchor QEA. March 18, 2009.

Anchor QEA. 2009c. Vibration Study Data Report. Gasco Siltronic Construction. Prepared for NW Natural. May 2009.

Anchor QEA. 2009d. *Capture Zone Field Test Plan.* Gasco. Portland, Oregon. Prepared for NW Natural for submittal to Oregon DEQ. September.

Anchor QEA and S.S. Papadopulos, Inc (SSPI). 2009. Groundwater Flow Model DNAPL Evaluation Supplemental Figures, NW Natural, Gasco Site, prepared for NW Natural. March. 2009.

Cohen, R.M., and J.W. Mercer. 1993. DNAPL Site Evaluation. EPA/600/R-93/022, United States Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma [also published as DNAPL Site Evaluation, C.K. Smoley].

DEQ. 2008. Groundwater/DNAPL Focused Feasibility Study Shoreline Segments 1 and 2, NW Natural Property and Northern Portion of the Siltronic Corporation Property. Letter from DEQ to NW Natural March 21, 2008.

DEQ 2009. Interim Design Report, Shoreline Segments 1 and 2, NW Natural Property and the Northern Portion of the Siltronic Corporation Property, Portland, Oregon, ESCI No.94. Letter from DEQ to NW Natural September 24, 2009.

EPA. 2008. A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems. National Risk Management Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Ada, Oklahoma. January 2008.

Gerhard, J.I., T Pang, and B.H. Kueper. 2007. Time Scales of DNAPL Migration in Sandy Aquifers Examined via Numerical Simulation. Ground Water, Vol. 45, No. 2, pp. 147 – 157.

Glynn. 2008. NW Natural – Gasco Site Compatibility / Permeability Study, GGE 05-1043. November 2008.

HAI. 2007. Remedial Investigation Report, NW Natural "Gasco" Facility. Portland, Oregon. April 30, 2007.

HAI. 2008. Investigation-Derived Waste Management, Remedial Investigation-Historical Manufactured Gas Plant Activities, Siltronic Corporation Property, 7200 NW Front Avenue, Portland, Oregon. February 2008.

MFA. 2007. Enhanced In-Situ Bioremediation Pilot Study Report, Siltronic Corporation. Prepared for Siltronic Corporation. Prepared by Maul Foster & Alongi, Inc. August 2007.

Palermo, M.R., J.E. Clausner, M.P. Rollings, G.L. Williams, T.E. Meyers, T.J. Fredette, and R.E. Randall. 1998. Dredging Operations and Environmental Research Program Guidance for Subaqueous Dredged Material Capping. U.S. Army Corps of Engineers, Waterways Experiment Station. Technical Report DOER-1. June 1998. Vicksburg, Mississippi.

Reible, D. and D. Lampert. 2009. Modeling for the Design of Active Layers for Contaminated Seidment Caps (v.3.12). http://www.caee.utexas.edu/reiblegroup/ University Station C 1786, University of Texas, Austin, TX 78712

Sevenson. 2009. Revised Wastewater Pilot Plant Testing Plan (Second Revision in Response to DEQ June 23, 2009 Comments). NW Natural. June.

TABLES

Table 2-1
Existing and Proposed Shoreline Area Monitoring Wells, Extraction Wells, and Piezometers
Gasco Siltronic
Portland, Oregon

Well Number	Water-Bearing Zone	Date Installed	Installation Method	Monument Type	Screen Type	Slot Size (inches)	Sand Pack (Colorado)	Well Diam. (inches)	Ground Surface (feet msl)	Top of Casing (feet msl)	Top of Casing (feet bgs)	Boring Depth (feet bgs)	Boring Depth (feet msl)	Top Screen (feet bgs)	Top Screen (feet msl)	Base Screen (feet bgs)	Base Screen (feet msl)
Existing Monitoring Wells																	
MW-1-22	Surficial Fill	24-Oct-95	Hollow-Stem Auger	Above-grade	Slotted PVC	0.020	10-20	2	32.00	34.75	(2.8)	22.0	10.0	11.0	21.0	21.0	11.0
MW-1-55	Alluvial	10-Jul-07	Sonic	Above-grade	Continuous wrap stainless steel	0.020	10-20	2	33.10	35.75	(2.7)	57.0	-23.9	45.0	-11.9	55.0	-21.9
MW-1-82	Alluvial	9-Jul-07	Sonic	Above-grade	Continuous wrap stainless steel	0.020	10-20	2	33.50	36.08	(2.6)	85.4	-51.9	72.0	-38.5	82.0	-48.5
MW-2-32	Surficial Fill	6-Nov-95	Hollow-Stem Auger	Flush	Slotted PVC	0.020	10-20	2	35.80	34.46	1.3	32.5	3.3	21.5	14.3	31.5	4.3
MW-2-61	Alluvial	8-Oct-98	Hollow-Stem Auger	Flush	Slotted PVC	0.020	10-20	2	34.70	34.41	0.3	61.5	-26.8	50.0	-15.3	60.0	-25.3
MW-2-104	Alluvial	25-Jun-07	Sonic	Flush	Continuous wrap stainless steel	0.020	10-20	2	34.90	34.92	(0.0)	116.5	-81.6	94.0	-59.1	104.0	-69.1
MW-3-26	Surficial Fill	1-Nov-95	Hollow-Stem Auger	Above-grade	Continuous wrap stainless steel	0.020	10-20	2	31.20	34.11	(2.9)	26.0	5.2	15.0	16.2	25.0	6.2
MW-3-56	Alluvial	1-Nov-95	Hollow-Stem Auger	Above-grade	Continuous wrap stainless steel	0.020	10-20	2	31.20	34.07	(2.9)	56.0	-24.8	45.0	-13.8	55.0	-23.8
MW-4-35	Surficial Fill	31-Oct-95	Hollow-Stem Auger	Above-grade	Continuous wrap stainless steel	0.020	10-20	2	31.70	34.54	(2.8)	35.0	-3.3	24.0	7.7	34.0	-2.3
MW-4-57	Alluvial	30-Oct-95	Hollow-Stem Auger	Above-grade	Continuous wrap stainless steel	0.020	10-20	2	31.70	34.53	(2.8)	57.0	-25.3	46.0	-14.3	56.0	-24.3
MW-4-101	Alluvial	16-Oct-98	Dual Wall Reverse Air	Above-grade	Slotted PVC (pre-pack)	0.010	20-40	2	31.80	34.36	(2.6)	120.0	-88.2	89.5	-57.7	99.5	-67.7
MW-5-32	Surficial Fill/Alluvial	27-Oct-95	Hollow-Stem Auger	Above-grade	Slotted PVC	0.020		2	25.10	27.83	(2.7)	32.0	-6.9	21.0	4.1	31.0	-5.9
MW-5-100	Alluvial	23-Oct-98	Dual Wall Reverse Air	Above-grade	Continuous wrap stainless steel	0.020	10-20	2	25.40	27.31	(1.9)	100.0	-74.6	88.0	-62.6	98.0	-72.6
MW-5-175	Alluvial	22-Oct-98	Dual Wall Reverse Air	Above-grade	Slotted PVC (pre-pack)	0.010	20-40	2	25.20	27.19	(2.0)	175.0	-149.8	163.0	-137.8	173.0	-147.8
MW-16-45	Alluvial	20-Jul-04	Sonic	Above-grade	Slotted stainless steel	0.010	10-20	2	30.81	33.12	(2.3)	49.0	-18.2	30.0	0.8	45.0	-14.2
MW-16-65	Alluvial	19-Jul-04	Sonic	Above-grade	Slotted stainless steel	0.010	10-20	2	30.60	33.11	(2.5)	68.0	-37.4	55.0	-24.4	65.0	-34.4
MW-16-125	Alluvial	15-Jul-04	Sonic	Above-grade	Slotted stainless steel	0.010	10-20	2	30.49	32.89	(2.4)	130.0	-99.5	115.0	-84.5	125.0	-94.5
MW-17-79	Alluvial	26-Jul-05	Sonic	Above-grade	Continuous wrap stainless steel	0.010	10-20	2	32.56	34.83	(2.3)	82.0	-49.4	38.5	-5.9	78.5	-45.9
MW-18-30	Surficial Fill	27-Feb-07	Sonic	Above-grade	Continuous wrap stainless steel	0.020	10-20	2	31.66	34.28	(2.6)	30.0	1.7	19.0	12.7	29.0	2.7
MW-18-180	Alluvial	26-Feb-07	Sonic	Above-grade	Continuous wrap stainless steel	0.020	10-20	2	31.70	33.92	(2.2)	230.0	-198.3	170.0	-138.3	180.0	-148.3
MW-19-22	Surficial Fill	6-Mar-07	Sonic	Above-grade	Continuous wrap stainless steel	0.020	10-20	2	27.40	29.82	(2.4)	23.0	4.4	12.0	15.4	22.0	5.4
MW-19-125	Alluvial	12-Mar-07	Sonic	Above-grade	Continuous wrap stainless steel	0.020	10-20	2	27.20	29.42	(2.2)	126.0	-98.8	115.0	-87.8	125.0	-97.8
MW-19-180	Alluvial	2-Mar-07	Sonic	Above-grade	Continuous wrap stainless steel	0.020	10-20	2	27.28	29.81	(2.5)	227.0	-199.7	170.0	-142.7	180.0	-152.7
MW-20-120	Alluvial	8-Mar-07	Sonic	Above-grade	Continuous wrap stainless steel	0.020	10-20	2	25.63	27.84	(2.2)	213.0	-187.4	110.0	-84.4	120.0	-94.4
MW-21-12	Surficial Fill	6-Jul-07	Sonic	Above-grade	Continuous wrap stainless steel	0.020	10-20	2	20.50	23.47	(3.0)	14.0	6.5	7.0	13.5	12.0	8.5
MW-21-75	Alluvial	5-Jul-07	Sonic	Above-grade	Continuous wrap stainless steel	0.020	10-20	2	20.50	23.13	(2.6)	77.0	-56.5	65.0	-44.5	75.0	-54.5
MW-21-115	Alluvial	2-Jul-07	Sonic	Above-grade	Continuous wrap stainless steel	0.020	10-20	2	20.50	23.47	(3.0)	118.0	-97.5	105.0	-84.5	115.0	-94.5
MW-21-166	Alluvial	28-Jun-07	Sonic	Above-grade	Continuous wrap stainless steel	0.020	10-20	2	20.50	23.19	(2.7)	193.0	-172.5	156.0	-135.5	166.0	-145.5
Proposed Monitoring Wells																	
MW-22-74	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	2	34.00	37.00	(3.0)	75.0	-41.0	64.0	-30.0	74.0	-40.0
MW-23-63	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	2	34.00	37.00	(3.0)	75.0	-41.0	64.0	-30.0	74.0	-40.0
MW-23-115	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	2	34.00	37.00	(3.0)	125.0	-91.0	115.0	-81.0	125.0	-91.0
MW-24-80	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	2	30.00	33.00	(3.0)	81.0	-51.0	70.0	-40.0	80.0	-50.0
MW-24-130	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	2	30.00	33.00	(3.0)	131.0	-101.0	120.0	-90.0	130.0	-100.0
MW-25-71	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	2	31.00	34.00	(3.0)	72.0	-41.0	61.0	-30.0	71.0	-40.0
MW-26-97	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	2	32.00	35.00	(3.0)	98.0	-66.0	87.0	-55.0	97.0	-65.0
MW-26-130	Deep Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	2	32.00	35.00	(3.0)	133.0	-101.0	122.0	-90.0	132.0	-100.0
MW-27-96	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	2	31.00	34.00	(3.0)	97.0	-66.0	86.0	-55.0	96.0	-65.0
MW-27-131	Deep Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	2	31.00	34.00	(3.0)	132.0	-101.0	121.0	-90.0	131.0	-100.0
MW-28-92	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	2	27.00	30.00	(3.0)	93.0	-66.0	82.0	-55.0	92.0	-65.0
MW-28-127	Deep Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	2	27.00	30.00	(3.0)	128.0	-101.0	117.0	-90.0	127.0	-100.0
MW-29-90	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	2	24.00	27.00	(3.0)	111.0	-87.0	100.0	-76.0	110.0	-86.0
MW-29-124	Deep Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	2	24.00	27.00	(3.0)	125.0	-101.0	114.0	-90.0	124.0	-100.0

Table 2-1
Existing and Proposed Shoreline Area Monitoring Wells, Extraction Wells, and Piezometers
Gasco Siltronic
Portland, Oregon

Well Number	Water-Bearing Zone	Date Installed	Installation Method	Monument Type	Screen Type	Slot Size (inches)	Sand Pack (Colorado)	Well Diam. (inches)	Ground Surface (feet msl)	Top of Casing (feet msl)	Top of Casing (feet bgs)	Boring Depth (feet bgs)	Boring Depth (feet msl)	Top Screen (feet bgs)	Top Screen (feet msl)	Base Screen (feet bgs)	Base Screen (feet msl)
Proposed Observation Wells																	
OW-1-35	Surficial Fill		Sonic	Above-grade	Continuous wrap stainless steel	0.035	10-20	2	35.00	38.00	(3.0)	37.0	-2.0	30.0	5.0	35.0	0.0
OW-2-32	Surficial Fill		Sonic	Above-grade	Continuous wrap stainless steel	0.035	10-20	2	34.00	37.00	(3.0)	34.0	0.0	27.0	7.0	32.0	2.0
OW-4-25	Surficial Fill		Sonic	Above-grade	Continuous wrap stainless steel	0.035	10-20	2	27.00	30.00	(3.0)	27.0	0.0	20.0	7.0	25.0	2.0
OW-5-30	Surficial Fill		Sonic	Above-grade	Continuous wrap stainless steel	0.035	10-20	2	32.00	35.00	(3.0)	32.0	0.0	25.0	7.0	30.0	2.0
OW-7-20	Surficial Fill		Sonic	Above-grade	Continuous wrap stainless steel	0.035	10-20	2	23.00	26.00	(3.0)	20.0	3.0	13.0	10.0	18.0	5.0
OW-8-20	Surficial Fill		Sonic	Above-grade	Continuous wrap stainless steel	0.035	10-20	2	23.00	26.00	(3.0)	20.0	3.0	13.0	10.0	18.0	5.0
OW-9-27	Surficial Fill		Sonic	Above-grade	Continuous wrap stainless steel	0.035	10-20	2	30.00	33.00	(3.0)	27.0	3.0	20.0	10.0	25.0	5.0
OW-10-20	Surficial Fill		Sonic	Above-grade	Continuous wrap stainless steel	0.035	10-20	2	32.00	35.00	(3.0)	22.0	10.0	15.0	17.0	20.0	12.0
Existing Extraction Wells																	
PW-01-80	Alluvial	9-Aug-05	Sonic	Flush	Continuous wrap stainless steel	0.020	10-20	6	32.00	31.80	0.2	82.0	-50.0	39.5	-7.5	79.5	-47.5
PW-3-85	Alluvial	20-Jun-07	Cable Tool	Above-grade	Continuous wrap stainless steel	0.035	10-20	8	25.00	26.80	(1.8)	95.0	-70.0	75.0	-50.0	85.0	-60.0
PW-3-118	Alluvial	13-Jun-07	Cable Tool	Above-grade	Continuous wrap stainless steel	0.035	10-20	8	25.50	27.00	(1.5)	128.0	-102.5	108.0	-82.5	118.0	-92.5
Proposed Extraction Wells																	
PW-1	Alluvial		Sonic	Above-grade	Continuous wrap stainless steel	0.035	10-20	8	35.00	38.00	(3.0)	82.0	-47.0	60.0	-25.0	80.0	-45.0
PW-2	Alluvial		Sonic	Above-grade	Continuous wrap stainless steel	0.035	10-20	8	34.00	37.00	(3.0)	81.0	-47.0	59.0	-25.0	79.0	-45.0
PW-4	Alluvial		Sonic	Above-grade	Continuous wrap stainless steel	0.035	10-20	8	27.00	30.00	(3.0)	99.0	-72.0	77.0	-50.0	97.0	-70.0
PW-5	Alluvial		Sonic	Above-grade	Continuous wrap stainless steel	0.035	10-20	8	32.00	35.00	(3.0)	79.0	-47.0	57.0	-25.0	77.0	-45.0
PW-6	Alluvial		Sonic	Above-grade	Continuous wrap stainless steel	0.035	10-20	8	31.00	34.00	(3.0)	103.0	-72.0	81.0	-50.0	101.0	-70.0
PW-7	Alluvial		Sonic	Above-grade	Continuous wrap stainless steel	0.035	10-20	8	23.00	26.00	(3.0)	70.0	-47.0	48.0	-25.0	68.0	-45.0
PW-8	Alluvial		Sonic	Above-grade	Continuous wrap stainless steel	0.035	10-20	8	23.00	26.00	(3.0)	70.0	-47.0	48.0	-25.0	68.0	-45.0
PW-9	Alluvial		Sonic	Above-grade	Continuous wrap stainless steel	0.035	10-20	8	30.00	33.00	(3.0)	77.0	-47.0	55.0	-25.0	75.0	-45.0
PW-10	Alluvial		Sonic	Above-grade	Continuous wrap stainless steel	0.035	10-20	8	32.00	35.00	(3.0)	79.0	-47.0	57.0	-25.0	77.0	-45.0
Existing Piezometers																	
PZ1-5	Alluvial	18-Mar-09	Manual	Above-grade	Solinst push point		NA	1	9.96	36.08	(26.1)	5.6	4.3	4.5	5.5	5.4	4.6
PZ1-20	Alluvial	18-Mar-09	Manual	Above-grade	Solinst push point		NA	1	10.15	36.43	(26.3)	20.5	-10.3	19.3	-9.2	20.2	-10.1
PZ2-5	Alluvial	19-Mar-09	Manual	Above-grade	Solinst push point		NA	1	2.89	37.92	(35.0)	6.7	-3.8	5.5	-2.6	6.4	-3.5
PZ2-20	Alluvial	18-Mar-09	Manual	Above-grade	Solinst push point		NA	1	3.38	37.90	(34.5)	21.7	-18.4	20.6	-17.2	21.5	-18.1
Proposed Piezometers																	
PZ1-50	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	1	10.00	36.50	(26.5)	50.5	-40.5	45.0	-35.0	50.0	-40.0
PZ2-43	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	1	3.00	38.00	(35.0)	43.5	-40.5	38.0	-35.0	43.0	-40.0
PZ3-10	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	1	-10.00	40.00	(50.0)	10.5	-20.5	5.0	-15.0	10.0	-20.0
PZ3-40	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	1	-10.00	40.00	(50.0)	40.5	-50.5	30.0	-40.0	35.0	-45.0
PZ4-10	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	1	-10.00	40.00	(50.0)	10.5	-20.5	5.0	-15.0	10.0	-20.0
PZ4-50	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	1	-10.00	40.00	(50.0)	50.5	-60.5	35.0	-45.0	40.0	-50.0
PZ5-5	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	1	10.00	13.00	(3.0)	5.5	4.5	4.0	6.0	5.0	5.0
PZ5-20	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	1	10.00	13.00	(3.0)	20.5	-10.5	15.0	-5.0	20.0	-10.0
PZ5-50	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	1	10.00	13.00	(3.0)	50.5	-40.5	45.0	-35.0	50.0	-40.0
PZ6-5	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	1	10.00	13.00	(3.0)	5.5	4.5	4.0	6.0	5.0	5.0
PZ6-20	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	1	10.00	13.00	(3.0)	20.5	-10.5	15.0	-5.0	20.0	-10.0
PZ6-50	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	1	10.00	13.00	(3.0)	50.5	-40.5	45.0	-35.0	50.0	-40.0
PZ7-5	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	1	10.00	13.00	(3.0)	5.5	4.5	4.0	6.0	5.0	5.0
PZ7-20	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	1	10.00	13.00	(3.0)	20.5	-10.5	15.0	-5.0	20.0	-10.0
PZ7-50	Alluvial		Sonic	Above-grade	Slotted PVC	0.020	10-20	1	10.00	13.00	(3.0)	50.5	-40.5	45.0	-35.0	50.0	-40.0

Table 2-2
Comparison of Groundwater Quality Above (Upper Alluvium) and Below (Deep Alluvium) the Aquitard

Well	Zone	Sample Dates	Benzene µg/L (ppb)		Naphthalene µg/L (ppb)		Total Cyanide mg/L (ppm)		Free Cyanide mg/L (ppm)	
MW-21-12	Surficial Fill	7/19/2007	0.5	U	2.9	U	0.0537		0.0048	
		5/14/2008	0.2	J	1.2		0.05		0.01	J
		9/15/2008	-		-		-		-	
		12/8/2008	0.31	J	0.94		0.09		0.005	J
MW-21-75	Upper Alluvium	7/18/2007	0.5	UJ	0.135	J	0.0648	J	0.0043	J
		5/14/2008	0.045	U	0.081		0.12		0.009	J
		9/15/2008	0.045	U	0.097		0.09		0.012	
		12/8/2008	0.045	U	0.048		0.14		0.005	J
MW-21-115	Upper Alluvium	7/18/2007	0.5	UJ	0.0989	J	0.0123	J	0.003	UJ
		5/15/2008	0.045	U	0.053		0.01		0.003	J
		9/15/2008	0.045	U	0.1		0.02		0.003	U
		12/8/2008	0.045	U	0.042		0.01		0.005	U
MW-21-165	Deep Alluvium	7/18/2007	0.5	UJ	0.0971	J	0.005	UJ	0.003	UJ
		5/14/2008	0.14	J	0.12		0.002	U	0.003	U
		9/15/2008	0.045	U	0.09		0.02	U	0.003	U
		12/8/2008	0.14	J	0.036		0.005	J	0.005	J
MW-16-45	Upper Alluvium	8/26/2004	2880		7500		0.138		-	
		12/22/2004	2680		8140		-		-	
		4/1/2005	2970		6060		-		-	
		6/21/2005	3190		10400		-		-	
		10/3/2005	3710		7820		0.131		-	
		4/3/2006	4210		29400		0.117		0.0013	U
		12/12/2006	5000		11000		0.14		0.005	U
		7/31/2007	4230		64100		0.412		0.003	U
		5/21/2008	4800		4800	J	0.51		0.005	
		9/17/2008	5600		12000		0.67		0.006	J
MW-16-65	Upper Alluvium	8/26/2004	1370		3600		0.402		-	
		8/26/2004	1250		3870		-		-	
		12/22/2004	1290		0.1	U	-		-	
		3/31/2005	1240		4840		-		-	
		6/21/2005	917		5700		-		-	
		10/3/2005	991		2900		0.25		-	
		4/3/2006	1090		3190		0.301		0.0149	
		10/23/2006	930		2500		0.31		0.005	U
		6/28/2007	698		837		0.18	J	0.003	UJ
		5/13/2008	690		2500		0.42		0.009	J
		9/11/2008	680	J	1200		0.28		0.007	J
MW-16-125	Upper Alluvium	9/30/2005	2.95		0.577		0.0775		NS	
		3/30/2006	0.5		0.452		0.0777		0.0016	
		10/16/2006	0.26		0.13		0.13		0.005	U
		6/28/2007	0.5		0.165		0.114	J	0.003	UJ
MW-18-30	Surficial Fill	7/31/2007	10100		-		1.65		0.003	
		5/14/2008	8600		1700000		2.22		0.006	J

Table 2-2
Comparison of Groundwater Quality Above (Upper Alluvium) and Below (Deep Alluvium) the Aquitard

Well	Zone	Sample Dates	Benzene µg/L (ppb)		Naphthalene µg/L (ppb)		Total Cyanide mg/L (ppm)		Free Cyanide mg/L (ppm)	
		9/17/2008	-		-		-		-	
		12/9/2008	-		-		-		-	
MW-18-180	Deep Alluvium	6/28/2007	0.5	U	0.575		0.0242	J	0.003	UJ
		5/13/2008	0.045	U	0.082		0.03		0.003	J
		9/11/2008	0.07	J	0.18		0.04		0.006	J
		12/9/2008	0.045	U	0.044		0.03		0.01	
MW-19-22	Surficial Fill	7/30/2007	6.58		297		0.121		0.003	U
		5/13/2008	1.0		270		0.12		0.004	J
		9/10/2008	3.4		230		0.12		0.007	J
		12/9/2008	4.0		120		0.14		0.013	
MW-19-125	Upper Alluvium	6/27/2007	16.7		2.95		0.0755		0.0087	
		5/14/2008	13		49		0.23		0.007	J
		9/10/2008	2.7		27		0.15		0.004	J
		12/9/2008	0.58		15		0.1	J	0.011	
MW-19-180	Deep Alluvium	6/27/2007	0.5	U	0.0954		0.0172		0.003	U
		5/13/2008	0.17	J	0.11		0.02		0.003	J
		9/10/2008	0.19	J	0.11		0.02		0.005	J
		12/9/2008	0.22	J	0.031		0.02		0.012	
MW-20-120	Upper Alluvium	6/28/2007	75		39.9		0.118		0.003	UJ
		5/15/2008	120		120		0.16		0.007	J
		9/10/2008	55		84		0.14		0.005	J
		12/9/2008	70		51		0.14		0.013	
MW-5-32	Surficial Fill/Alluvium	12/5/1995	0.5	U	11		0.101		-	
		3/19/1996	0.5	U	1		0.11		-	
		3/19/1996	-		0.61		-		-	
		6/20/1996	0.5	U	0.42		0.05		-	
		10/1/1996	0.5	U	10	U	0.14		-	
		2/25/1997	0.5	U	0.16		0.11		-	
		8/27/1997	0.5	U	1.0	U	0.14		-	
		2/17/1998	0.5	U	0.1	U	0.17		-	
		6/2/1998	0.5	U	0.67		0.18		-	
		8/26/1998	0.5	U	3.4		0.23		-	
		11/18/1998	0.5	U	0.1	U	0.25		-	
		2/16/1999	0.5	U	0.1	U	0.13		-	
		5/14/1999	0.5	U	0.95		0.15		-	
		8/24/1999	0.749		0.12		0.18		-	
		10/27/1999	0.5	U	0.1	U	0.19		-	
		3/30/2000	0.5	U	0.1	U	0.02	U	-	
		10/5/2000	0.5	U	0.1	U	-		-	
		3/29/2001	0.5	U	0.13		0.178		-	
		8/16/2004	0.5	U	0.1	U	0.521		-	
		4/1/2005	0.5	U	0.136		-		-	
		9/27/2005	0.5	U	0.999		0.09		-	

Table 2-2
Comparison of Groundwater Quality Above (Upper Alluvium) and Below (Deep Alluvium) the Aquitard

Well	Zone	Sample Dates	Benzene µg/L (ppb)		Naphthalene µg/L (ppb)		Total Cyanide mg/L (ppm)		Free Cyanide mg/L (ppm)	
		3/29/2006	0.5	U	0.192	U	0.106		0.0031	
		10/18/2006	0.14	U	0.068	J	0.09		0.005	J
		6/25/2007	0.5	U	4.63		-		-	
		7/30/2007	-		-		0.106		0.003	U
		5/14/2008	0.045	U	0.24		0.11		0.006	J
		9/10/2008	0.34	J	0.34		0.09		0.007	J
MW-5-100	Upper Alluvium	11/18/1998	5000		7100		0.66		-	
		2/17/1999	6650		5010		0.66		-	
		5/14/1999	11400		7440		0.44		-	
		8/25/1999	11800		13300		0.84		-	
		10/28/1999	10300		7450		0.69		-	
		3/30/2000	9550		9800		0.56		-	
		10/6/2000	9180		10100		-		-	
		10/6/2000	9020		9200		-		-	
		3/29/2001	9560		9600		0.142		-	
		4/5/2002	8750		82300		1.8		-	
		4/5/2002	8950		4310		1.54		-	
		3/19/2003	6600		5600		0.56		-	
		8/24/2004	11500		11900		0.816		-	
		4/1/2005	19800		8730		-		-	
		9/21/2005	12300		6530		0.869		-	
		4/4/2006	11300		8390		0.814		0.0283	
		10/27/2006	11000		7100		1.06		0.005	J
		6/25/2007	10100		7320		-		-	
		7/30/2007	-		-		0.747		0.0074	J
		5/14/2008	12000		7800		0.99		0.041	
		9/10/2008	11000		9900		0.91		0.036	
MW-5-175	Deep Alluvium	10/16/2006	0.14	U	0.047		0.04		0.005	U
		6/25/2007	0.5	U	0.114		0.0145	J	0.0022	J
		5/14/2008	0.05	J	0.076		0.02		0.005	J
		9/10/2008	0.045	U	0.075		0.01		0.004	J
WS-14-125	Upper Alluvium	6/12/2007	5430		7580		0.273		0.00563	J
		5/15/2008	6400		7800		0.33		0.008	J
		8/4/2008	4000		NS[1]		0.11		0.014	
		9/25/2008	4500		6800		0.29		0.032	
WS-14-161	Deep Alluvium	6/12/2007	0.09	U	15.7		0.005	U	0.003	UR
		5/15/2008	0.44	J	140		0.002	U	0.003	J
		8/4/2008	0.34		NS[1]		0.01	U	0.01	U
		9/25/2008	0.79		120		0.002	U	0.003	J
WS-11-125	Upper Alluvium	2/14/2008	799		NS[1]		0.62		0.01	U
		5/15/2008	560		11000		0.61		0.006	J
		8/6/2008	290		NS[1]		0.46		0.031	
		9/29/2008	350		11000		0.53		0.003	U

Table 2-2
Comparison of Groundwater Quality Above (Upper Alluvium) and Below (Deep Alluvium) the Aquitard

Well	Zone	Sample Dates	Benzene µg/L (ppb)		Naphthalene µg/L (ppb)		Total Cyanide mg/L (ppm)		Free Cyanide mg/L (ppm)	
WS-11-161	Deep Alluvium	6/12/2007	8.53		49.9		0.005	U	0.003	UR
		5/15/2008	25		110		0.01	J	0.004	J
		8/6/2008	19.8		NS[1]		0.01	U	0.01	U
		9/29/2008	23		89		0.002	U	0.003	U
WS-12-125	Upper Alluvium	6/12/2007	6.44		0.544		0.452		0.0078	J
		5/21/2008	6.6		0.088	U	0.53		0.007	
		8/6/2008	4.58		NS[1]		0.35		0.027	
		9/25/2008	6.2		0.056		0.43		0.149	
WS-12-161	Deep Alluvium	6/12/2007	0.09	U	0.0952	U	0.006	J	0.003	UR
		5/21/2008	0.07	J	0.021	U	0.008		0.005	
		8/5/2008	0.3	U	NS[1]		0.01	U	0.01	U
		9/25/2008	0.06	J	0.025		0.002	U	0.006	J
WS-8-33	Surficial Fill	10/9/2001	107		485		0.02	UJ	-	
		12/13/2001	68		287	J	0.854		-	
		4/3/2002	89.1		110		0.416		-	
		4/3/2002	87.4		101		0.615		-	
		7/10/2002	65.9		77.4		0.724		-	
		7/10/2002	68.1		77.6		0.726		-	
		5/21/2008	76		130	J	0.6		0.006	
		9/39/2008	110		170		0.77		0.01	
WS-8-59	Upper Alluvium	10/8/2001	14.7		22.7		0.468		-	
		10/8/2001	21.4		22.5		0.456		-	
		12/12/2001	26.8		10.5		0.725	J	-	
		12/12/2001	27		10.8		0.066	J	-	
		4/3/2002	13		1.13		1.42		-	
		7/10/2002	20.8		0.63		0.459		-	
		7/16/2007	7.08		0.0971	U	0.538		0.0061	
		5/21/2008	13		0.37	J	0.45		0.004	
		9/29/2008	2.7		0.16		0.63		0.003	U

Table 3-1
Summary of DNAPL Testing Results: Physical and Chemical

Parameter	Unit of Measure	Gasco Property Wells				
		Surficial Fill Unit			Alluvial Unit	
		Well MW-6-32	Well MW-10-25	Well MW-11-32	Well MW-16-45	Well PW-01-80
		Screen: 22-32 feet bgs	Screen: 15-25 feet bgs	Screen: 22-32 feet bgs	Screen: 30-45 feet bgs	Screen: 40-80 feet bgs
		Sample No.2708-981214-MW6-32-01	Sample No. 2708-981214-MW10-25-02	Sample No. 2708-981214-MW11-32-03	Sample No. 2708-041011MW-16-45-0il	Sample No. 2708-070221-PW01-Oil
Total Metals[1]	mg/kg (ppm)					
Arsenic		2.75	3.85	-	-	-
Barium		ND<0.500	0.700	-	-	-
Cadmium		ND<0.500	ND<0.500	-	-	-
Chromium		0.700	0.850	-	-	-
Lead		ND<10	ND<10	-	-	-
Mercury		0.059	ND<0.0500	-	-	-
Selenium		0.550	ND<0.500	-	-	-
Silver		ND<0.500	ND<0.500	-	-	-
Aromatic Hydrocarbons[2]	mg/kg (ppm)					
Benzene		589	14,400	2,740	ND<10.0	1,000
cis-1,2-DCE		-	-	-	ND<10	ND<764
Ethylbenzene		2,220	5,320	1,760	34.4	2,228
Isopropylbenzene		-	-	-	ND<20	ND<1,590
n-Propylbenzene		-	-	-	ND<10	ND<794
1,2,4-Trimethylbenzene		-	-	-	54.9	976
1,3,5-Trimethylbenzene		-	-	-	16.2	ND<794
Naphthalene		-	-	-	1,720	75,400
Toluene		ND<5.00	21,900	2,950	17.8	ND<794
Trichloroethene		-	-	-	ND<10	ND<794
Xylene		1,240	19,500	4,400	66.1	ND<1,590
PAHs [3]	mg/kg (ppm)					
Total PAHs		214,900	189,700	164,470	32,787	46,910
Total Carcinogenic PAHs		9,300	19,490	16,210	2,647	ND
Petroleum Hydrocarbon ID[4]	None					
Gasoline-Range (mg/kg)		Detected [12]	Detected [12]	Detected [12]	Not Detected	22,900
Diesel-Range (mg/kg)		Detected [12]	Detected [12]	Detected [12]	Detected [12]	545,000 [12]
Heavy Oil-Range (mg/kg)		Detected [12]	Detected [12]	Detected [12]	Detected [12]	175,000 [12]
Reactive Cyanide [5]	mg/kg (ppm)					
		ND<0.200	ND<0.200	-	-	-
Reactive Sulfide [6]	mg/kg (ppm)					
		434	ND<50.0	-	-	-
Specific Gravity [7]	gm/cc				1.084 @ 70F; 1.079 @100F;	1.1006 @ 70F; 1.0955 @100F;
		1.05	1.05	1.09	1.080 @130F	1.0920 @130F

Table 3-1
Summary of DNAPL Testing Results: Physical and Chemical

Parameter	Unit of Measure	Gasco Property Wells				
		Surficial Fill Unit			Alluvial Unit	
		Well MW-6-32	Well MW-10-25	Well MW-11-32	Well MW-16-45	Well PW-01-80
		Screen: 22-32 feet bgs	Screen: 15-25 feet bgs	Screen: 22-32 feet bgs	Screen: 30-45 feet bgs	Screen: 40-80 feet bgs
		Sample No.2708-981214-MW6-32-01	Sample No. 2708-981214-MW10-25-02	Sample No. 2708-981214-MW11-32-03	Sample No. 2708-041011MW-16-45-0il	Sample No. 2708-070221-PW01-Oil
Viscosity [8]	cSt				105 @ 70F; 40.1@100F;	65.6 @ 70F; 24.1@100F;
		7.2 @ 50C (122F)	14.7 @ 50C (122F)	45.7 @ 50C (122F)	18.7@130F	13.3 @130F
Ignitability [9]	degrees F					
		No Flash to 150 degrees F	94.0 degrees F	-	No Flash to 150 degrees F	No Flash to 150 degrees F
Heating Value [10]	BTU/lb					
		9,230	12,230	12,280	-	-
pH [11]	pH unit					
		6.26	4.30	-	8.28	7.10
Interfacial/Surface Tension [13]	dynes/centimeter					
Water with Air		-	-	-	66.7 @ 70F	66.9 @ 75F
DNAPL with Air		-	-	-	34.9 @ 70F	36.2 @ 75F
DNAPL with Water		-	-	-	14.2 @ 70F	15.8 @ 75F

Note:

1 = EPA Method 6010/6020/7471
2 = EPA Method 8020A or EPA 8260B
3 = EPA Method 8270 SIM or 8270C
4 = EPA Method 8015M or NW-TPH Methodology or EPA 8015
5 = EPA Method 9010A
6 = EPA Method 9030
7 = SM 2710F
8 = ASTM Method D-445
9 = EPA Method 1010
10 = ASTM Method D2015
11 = EPA Method 150.1/9040A
12 = Laboratory reports that detected hydrocarbons have pattern and range consistent with creosotes
13 = DuNuoy Method - ASTM D971
J = Estimated concentration, results are between the Method Detection Limit (MDL) and the Method Reporting Limit (MRL).

bgs=below ground surface
cc=cubic centimeter
cSt = centistokes
BTU = british thermal unit
DNAPL = dense non-aqueous phase liquids
EPA = U. S. Environmental Protection Agency
gm = gram
lb = pound
mg/kg = milligrams/kilogram

Table 3-2a

Analytical Results of Volatile Organic Compounds Characterization of Soil Generated from Borings at Proposed Vertical Barrier Alignment

	F002 Threshold Screening Values[1]	RCRA "D-list" Maximum Concentrations (20-times TCLP)	GS-IDW1-040209 4/2/2009 Composite		GS-IDW2-040209 4/2/2009 Composite		GS-IDW3-040209 4/2/2009 Composite		GS-IDW4-101408 10/14/2008 Composite		GS-IDW5-101408 10/14/2008 Composite	
Volatile Organic Compounds (ug/kg)												
1,1,1,2-Tetrachloroethane			2900	U	31	U	30	U	0.94	U	0.48	U
1,1,1-Trichloroethane			710	U	7.6	U	7.4	U	0.94	U	0.48	U
1,1,2,2-Tetrachloroethane			710	U	7.6	U	7.4	U	0.94	U	0.48	U
1,1,2-Trichloroethane			710	U	7.6	U	7.4	U	0.94	U	0.48	U
1,1-Dichloroethane			710	U	7.6	U	7.4	U	26000	U	26000	U
1,1-Dichloroethylene	26,000,000	14,000	710	U	7.6	U	7.4	U	0.94	U	0.48	U
1,1-Dichloropropane			710	U	7.6	U	7.4	U	0.94	U	0.48	U
1,2,3-Trichlorobenzene			710	U	7.6	U	7.4	U	3.8	U	1.9	U
1,2,3-Trichloropropane			710	U	7.6	U	7.4	U	0.94	U	0.48	U
1,2,4-Trichlorobenzene			710	U	7.6	U	7.4	U	3.8	U	1.9	U
1,2,4-Trimethylbenzene			710	U	7.6	U	7.4	U	3.8	U	**2.8**	
1,2-Dibromoethane			2900	U	31	U	30	U	3.8	U	1.9	U
1,2-Dibromo-3-chloropropane			710	U	7.6	U	7.4	U	3.8	U	1.9	U
1,2-Dichlorobenzene			**8200**		**0.75**	**J**	**69**		0.94	U	0.48	U
1,2-Dichloroethane		10,000	2900	U	31	U	30	U	0.94	U	0.48	U
1,2-Dichloropropane			710	U	7.6	U	7.4	U	0.94	U	0.48	U
1,3-Dichlorobenzene			710	U	7.6	U	7.4	U	0.94	U	0.48	U
1,3-Dichloropropane			710	U	7.6	U	7.4	U	0.94	U	0.48	U
1,3,5-rimethylbenzene			710	U	7.6	U	7.4	U	3.8	U	1.9	U
1,4-Dichlorobenzene		150,000	**2900**		**0.26**	**J**	**41**		0.94	U	0.48	U
2,2-Dichloropropane			710	U	7.6	U	7.4	U	0.94	U	0.48	U
2-Butanone (MEK)		4,000,000	710	U	7.6	U	7.4	U	38	U	19	U
2-Chlorotoluene			710	U	7.6	U	7.4	U	3.8	U	1.9	U
2-Hexanone			710	U	7.6	U	7.4	U	38	U	19	U
4-Chlorotoluene			29000	U	**5.4**	**J**	30	U	3.8	U	1.9	U
4-Isopropyltoluene			2900	U	31	U	30	U	3.8	U	1.9	U
4-Methyl-2-pentanone (MIBK)			29000	U	31	U	30	U	38	U	19	U
Acetone			2900	U	31	U	30	U	38	U	19	U
Benzene		10,000	**800**	**J**	31	U	**10**	**J**	0.94	U	0.48	U
Bromochloromethane			29000	U	**63**		**44**		0.94	U	0.48	U
Bromodichloromethane			**570**	**J**	7.6	U	**0.35**	**J**	0.94	U	0.48	U
Bromobenzene			2900	U	7.6	U	7.4	U	3.8	U	1.9	U
Bromoform			710	U	7.6	U	7.4	U	0.94	U	0.48	U
Bromomethane			710	U	7.6	U	7.4	U	0.94	U	0.48	U
Carbon disulfide			710	U	7.6	U	7.4	U	0.94	U	0.48	U
Carbon tetrachloride		10,000	710	U	**6.1**	**J**	7.4	U	0.94	U	0.48	U
Chlorobenzene		2,000,000	710	U	**0.17**	**J**	**0.21**	**J**	0.94	U	0.48	U
Chloroethane			710	U	7.6	U	7.4	U	0.94	U	0.48	U
Chloroform		120,000	710	U	7.6	U	7.4	U	0.94	U	0.48	U
Chloromethane			710	U	7.6	U	7.4	U	0.94	U	0.48	U
cis-1,2-Dichloroethene	4,900,000		710	U	7.6	U	7.4	U	4900	U	4900	U
cis-1,3-Dichloropropene			710	U	7.6	U	7.4	U	0.94	U	0.48	U
Dibromochloromethane			710	U	7.6	U	7.4	U	0.94	U	0.48	U
Dibromomethane			710	U	7.6	U	7.4	U	0.94	U	0.48	U
Dichlorodifluoromethane			710	U	7.6	U	7.4	U	0.94	U	0.48	U
Ethylbenzene			**130**	**J**	**4.4**	**J**	**2.9**	**J**	**1.4**		**1.5**	
Hexachlorobutadiene		10,000	**4800**		**0.26**	**J**	**31**		3.8	U	1.9	U
Isopropylbenzene			2900	U	31	U	30	U	3.8	U	1.9	U
m,p-Xylene			2900	U	31	U	30	U	**1.4**		**2**	
Methylene chloride			**900**	**J**	31	U	**10**	**J**	3.8	U	1.9	U
n-Butylbenzene			29000	U	**0.5**	**J**	**1**	**J**	3.8	U	1.9	U
n-Propylbenzene			**6400**		**0.33**	**J**	**35**		3.8	U	1.9	U
Naphthalene			2900	U	31	U	30	U	**390**		**210**	
o-Xylene			**410**	**J**	31	U	**4.3**	**J**	0.94	U	**0.89**	
sec-Butylbenzene			**430000**		**94**		**98**		3.8	U	1.9	U
Styrene			**3300**		7.6	U	**18**		0.94	U	0.48	U
tert-Butylbenzene			**290**	**J**	31	U	**2.2**	**J**	3.8	U	1.9	U
Tetrachloroethene		14,000	**84**	**J**	7.6	U	7.4	U	0.94	U	0.48	U
Toluene			2900	U	31	U	**0.32**	**J**	0.94	U	0.48	U
trans-1,2-Dichloroethene	8,900,000		710	U	7.6	U	7.4	U	8900	U	8900	U
trans-1,3-Dichloropropene			**1100**		**0.23**	**J**	**2 J**	**J**	0.94	U	0.48	U
Trichloroethene	3,400	10,000	710	U	7.6	U	7.4	U	3.4	U	3.4	U
Trichlorofluoromethane			710	U	7.6	U	7.4	U	0.94	U	0.48	U
Vinyl chloride	3,900	4,000	710	U	7.6	U	7.4	U	3.9	U	3.9	U

Notes:

Bold = Detected result

1 - screening values proposed in Gasco IDW Plan dated February 26, 2008

J = Estimated value

U = Compound analyzed, but not detected above detection limit

Table 3-2b

Analytical Results for Conventionals, Metals, and Total Petroleum Hydrocarbons Characterization of Soil Generated from Borings at Proposed Vertical Barrier Alignment

	RCRA "D-list" Maximum Concentrations (20-times TCLP)	GS-IDW1-101408 10/14/2008 Composite		GS-IDW2-101408 10/14/2008 Composite		GS-IDW3-101408 10/14/2008 Composite		GS-IDW4-101408 10/14/2008 Composite		GS-IDW5-101408 10/14/2008 Composite	
Conventionals											
Cyanide (mg/kg)		**1.87**		**7.69**		ND	U	**1.89**		ND	U
Total solids (pct)		**33.3**		**50.3**		**58.9**		**38.1**		**66.3**	
Metals (mg/kg)											
Arsenic	100	**6.2**		**4.3**		**3.0**		**3.4**		**2.5**	
Barium	2000	**138**		**220**		**178**		**129**		**121**	
Cadmium	20	**0.53**		**0.3**		**0.18**		**0.5**		**0.24**	
Chromium	100	**34.5**		**29.9**		**31.5**		**24.1**		**19.4**	
Lead	100	**99.3**		**48.1**		**13.6**		**15.6**		**22.5**	
Mercury	4	**0.14**		**0.16**		**0.03**		**0.04**		**0.1**	
Selenium	20	**2.8**		1.1	U	0.9	U	1.0	U	1.1	U
Silver	100	**0.15**		**0.12**		**0.06**		**0.11**		**0.06**	
TPH (mg/kg)											
Diesel Range		**6500**	**DZ**	**1300**	**DZ**	**480**	**Z**	**4100**	**DZ**	**3800**	**DZ**
Gasoline Range		**2000**	**Z**	**43**	**Z**	**55**	**Z**	**470**	**Z**	**300**	**Z**
Residual Range		**3800**	**DZ**	**2200**	**DZ**	**690**	**Z**	**3300**	**DZ**	**4300**	**DZ**

Notes:

Bold = Detected result

J = Estimated value

U = Compound analyzed, but not detected above detection limit

Z = The chromatographic fingerprint does not resemble a petroleum product

D = The report result is from a dilution

Table 3-2c
Analytical Results for
Polycyclic Aromatic Hydrocarbons and Semi-Volatile Organics Characterization of Soil Generated from Borings at Proposed Vertical Barrier Alignment

	GS-IDW1-040209 4/2/2009 Composite	GS-IDW1-040209 4/2/2009 Composite	GS-IDW1-040209 4/2/2009 Composite	GS-IDW1-040209 4/2/2009 Composite	GS-IDW1-040209 4/2/2009 Composite
Aromatic Hydrocarbons (ug/kg)					
2-Methylnaphthalene	**49000**	**670**	**2500**	**46000**	**28000**
Acenaphthene	**38000**	**1900**	**2100**	**68000**	**34000**
Acenaphthylene	**9500**	**3300**	**1100**	**9200**	**6600**
Anthracene	**32000**	**6900**	**2500**	**49000**	**26000**
Benzo(a)anthracene	**27000**	**13000**	**3800**	**37000**	**24000**
Benzo(a)pyrene	**33000**	**19000**	**6800**	**51000**	**34000**
Benzo(b)fluoranthene	**27000**	**17000**	**5900**	**43000**	**27000**
Benzo(g,h,i)perylene	**22000**	**14000**	**5000**	**32000**	**22000**
Benzo(k)fluoranthene	**9300**	**5900**	**2000**	**14000**	**8900**
Chrysene	**31000**	**15000**	**4700**	**44000**	**29000**
Dibenzo(a,h)anthracene	**2900**	**1800**	**640**	**4100**	**2800**
Fluoranthene	**77000**	**36000**	**7600**	**140000**	**83000**
Fluorene	**24000**	**2600**	**1500**	**35000**	**19000**
Indeno(1,2,3-c,d)pyrene	**22000**	**14000**	**4900**	**33000**	**22000**
Naphthalene	**100000**	**2100**	**4200**	**140000**	**69000**
Phenanthrene	**150000**	**26000**	**10000**	**210000**	**120000**
Pyrene	**89000**	**40000**	**11000**	**130000**	**87000**
Semi-Volatile Organics (ug/kg)					
Dibenzofuran	**5100**	**270**	**260**	**5400**	**3000**

Notes:
Bold = Detected result
J = Estimated value
U = Compound analyzed, but not detected above detection limit

Table 4-1
Groundwater Treatment System Effluent Criteria

Discharge Limitations		
Parameter	**Monthly Average**	**Daily Maximum**
Benzene	0.66 (µg/L)	1.1 (µg/L)
Benzo(a)Anthracene	Not to exceed EPA Method 625 Quantitation Limit of 1 µg/L	
Benzo(a)Pyrene	Not to exceed EPA Method 625 Quantitation Limit of 1 µg/L	
Benzo(b)Flouranthene	Not to exceed EPA Method 625 Quantitation Limit of 1 µg/L	
Benzo(k)Flouranthene	Not to exceed EPA Method 625 Quantitation Limit of 1 µg/L	
Copper	Not to exceed EPA Method 200.8 Quantitation Limit of 10 µg/L	17.7 (µg/L)
Chromium VI	Not to exceed EPA Method 218.6 Quantitation Limit of 10 µg/L	16 (µg/L)
Chrysene	Not to exceed EPA Method 625 Quantitation Limit of 1 µg/L	
Free Cyanide	Not to exceed ASTM Method 4282-95 Quantitation Limit of 10 µg/L	
Dibenzo(a,h)Anthracene	Not to exceed EPA Method 625 Quantitation Limit of 1 µg/L	
Indeno(1,2,3-Cd)Pyrene	Not to exceed EPA Method 625 Quantitation Limit of 1 µg/L	
Iron (Dissolved)	300.0 (µg/L)	520 (µg/L)
Manganese (Dissolved)	50.0 (µg/L)	86.6 (µg/L)
Mercury	Not to exceed EPA Method 245.7 Quantitation Limit of 0.01 µg/L	
Pentachlorophenol	Not to exceed EPA Method 625 Quantitation Limit of 2 µg/L	
pH	6.5 S.U.	8.5. S.U.
Temperature	7-day average of the Daily Maximums not to exceed 68 degrees Fahrenheit	

Table 4-2
Extraction Well PW-3 Pump Tests

Test	Pumping Rate (gpm)	Duration (minutes)
PW-3-85 Step-Drawdown Test		
Step 1	20	240
Step 2	30	251
Step 3	40	954
PW-3-118 Step-Drawdown Test		
Step 1	30	240
Step 2	40	240
Step 3	50	521
Constant Rate Test		
PW-3-85	40	420
PW-3-118	50	420

Table 4-3

Predicted Horizontal DNAPL Travel Distance due to Increased Gradient from Nearshore Groundwater Pumping

Extraction Well Configuration	Groundwater Gradient Increase in Former Effluent Pond Area	Velocity (ft/day)	Distance traveled (ft) over the following time periods			
			0.5 years	1 year	2 years	3 years
Shallow Depth Extraction Wells	0.01	0.0047	0.9	1.7	3.5	5.2
	0.02	0.0095	1.7	3.5	6.9	10.4
Intermediate Depth Extraction Wells	0.001	0.00047	0.1	0.2	0.3	0.5
	0.002	0.00095	0.2	0.3	0.7	1.0

Table 4-4
Source Control Performance Monitoring Plan

Well ID	Water-Bearing Zone	Monitoring Water Level Transducer	Controlling Water Level Transducer	Conductivity Probe	Current Sampling	Source Control Sampling Program	
					Semi-Annual	Tiered[2]	Annual[3]
Existing Shoreline Monitoring Wells							
MW-1-22	Surficial Fill				X		X
MW-1-55	Alluvial				X		X
MW-1-82	Alluvial				X		X
MW-2-32	Surficial Fill				X		X
MW-2-61	Alluvial				X		X
MW-2-104	Alluvial				X		X
MW-3-26	Surficial Fill				X		X
MW-3-56	Alluvial				X		X
MW-4-35	Surficial Fill				X		X
MW-4-57	Alluvial				X		X
MW-4-101	Alluvial				X		X
MW-5-32	Surficial Fill/Alluvial	X			X		X
MW-5-100	Alluvial		X		X		X
MW-5-175	Alluvial				X		X
MW-16-45	Alluvial				X		X
MW-16-65	Alluvial				X		X
MW-16-125	Alluvial				NS		X
MW-17-79	Alluvial				X		
MW-18-30	Surficial Fill	X			X		X
MW-18-180	Alluvial				X		X
MW-19-22	Surficial Fill	X			X		X
MW-19-125	Alluvial				X		X
MW-19-180	Alluvial				X		X
MW-20-120	Alluvial		X		X		X
MW-21-12	Surficial Fill				X		X
MW-21-75	Alluvial		X		X		X
MW-21-115	Alluvial				X		X
MW-21-166	Alluvial	X			X		X
Monitored Siltronics Wells							
WS-11-161	Alluvial	X					
WS-14-161	Alluvial	X					
WS-22-112	Alluvial		X				
WS-26-86	Alluvial		X				
Proposed Monitoring Wells							
MW-22-74	Alluvial		X				X
MW-23-74	Alluvial		X				X
MW-23-115	Alluvial	X					X
MW-24-80	Alluvial		X				X
MW-24-130	Alluvial	X					X
MW-25-76	Alluvial		X				X
MW-26-97	Alluvial		X				X

Table 4-4
Source Control Performance Monitoring Plan

Well ID	Water-Bearing Zone	Monitoring Water Level Transducer	Controlling Water Level Transducer	Conductivity Probe	Current Sampling	Source Control Sampling Program	
					Semi-Annual	Tiered[2]	Annual[3]
MW-26-130	Deep Alluvial	X					X
MW-27-96	Alluvial		X				X
MW-27-131	Deep Alluvial	X					X
MW-28-92	Alluvial		X				X
MW-28-127	Deep Alluvial	X					X
MW-29-90	Alluvial		X				X
MW-29-124	Deep Alluvial	X					X
Proposed Observation Wells							
OW-1-35	Surficial Fill	X					X
OW-2-32	Surficial Fill	X					X
OW-2-79	Alluvial		X	X			
OW-3-25	Surficial Fill	X					X
OW-4-97	Alluvial		X	X			
OW-5-30	Surficial Fill	X					X
OW-6-101	Alluvial		X	X			
OW-7-20	Surficial Fill	X					X
OW-8-20	Surficial Fill	X					X
OW-9-27	Surficial Fill	X					X
OW-10-20	Surficial Fill	X					X
Existing Extraction Wells							
PW-01-80	Alluvial						
PW-3-85	Alluvial					X	
PW-3-118	Alluvial					X	
Proposed Extraction Wells							
PW-1	Alluvial					X	
PW-2	Alluvial					X	
PW-4	Alluvial					X	
PW-5	Alluvial					X	
PW-6	Alluvial					X	
PW-7	Alluvial					X	
PW-8	Alluvial					X	
PW-9	Alluvial					X	
PW-10	Alluvial					X	
Existing Piezometers							
PZ1-5	Alluvial						
PZ1-20	Alluvial						
PZ2-5	Alluvial						
PZ2-20	Alluvial						
Proposed Piezometers							
PZ1-50	Alluvial						
PZ2-43	Alluvial						
PZ3-10	Alluvial						
PZ3-40	Alluvial						

Table 4-4
Source Control Performance Monitoring Plan

Well ID	Water-Bearing Zone	Monitoring Water Level Transducer	Controlling Water Level Transducer	Conductivity Probe	Current Sampling	Source Control Sampling Program	
					Semi-Annual	Tiered[2]	Annual[3]
PZ4-10	Alluvial						
PZ4-50	Alluvial						
PZ5-5	Alluvial	X					X
PZ5-20	Alluvial	X					X
PZ5-50	Alluvial	X					X
PZ6-5	Alluvial	X					X
PZ6-20	Alluvial	X					X
PZ6-50	Alluvial	X					X
PZ7-5	Alluvial	X					X
PZ7-20	Alluvial	X					X
PZ7-50	Alluvial	X					X

Notes:

[1] 2009 Groundwater Monitoring Program, Hahn and Associates, Inc. The sampling frequency of these wells will be changed from semi-annual to annual.

[2] Tiered Monitoring Program entails monthly sampling for the first year, followed by quarterly sampling for the second year, semi-annual sampling until year 5, and then annual sampling thereafter.

[3] Annually sampled wells will be initially sampled following well installation and development, and then on an annual basis thereafter.

gray denotes a well planned for abandonment

Table 5-1
Permit Information

	Trigger	Jurisdiction	Review Time	Submitted?	Fee (estimate)
Greenway Letter of Determination	Work within Greenway Setback; however, formal permitting is not required for cleanup projects	City of Portland	Minimum of 4 weeks from receipt of complete application	Received determination for borings and access road development	~$3,500
1200-C	Disturbance of more than on1e acre of land and potential for stormwater to enter surface waters	State of Oregon, City of Portland	~60 days; 90 days if more than 5 acres are involved, as this triggers public review		$1,510 for year 1, $765 for each additional year permit is active

FIGURES

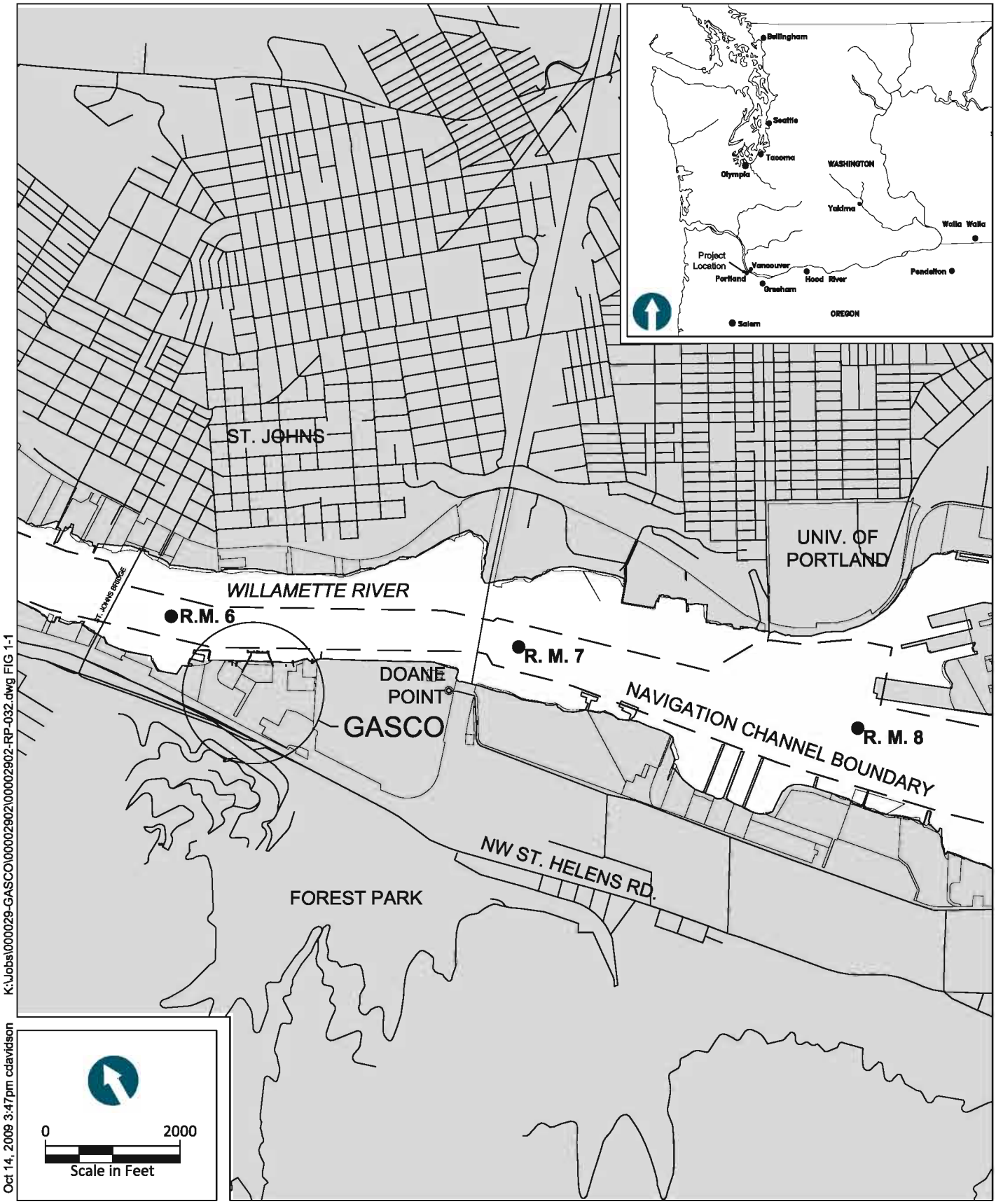
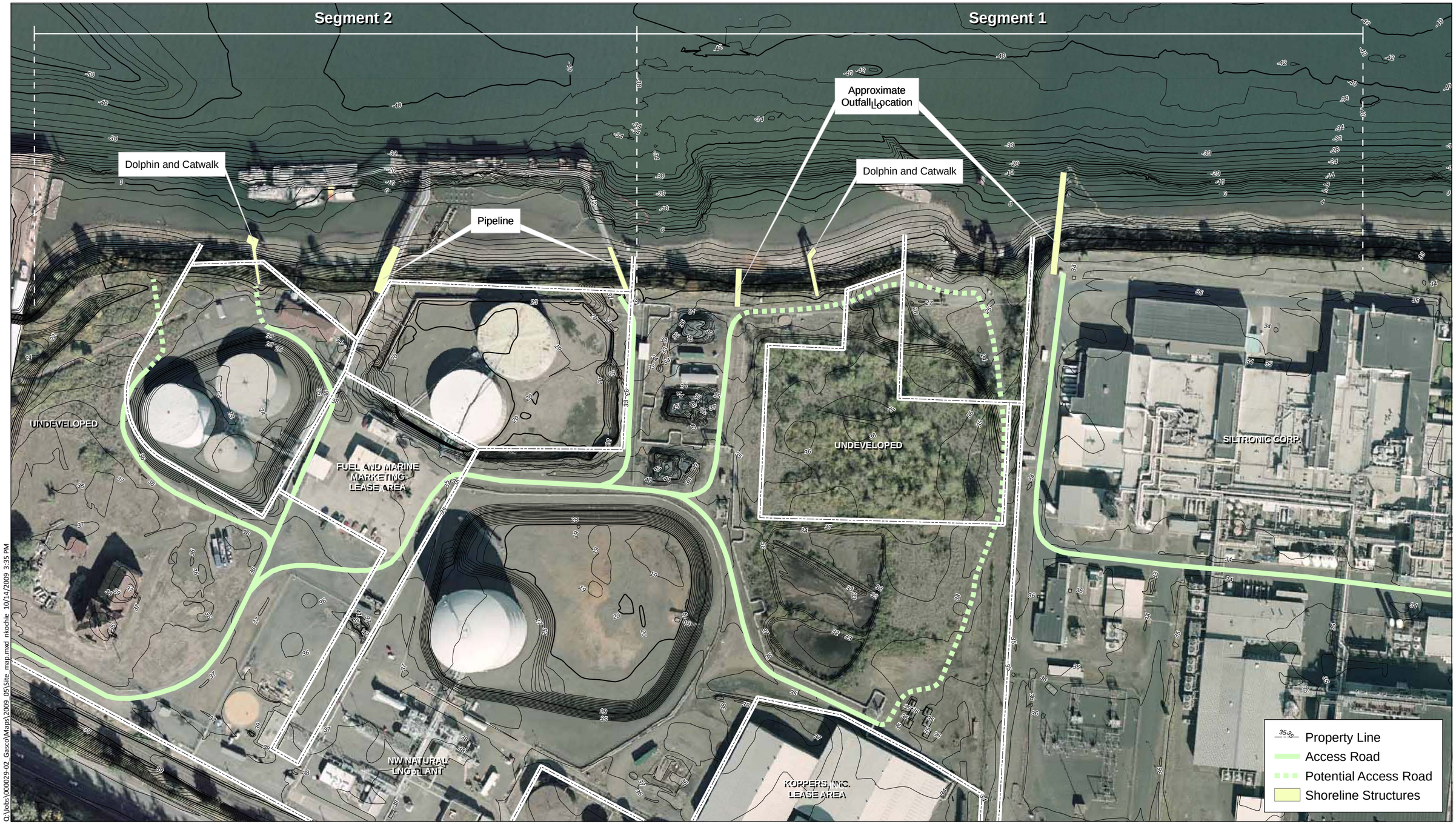


Figure 1-1
Site Vicinity Map
Gasco Groundwater Source Control
Interim Design Report

ANCHOR QEA



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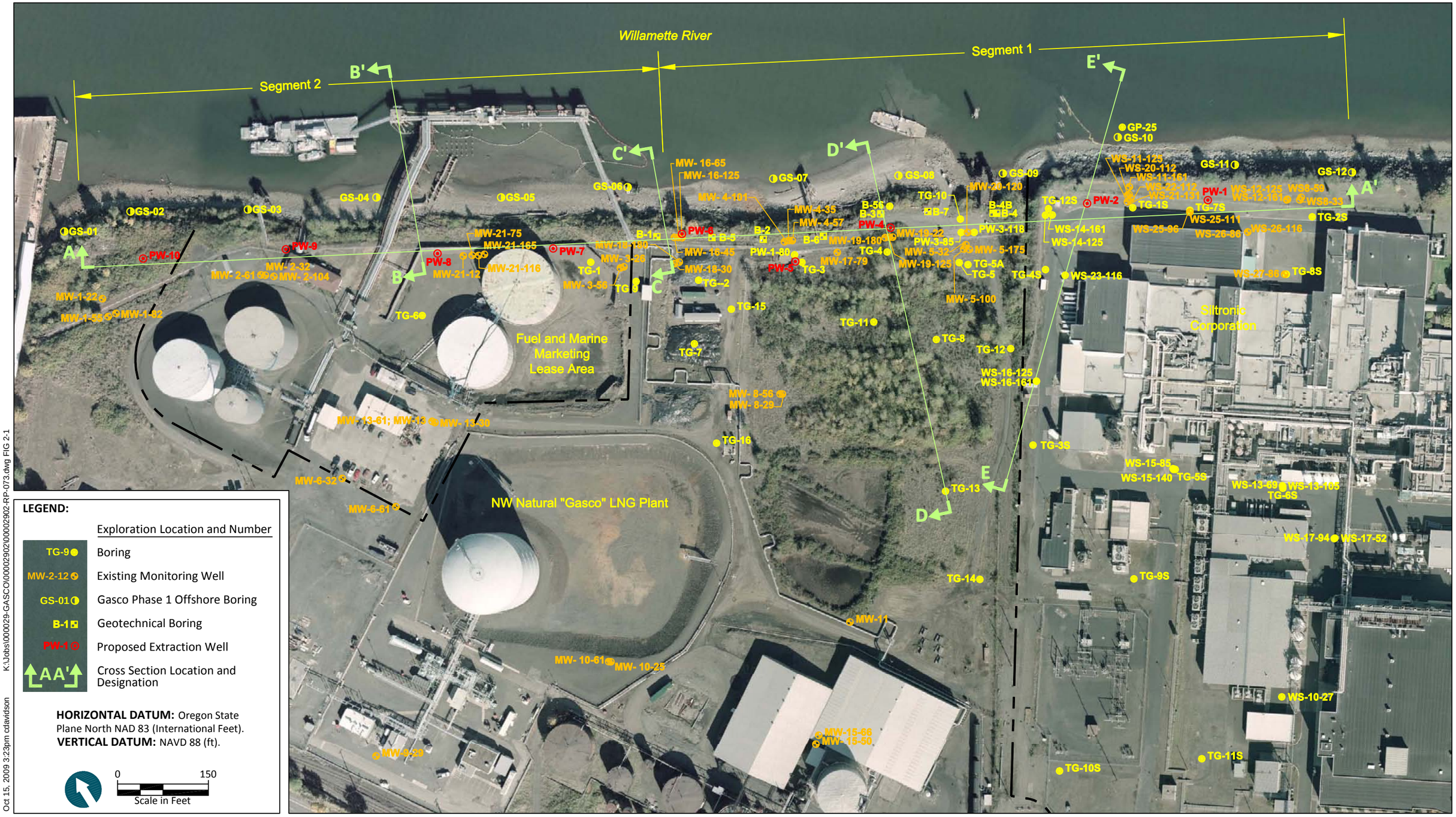
ANCHOR QEA

Feet
0 75 150 225 300

Figure 1-2
General Site Map
Gasco Groundwater Source Control
Interim Design Report



LEGEND:

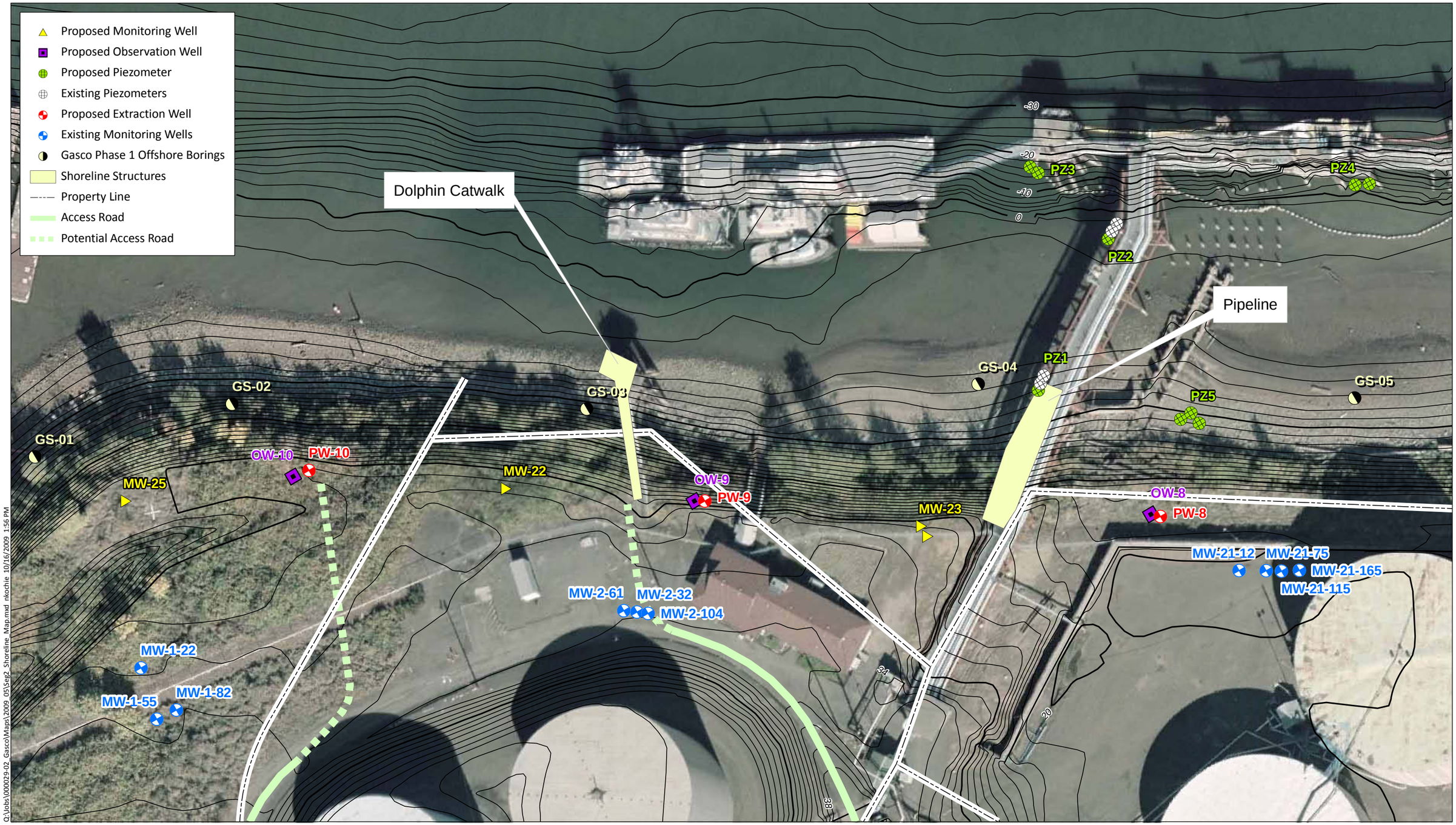
	Exploration Location and Number
TG-9	Boring
MW-2-12	Existing Monitoring Well
GS-01	Gasco Phase 1 Offshore Boring
B-1	Geotechnical Boring
PW-1	Proposed Extraction Well
AA'	Cross Section Location and Designation

HORIZONTAL DATUM: Oregon State Plane North NAD 83 (International Feet).
VERTICAL DATUM: NAVD 88 (ft).

K:\Jobs\000029-GASCO\00002902\00002902-RP-073.dwg FIG 2-1
Oct 15, 2009 3:23pm cdavidson

ANCHOR QEA

Figure 2-1
Monitoring Well Location Map
Gasco Groundwater Source Control
Interim Design Report



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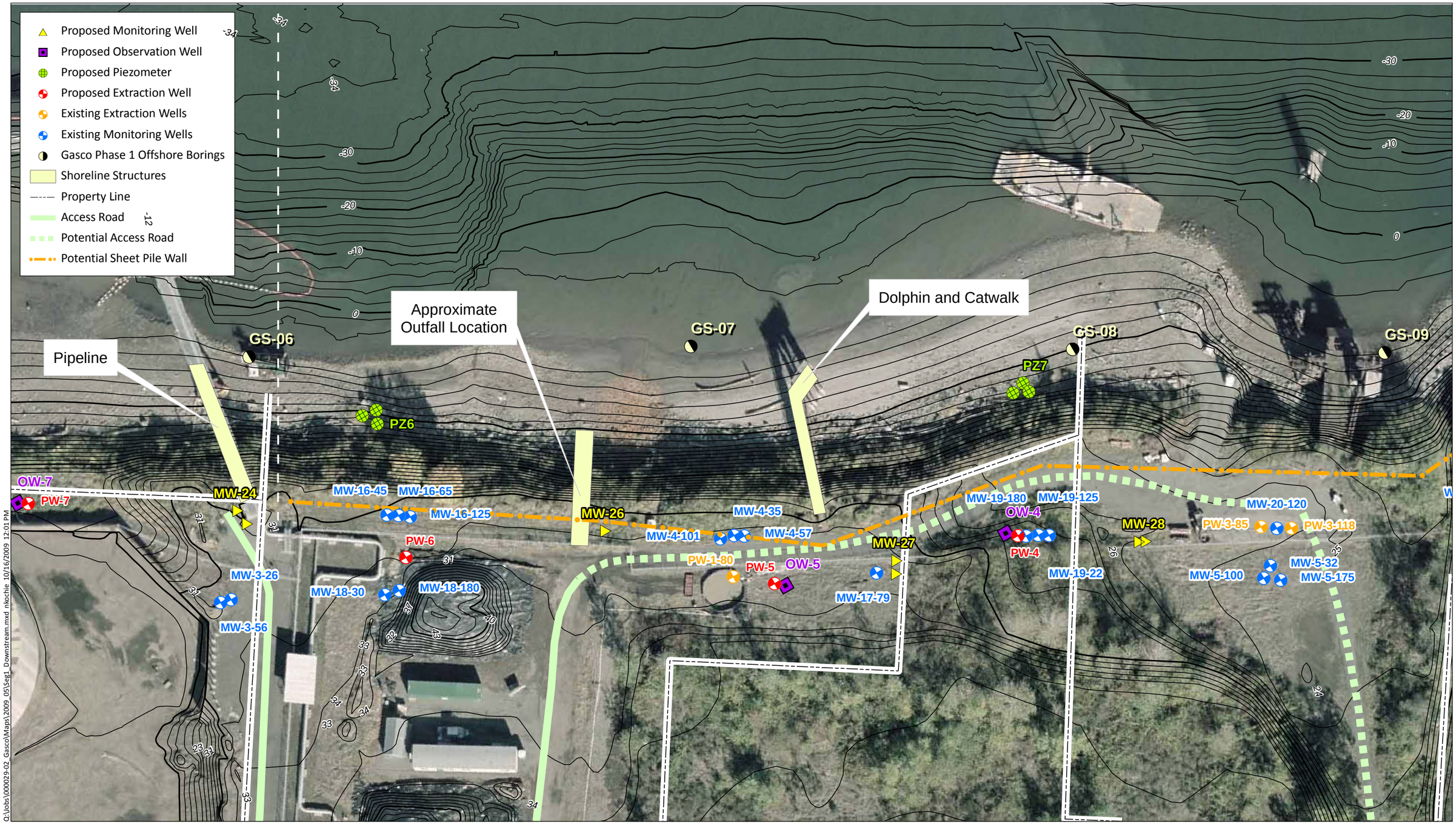
ANCHOR QEA

Feet
0 50 100

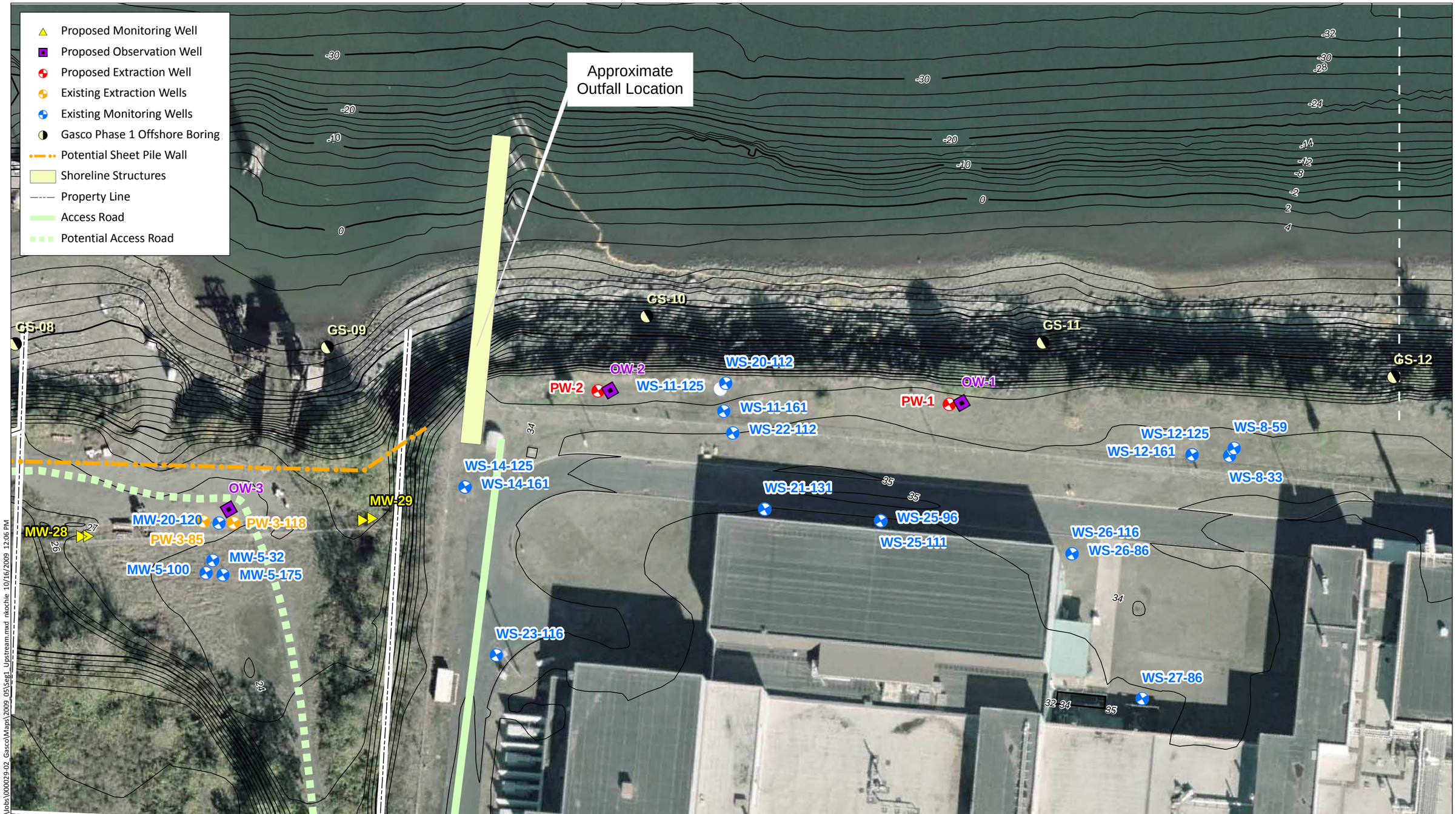
Figure 2-2a
Shoreline Map
Gasco Groundwater Source Control
Interim Design Report



ANCHOR QEA

Feet
0 50 100

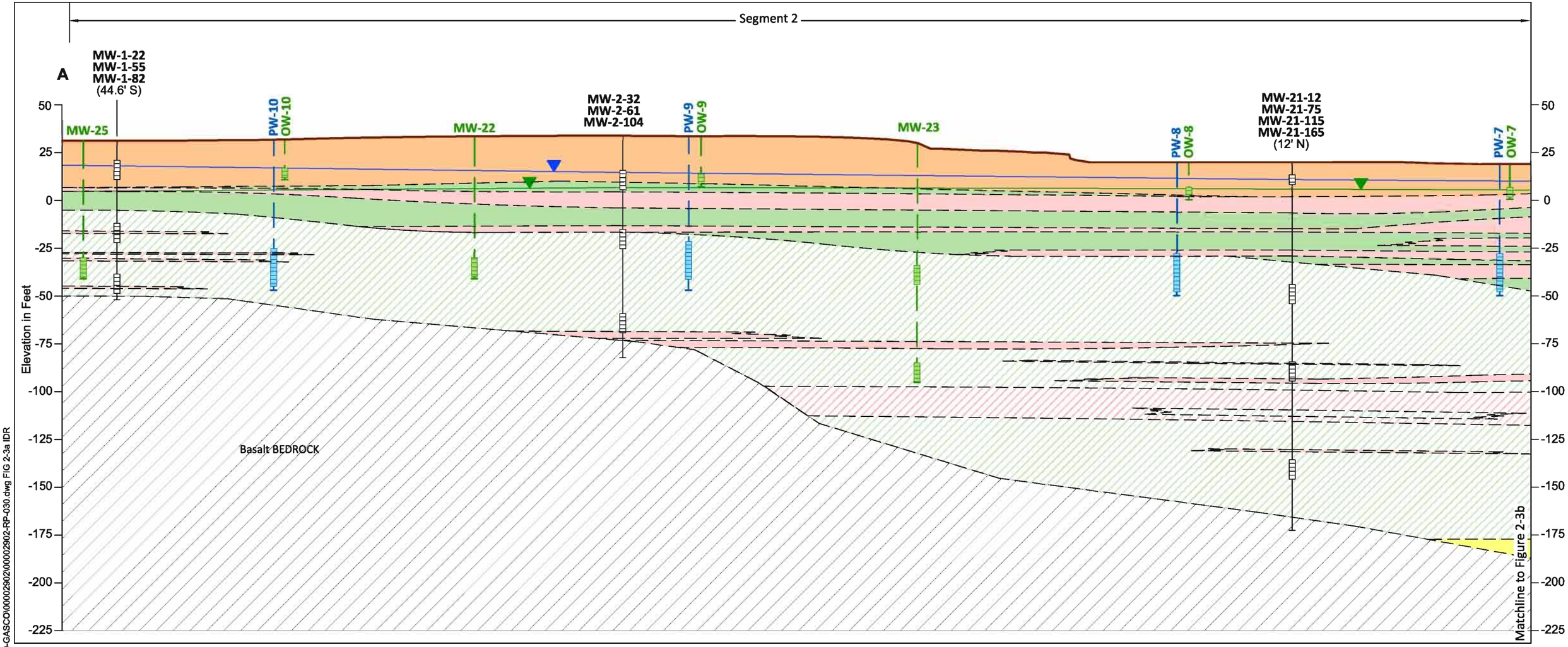
Figure 2-2b
Shoreline Map
Gasco Groundwater Source Control
Interim Design Report



ANCHOR QEA

Feet
0 50 100

Figure 2-2c
Shoreline Map
Gasco Groundwater Source Control
Interim Design Report



LEGEND:

- Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers
- Aquitard; Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers
- Primarily fine to medium grained SAND and SILTY-SAND interbedded with thin silt and sandy-silt layers
- Fill composed of gravel, silt, sand, metal, brick, and concrete debris
- Alluvial GRAVEL, sandy gravel, gravelly sand, and gravelly silt
- Primarily medium grained SAND with generally less than 15% fines.
- Basalt BEDROCK
- Potentiometric Surface of Surficial Fill (measured 9/07)
- Potentiometric Surface of Alluvium (measured 9/07)
- Existing Ground Surface

MW-21-116—Boring ID

xx—Boring ID

Proposed Extraction Well
Proposed Well or Piezometer
Existing Well or Piezometer

—Well Screen

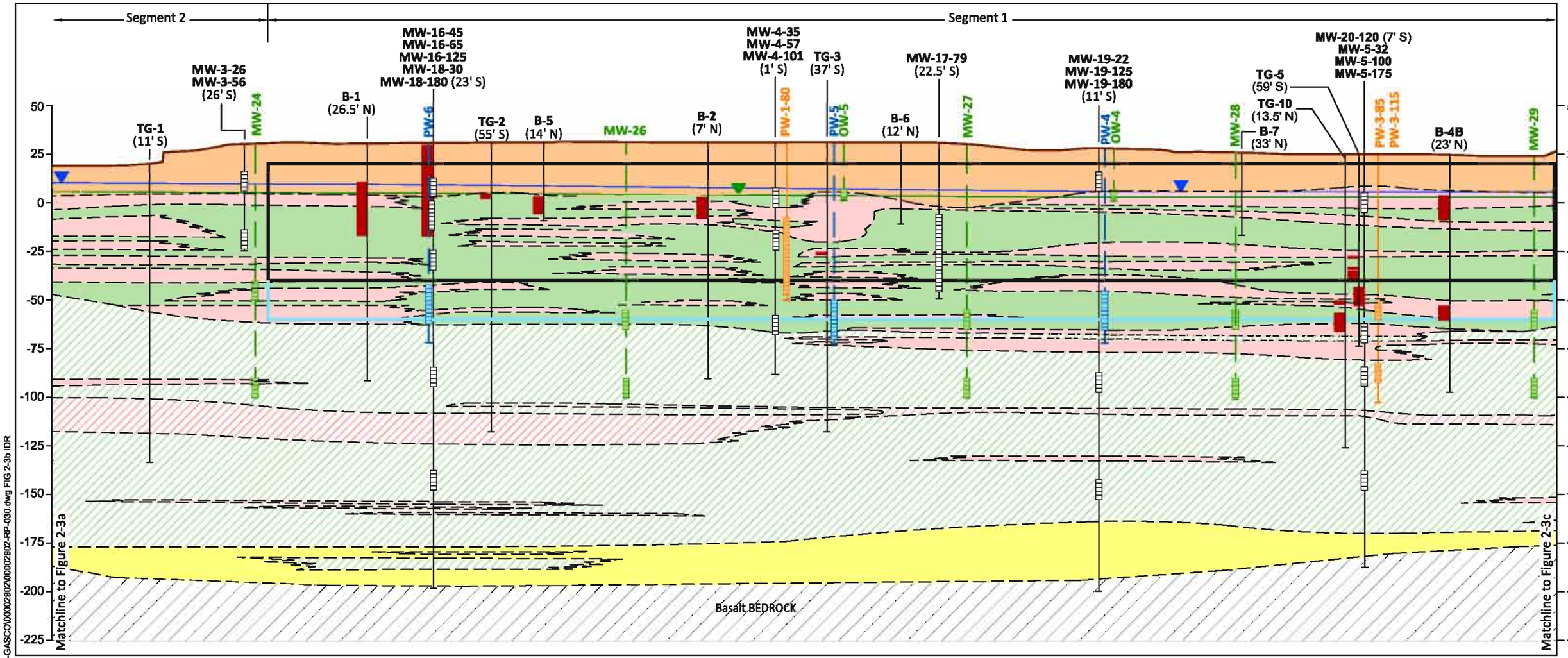
0 50
Scale in Feet

NOTES:
Geologic contacts are inferred between borings.

K:\Jobs\000029-GASCO\00002902\00002902-RP-030.dwg FIG 2-3a IDR
Oct 16, 2009 3:25pm heriksen

ANCHOR QEA

Figure 2-3a
Geologic Cross Section A-A'
Gasco Groundwater Source Control
Interim Design Report



LEGEND:

- Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers
- Aquitard; Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers
- Primarily fine to medium grained SAND and SILTY-SAND interbedded with thin silt and sandy-silt layers
- Fill composed of gravel, silt, sand, metal, brick, and concrete debris
- Alluvial GRAVEL, sandy gravel, gravelly sand, and gravelly silt
- Primarily medium grained SAND with generally less than 15% fines.
- Basalt BEDROCK
- Potentiometric Surface of Surficial Fill (measured 9/07)
- Potentiometric Surface of Alluvium (measured 9/07)
- Existing Ground Surface
- -40' - Potential Vertical Barrier Wall
- -60' - Potential Vertical Barrier Wall

MW-24 — Boring ID

xx — Boring ID

NAPL and/or Tar Interval

Well Screen

0 50
Scale in Feet

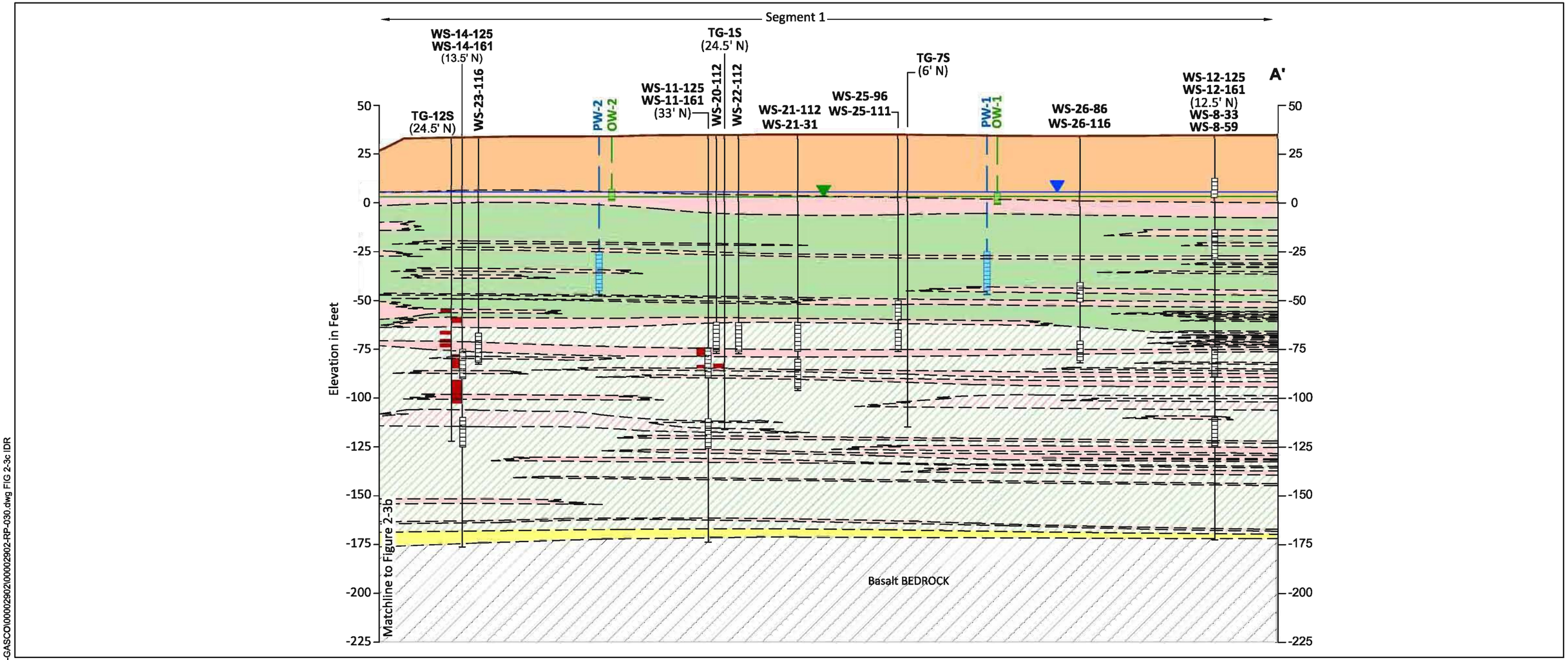
NOTES:
Geologic contacts are inferred between borings.

K:\Jobs\000029-GASCO\00002802\00002802-RP-030.dwg FIG 2-3b IDR

Oct 15, 2008 3:33pm cdavidson

ANCHOR QEA

Figure 2-3b
Geologic Cross Section A-A'
Gasco Groundwater Source Control
Interim Design Report



LEGEND:

- Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers
- Aquitard; Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers
- Primarily fine to medium grained SAND and SILTY-SAND interbedded with thin silt and sandy-silt layers
- Fill composed of gravel, silt, sand, metal, brick, and concrete debris
- Alluvial GRAVEL, sandy gravel, gravelly sand, and gravelly silt
- Primarily medium grained SAND with generally less than 15% fines.
- Basalt BEDROCK
- Potentiometric Surface of Surficial Fill (measured 9/07)
- Potentiometric Surface of Alluvium (measured 9/07)
- Existing Ground Surface
- MW-24 — Boring ID
- xx — Boring ID
- NAPL and/or Tar Interval
- Well Screen

Proposed Extraction Well
Proposed Well or Piezometer
Existing Well or Piezometer

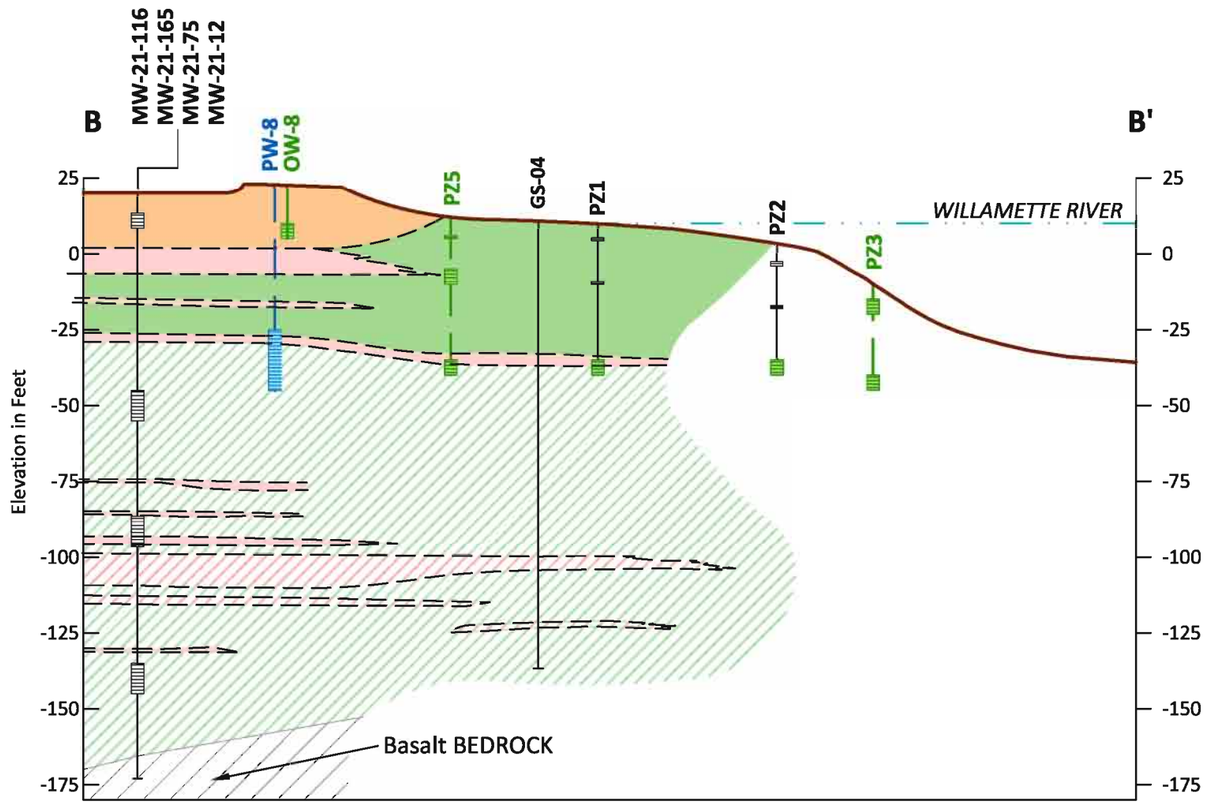
0 50
Scale in Feet

NOTES:
Geologic contacts are inferred between borings.

K:\Jobs\000029-GASCO\00002902\00002902-RP-030.dwg FIG 2-3c IDR
Oct 15, 2009 3:32pm cdavidson

ANCHOR QEA

Figure 2-3c
Geologic Cross Section A-A'
Gasco Groundwater Source Control
Interim Design Report



LEGEND:

- Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers
- Aquitard; Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers
- Primarily fine to medium grained SAND and SILTY-SAND interbedded with thin silt and sandy-silt layers
- Primarily medium grained SAND with generally less than 15% fines.
- Fill composed of gravel, silt, sand, metal, brick, and concrete debris
- Basalt BEDROCK
- Existing Ground Surface
- Approximate Willamettter River Elevation

MW-21-116—Boring ID

xx—Boring ID

Well Screen

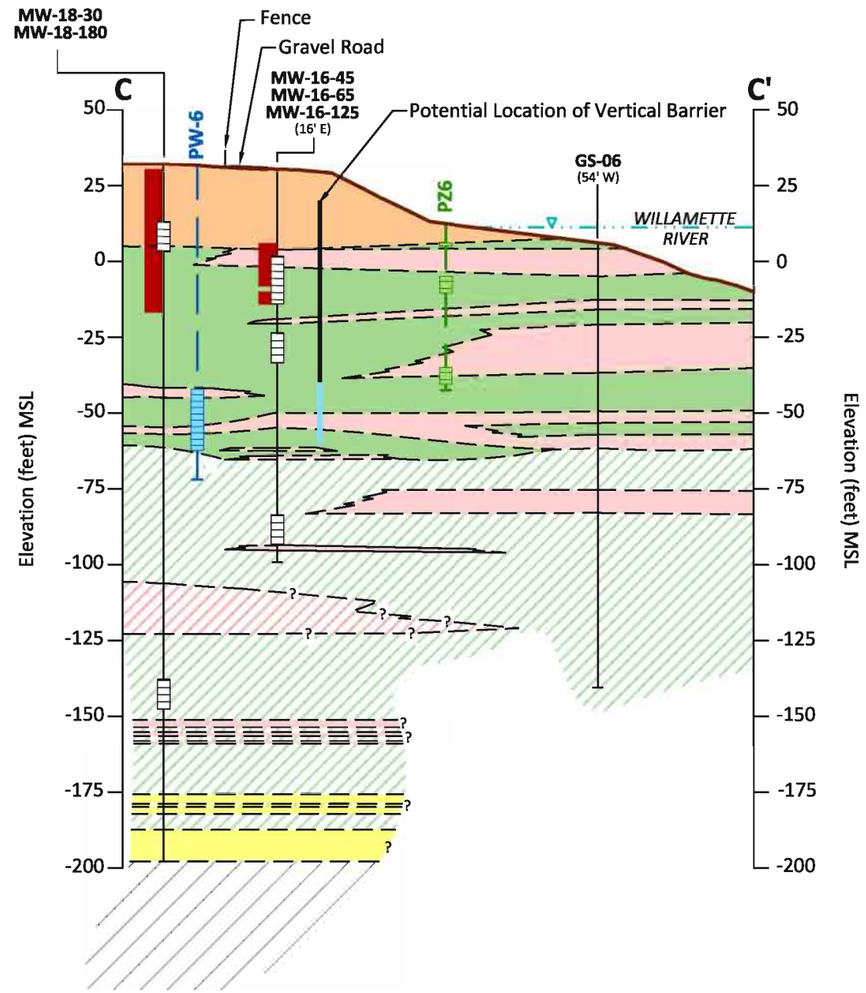
0 50
Scale in Feet

NOTES:
1. City of Portland vertical datum
2. Geologic contacts are inferred between borings.

Oct 14, 2009 12:18pm cdavidson K:\Jobs\000029-GASCO\00002902\00002902-RP-045.dwg FIG 2-4 IDR

ANCHOR QEA

Figure 2-4
Geologic Cross Section B-B'
Gasco Groundwater Source Control
Interim Design Report



LEGEND:

- Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers
- Aquitard; Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers
- Primarily fine to medium grained SAND and SILTY-SAND interbedded with thin silt and sandy-silt layers
- Fill composed of gravel, silt, sand, metal, brick, and concrete debris
- Alluvial GRAVEL, sandy gravel, gravelly sand, and gravelly silt
- Primarily medium grained SAND with generally less than 15% fines.
- Basalt BEDROCK
- Existing Ground Surface
- Approximate Willametter River Elevation
- -40' - Potential Vertical Barrier Wall
- -60' - Potential Vertical Barrier Wall

MW-18-30 — Boring ID

xx — Boring ID

NAPL and/or Tar Interval

Well Screen

0 50
Scale in Feet

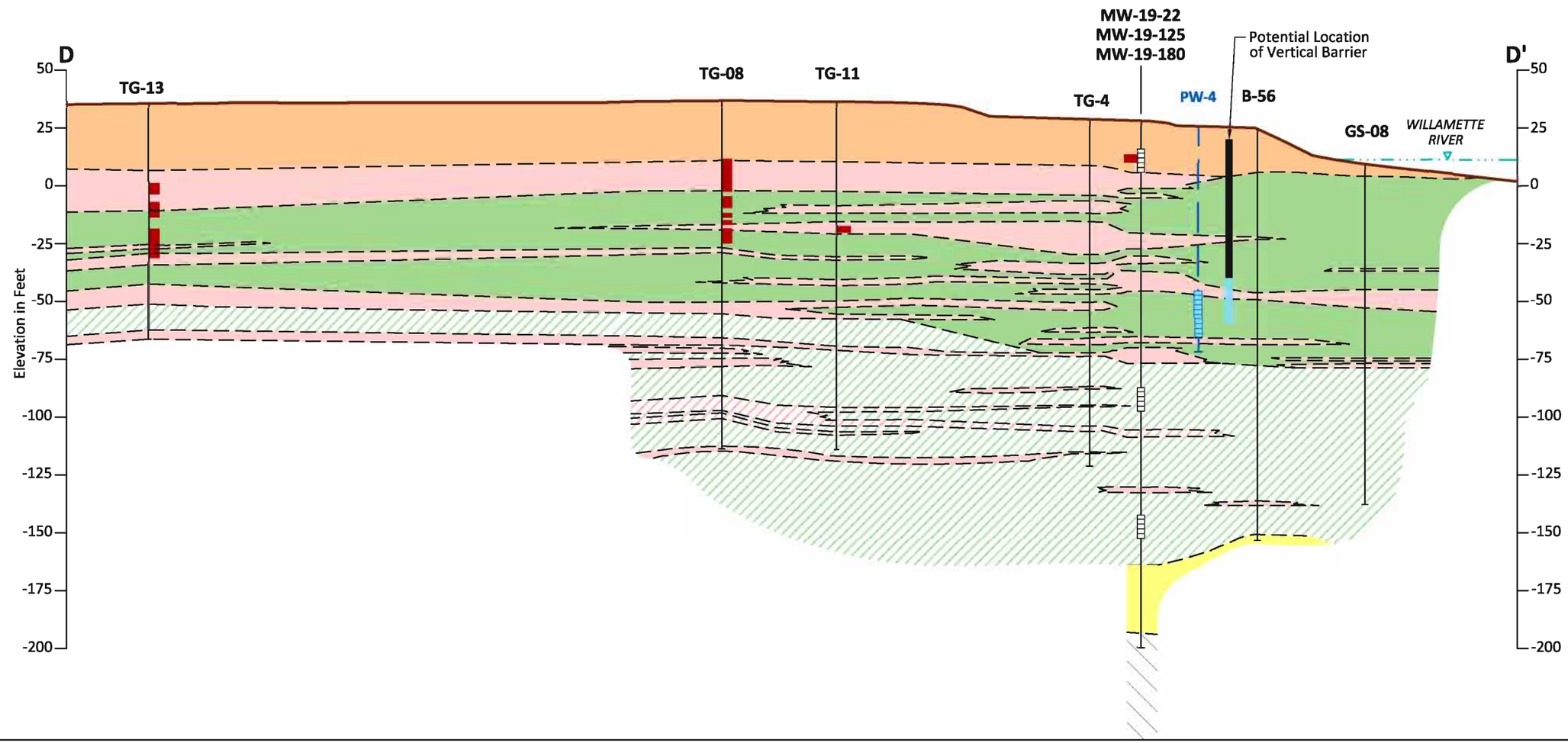
NOTES:
Geologic contacts are inferred between borings.

K:\Jobs\000029-GASCO\00002902\00002902-RP-045.dwg FIG 2-5 IDR

Oct 15, 2009 3:37pm cdavidson

ANCHOR QEA

Figure 2-5
Geologic Cross Section C-C'
Gasco Groundwater Source Control
Interim Design Report



LEGEND:

- Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers
- Aquitard; Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers
- Primarily fine to medium grained SAND and SILTY-SAND interbedded with thin silt and sandy-silt layers
- Fill composed of gravel, silt, sand, metal, brick, and concrete debris
- Alluvial GRAVEL, sandy gravel, gravelly sand, and gravelly silt
- Primarily medium grained SAND with generally less than 15% fines.
- Basalt BEDROCK
- Existing Ground Surface
- Approximate Willametter River Elevation
- -40' - Potential Vertical Barrier Wall
- -60' - Potential Vertical Barrier Wall

MW-21-116 — Boring ID

xx — Boring ID

NAPL and/or Tar Interval

Well Screen

Proposed Extraction Well

Proposed Well or Piezometer

Existing Well or Piezometer

0 50

Scale in Feet

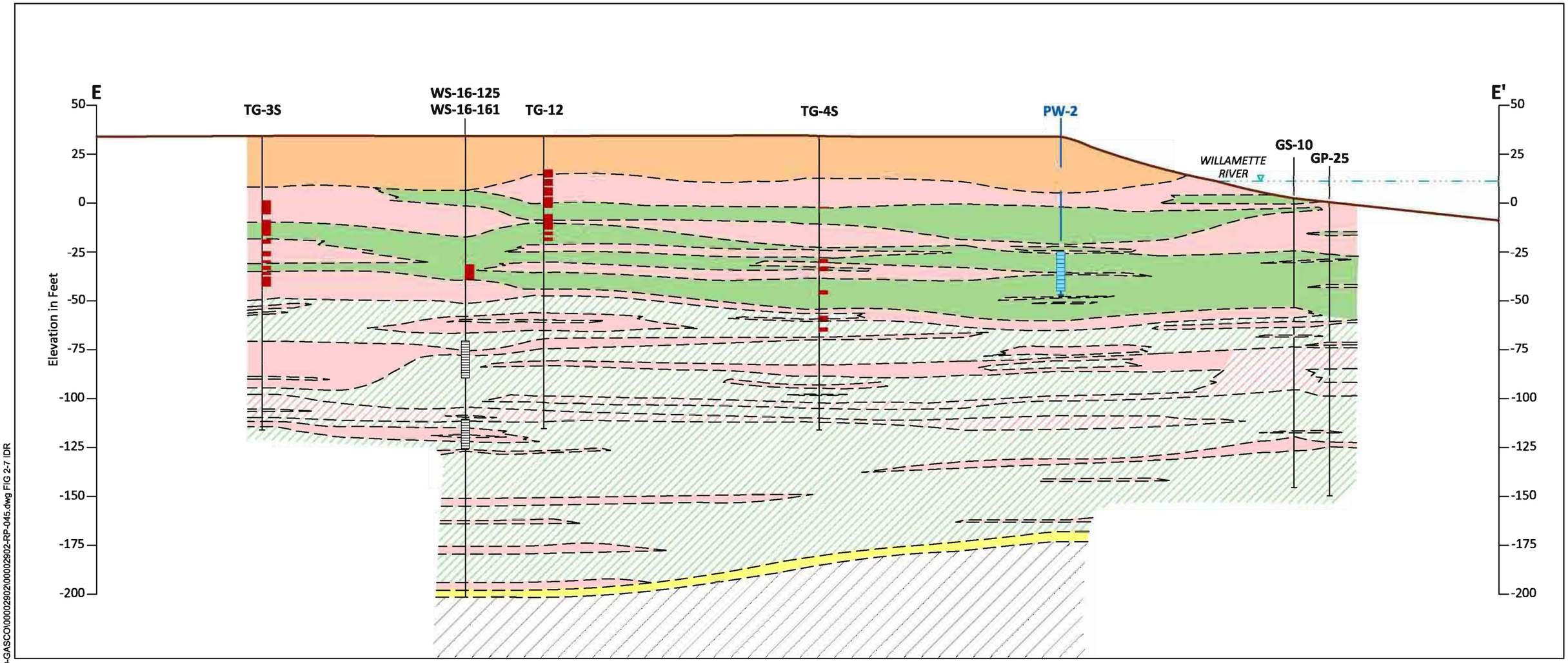
NOTES:
Geologic contacts are inferred between borings.

K:\Jobs\000029-GASCO\00002902\00002902-RP-045.dwg FIG 2-6 IDR

Oct 15, 2009 3:37pm cdavidson

ANCHOR QEA

Figure 2-6
Geologic Cross Section D-D'
Gasco Groundwater Source Control
Interim Design Report



LEGEND:

- Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers
- Aquitard; Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers
- Primarily fine to medium grained SAND and SILTY-SAND interbedded with thin silt and sandy-silt layers
- Fill composed of gravel, silt, sand, metal, brick, and concrete debris
- Alluvial GRAVEL, sandy gravel, gravelly sand, and gravelly silt
- Primarily medium grained SAND with generally less than 15% fines.
- Basalt BEDROCK
- Existing Ground Surface

MW-21-116 — Boring ID

xx — Boring ID

NAPL and/or Tar Interval

Well Screen

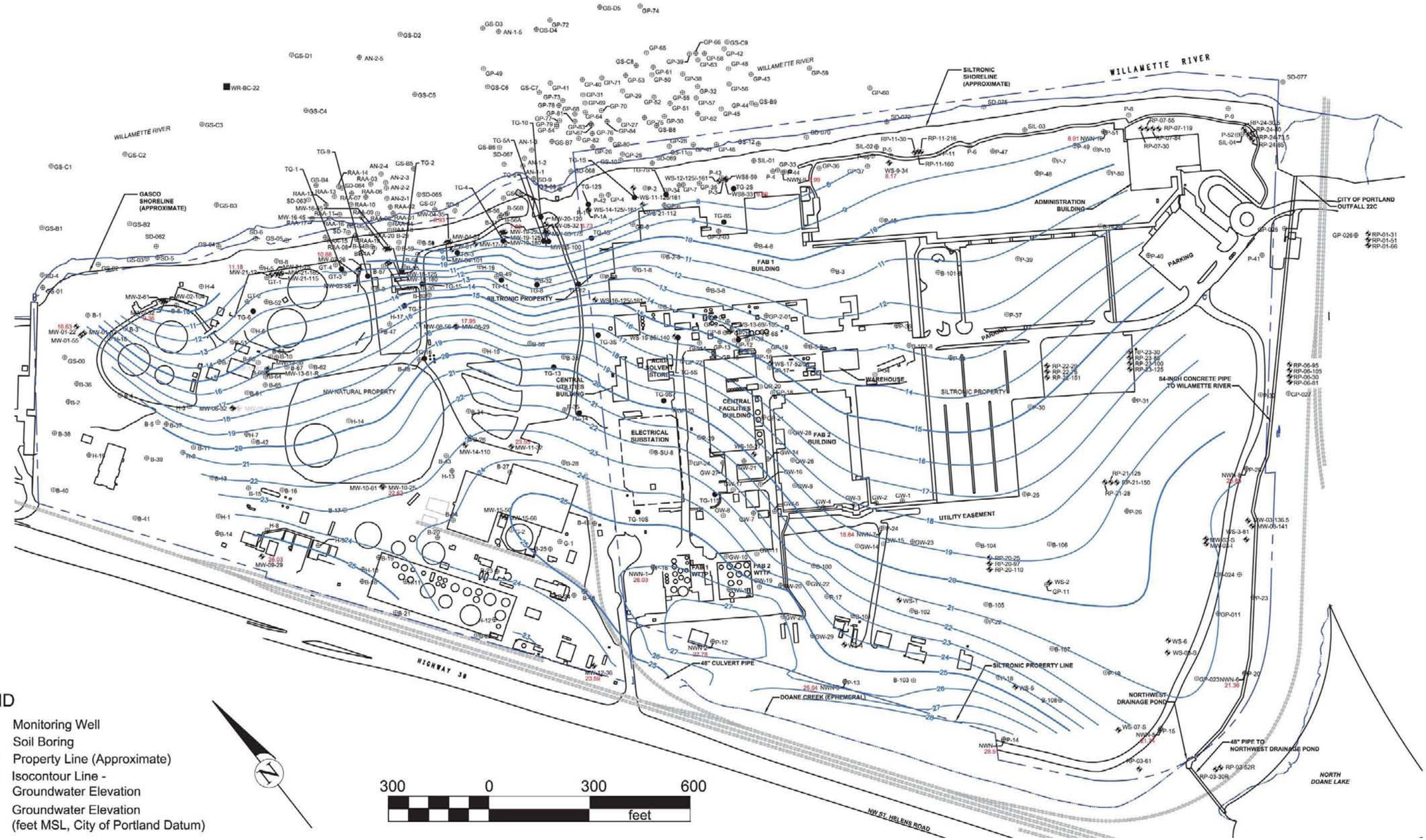
0 50
Scale in Feet

NOTES:
Geologic contacts are inferred between borings.

K:\Jobs\000029-GASCO\00002902\00002902-RP-045.dwg FIG 2-7 IDR
Oct 15, 2009 1:52pm cdavidson

ANCHOR QEA

Figure 2-7
Geologic Cross Section E-E'
Gasco Groundwater Source Control
Interim Design Report

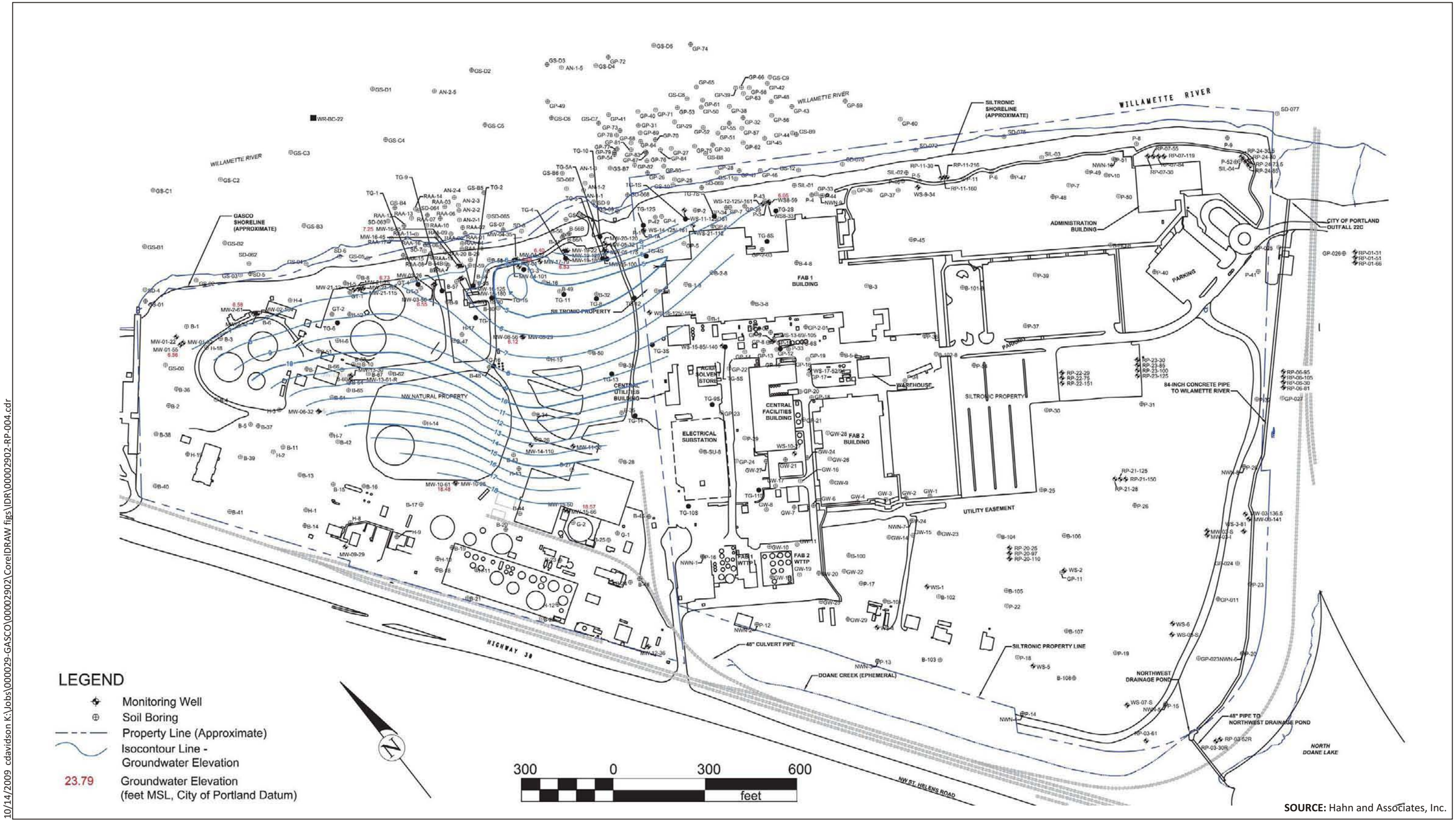


SOURCE: Hahn and Associates, Inc.

10/14/2009 cdavidson K:\Jobs\000029-GASCO\00002902\CorelDRAW figs\IDR\00002902-RP-004.cdr

ANCHOR QEA

Figure 2-8a
Groundwater Elevation Map - Surficial Fill WBZ Wells
Gasco Groundwater Source Control
Interim Design Report

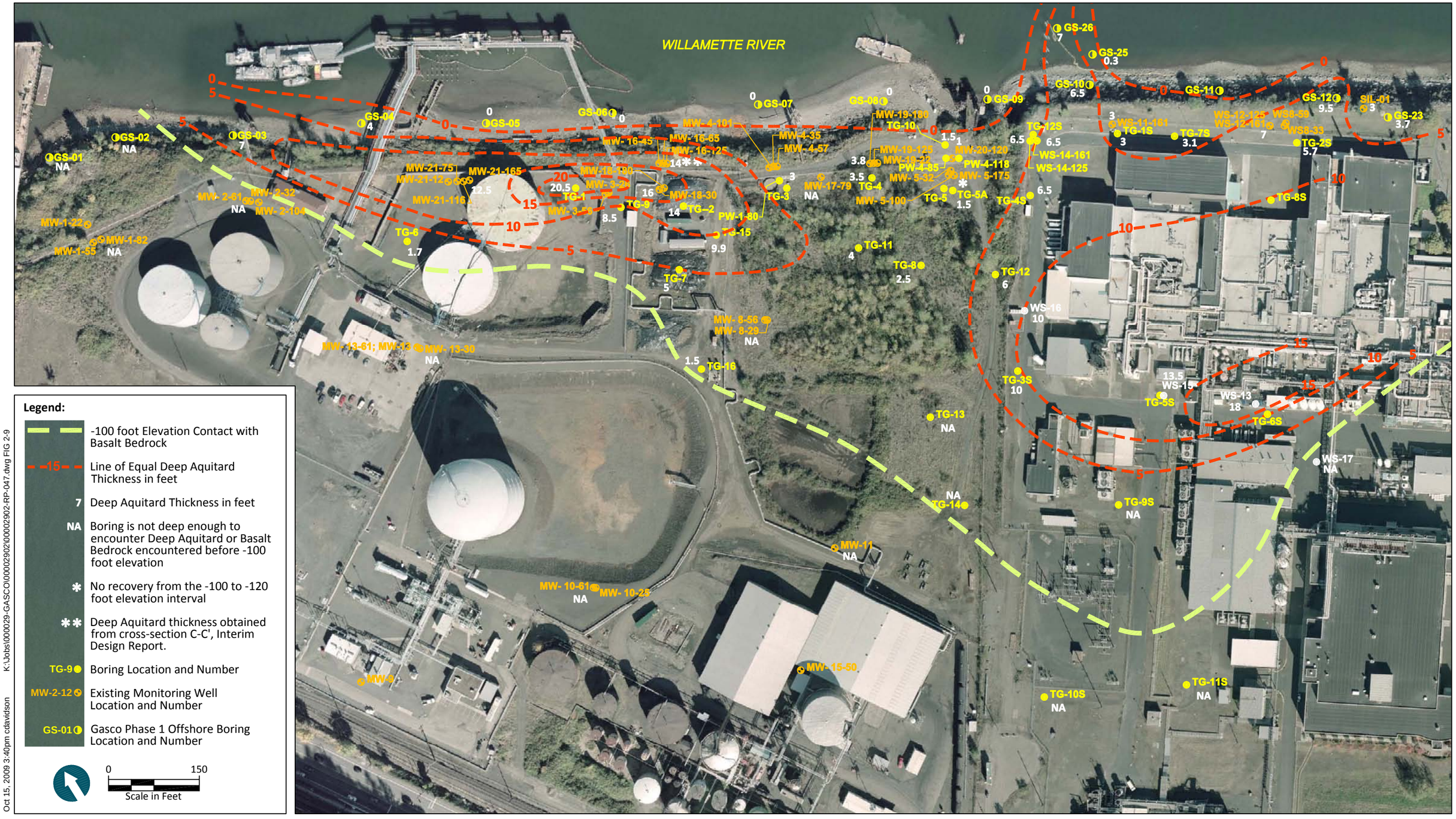


SOURCE: Hahn and Associates, Inc.

10/14/2009 cdavidson K:\Jobs\000029-GASCO\00002902\CorelDRAW figs\IDR\00002902-RP-004.cdr

ANCHOR QEA

Figure 2-8b
Groundwater Elevation Map - Alluvial WBZ Wells - to 80' BGS
Gasco Groundwater Source Control
Interim Design Report



K:\Jobs\000029-GASCO\0000292\0000292-RP-047.dwg FIG 2-9

Oct 15, 2009 3:40pm cdavidson

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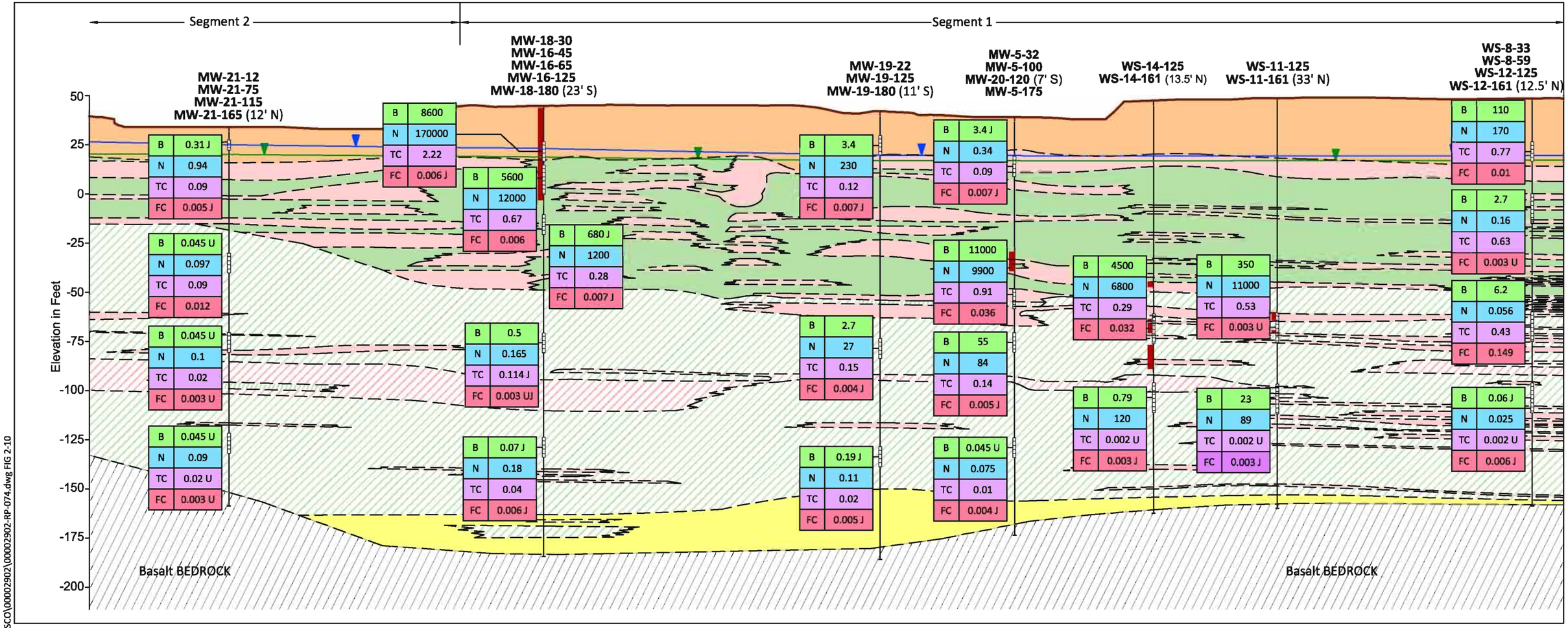
Figure 2-9
Deep Aquitard Isopach Map
Gasco Groundwater Source Control
Interim Design Report



K:\Jobs\000029-GASCO\00002902\00002902-RP-074.dwg FIG 2-10

Oct 14, 2009 12:51pm cdavidson

LEGEND:

- Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers
- Aquitard; Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers
- Primarily fine to medium grained SAND and SILTY-SAND interbedded with thin silt and sandy-silt layers
- Fill composed of gravel, silt, sand, metal, brick, and concrete debris
- Alluvial GRAVEL, sandy gravel, gravelly sand, and gravelly silt
- Primarily medium grained SAND with generally less than 15% fines.
- Basalt BEDROCK
- Potentiometric Surface of Surficial Fill (measured 9/07)
- Potentiometric Surface of Alluvium (measured 9/07)
- Existing Ground Surface

MW-21 — Boring ID

xx — Boring ID

Existing Well or Piezometer

NAPL and/or Tar Interval

Well Screen

- B — Benzene in ppb
- N — Naphthalene in ppb
- TC — Total Cyanide in ppm
- FC — Free Cyanide in ppm
- U — Not Detected at the Detection Limit
- J — Estimated Value
- NS — Not Sampled

0 100

Scale in Feet

Vertical Exaggeration x 2

NOTES:

1. Samples collected September 9 and 10, 2008.
2. No sample taken in Sep. 2008 at MW-21-12. Table presents closest sample date Dec. 2008.
3. No sample taken in Sep. 2008 at MW-16-125. Table presents closest sample date Aug. 2007.
4. No sample taken in Sep. 2009 at MW-18-30. Table presents closest sample date May. 2008.
5. Geologic contacts are inferred between borings.

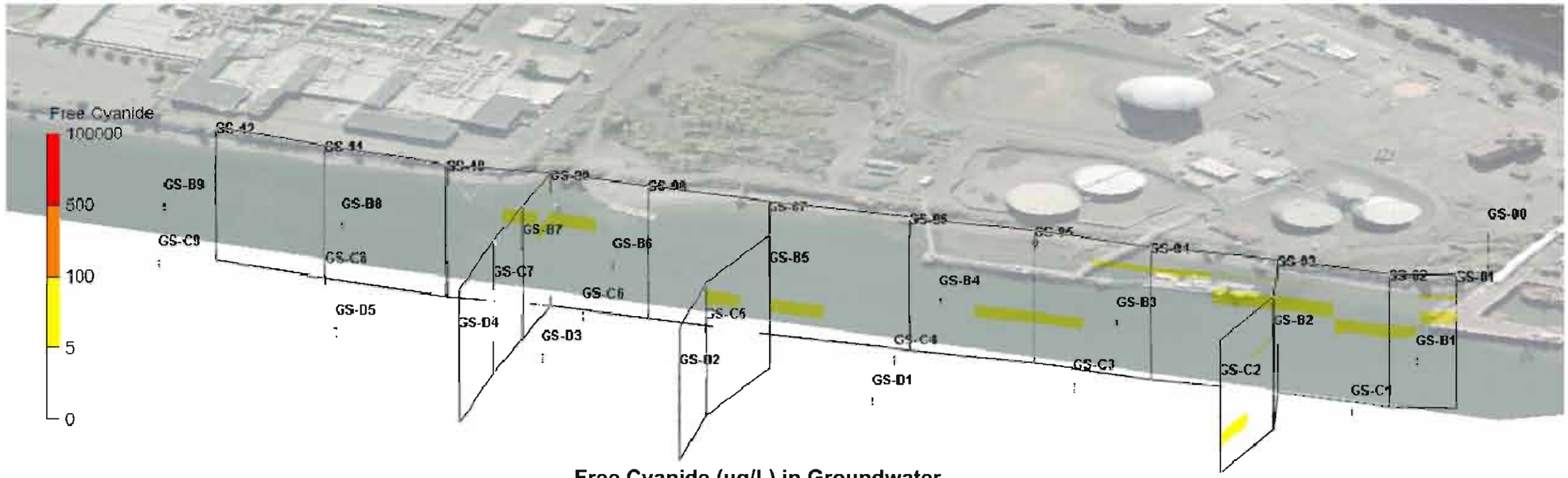
ANCHOR QEA

Figure 2-10

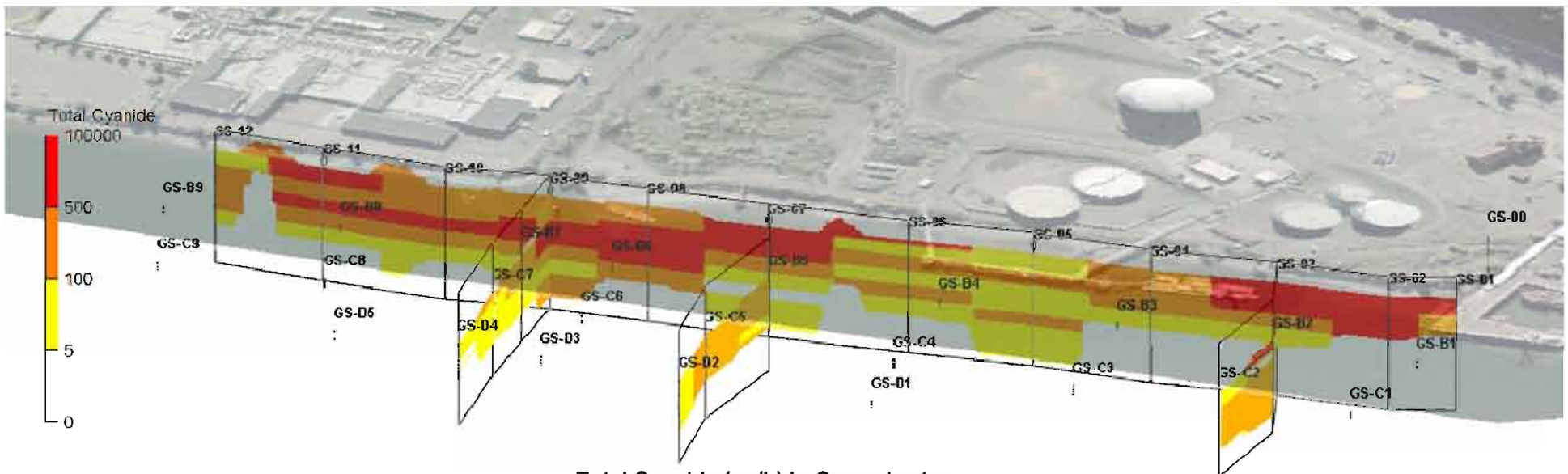
Shoreline Groundwater Qaulity Data, Section A-A'

Gasco Groundwater Source Control

Interim Design Report



Free Cyanide (ug/L) in Groundwater



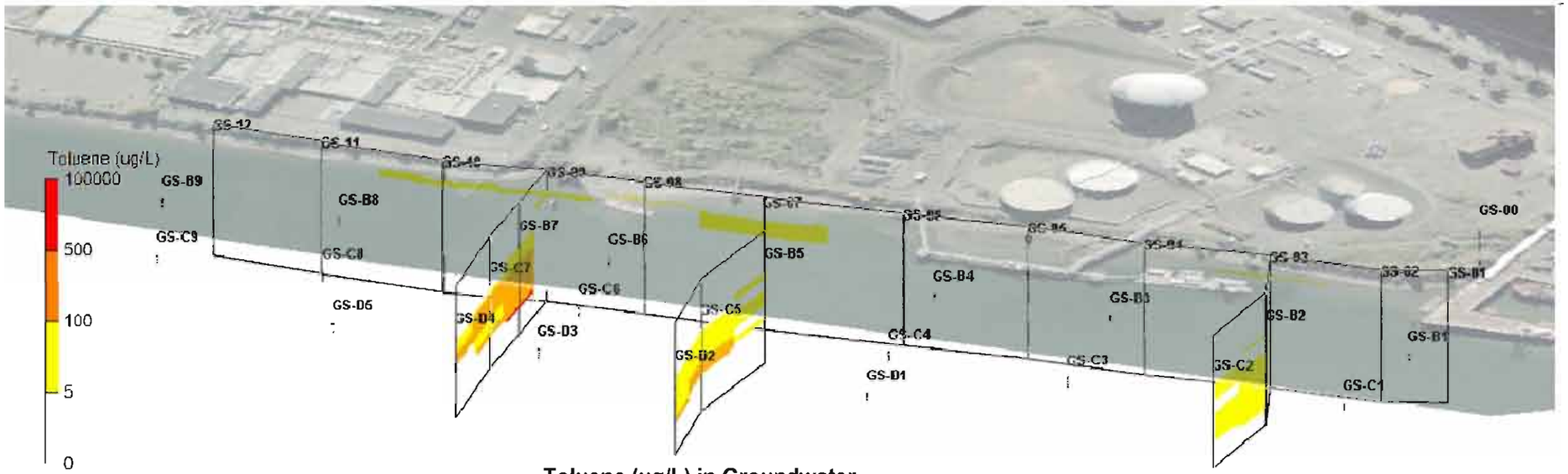
Total Cyanide (ug/L) in Groundwater

NOTE: Locations are approximate and are for visualization purposes only.

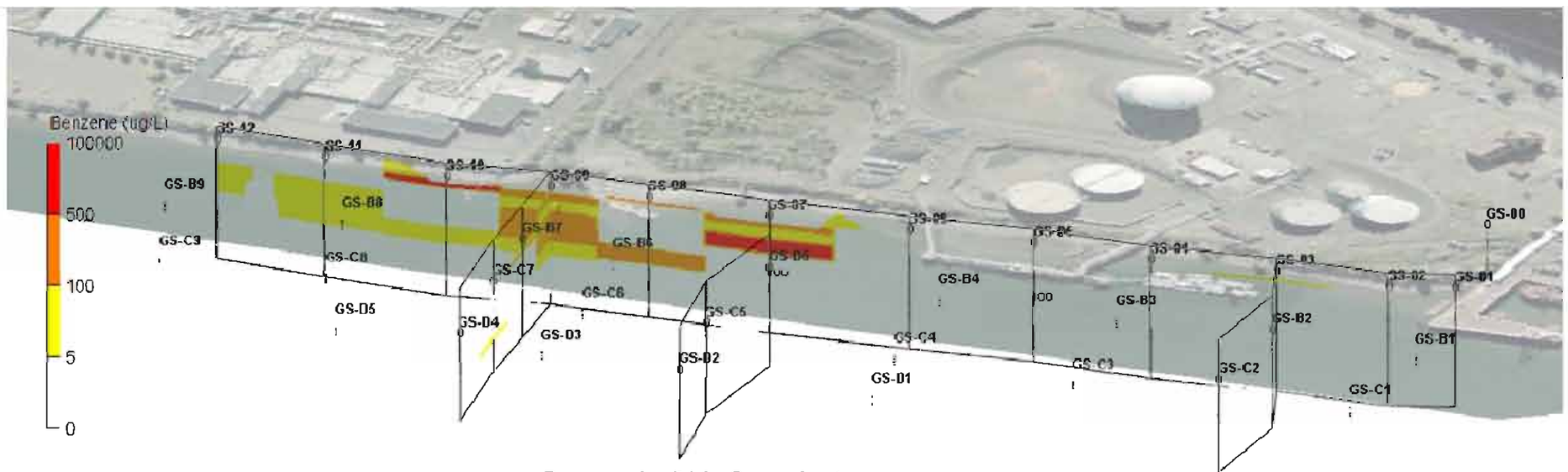
Oct 14, 2009 3:55pm cdavidson K:\Jobs\000029-GASCO\00002802\00002902-RP-033.dwg FIG 2-11a

ANCHOR QEA

Figure 2-11a
3D MGP Plume Maps - Free and Total Cyanide
Gasco Groundwater Source Control
Interim Design Report



Toluene (ug/L) in Groundwater



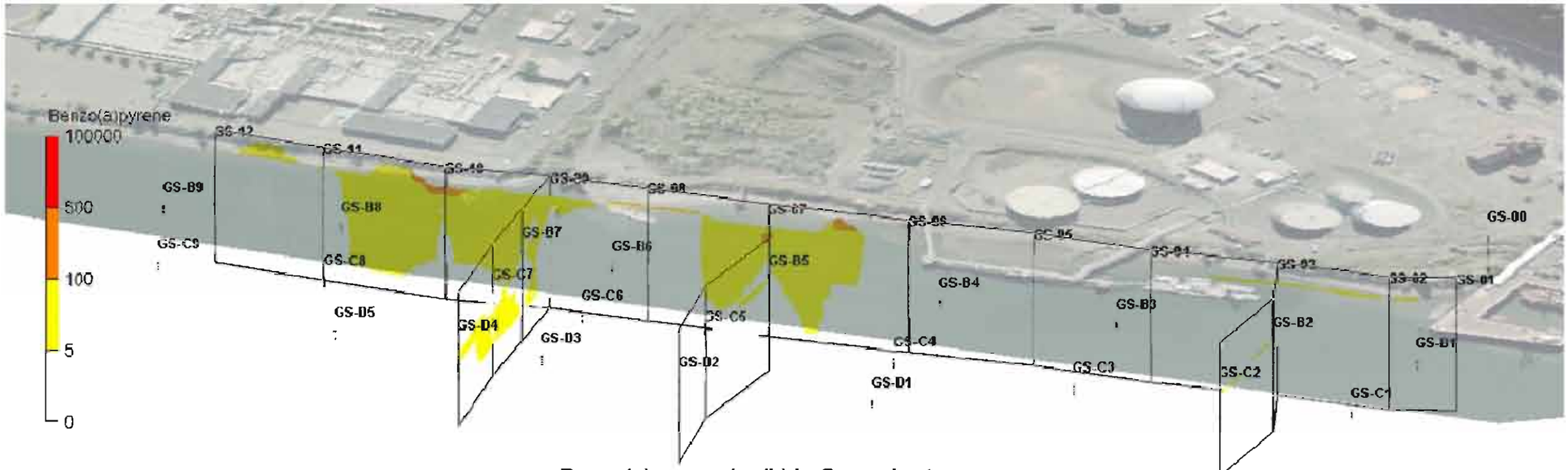
Benzene (ug/L) in Groundwater

NOTE: Locations are approximate and are for visualization purposes only.

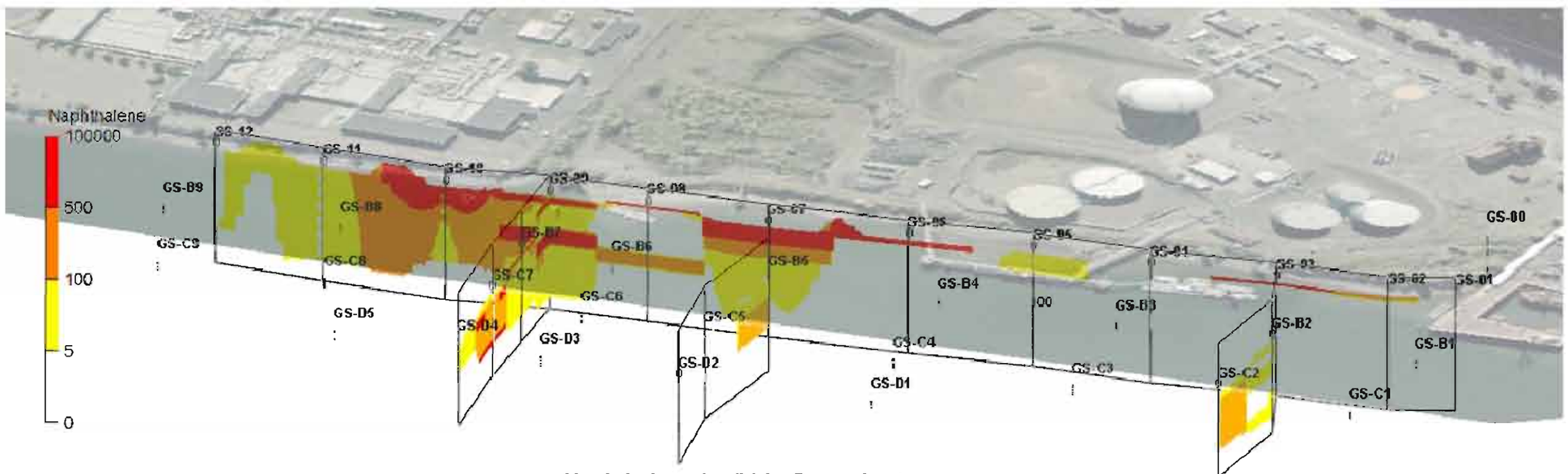
ANCHOR QEA

Figure 2-11b
3D MGP Plume Maps - Toluene and Benzene
Gasco Groundwater Source Control
Interim Design Report

Oct 14, 2009 9:33am cdavidson K:\Jobs\000029-GASCO\00002802\00002902-RP-033.dwg FIG 2-11b



Benzo(a)pyrene (ug/L) in Groundwater



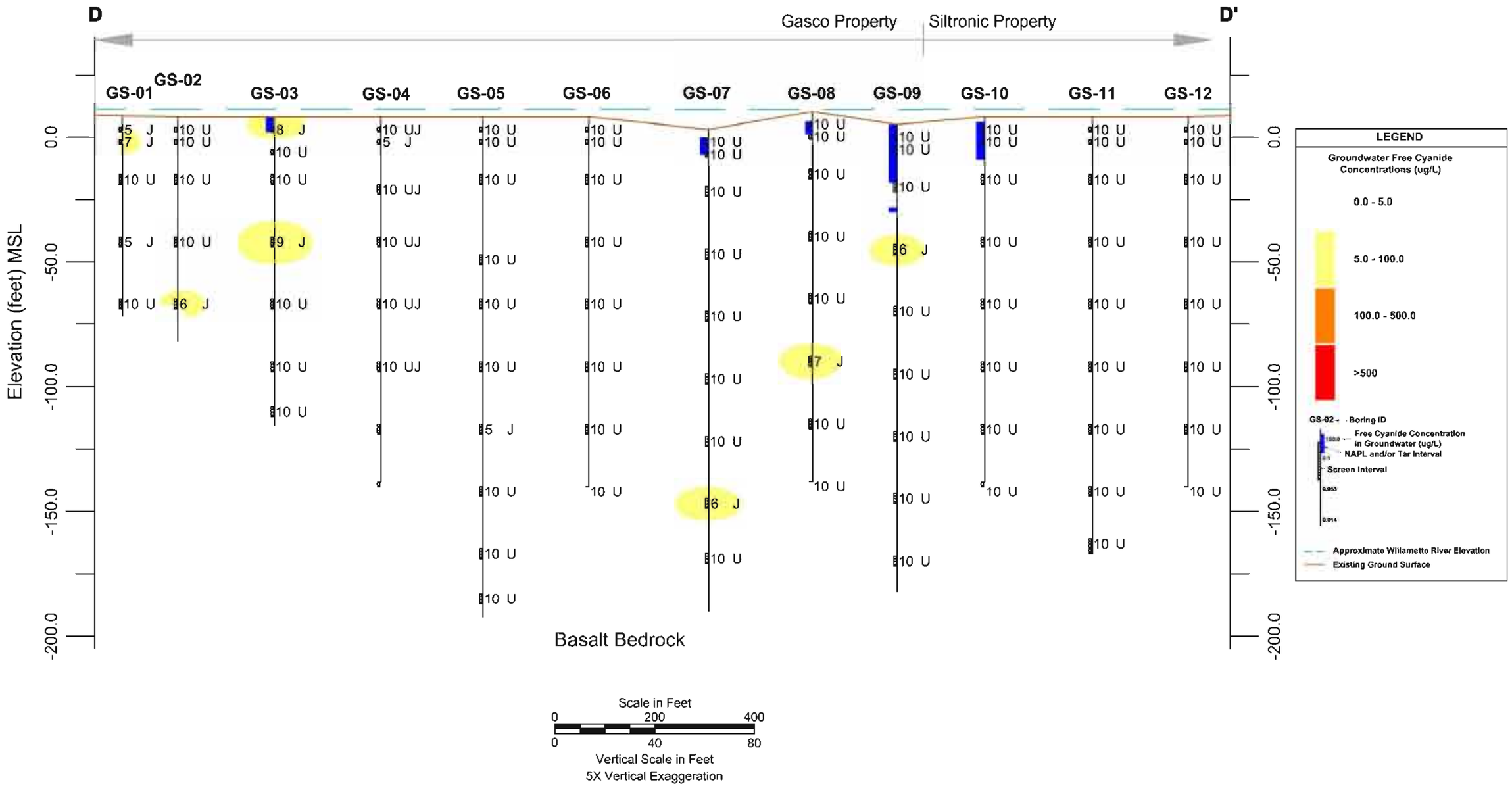
Naphthalene (ug/L) in Groundwater

NOTE: Locations are approximate and are for visualization purposes only.

Oct 14, 2009 9:33am cdavidson K:\Jobs\000029-GASCO\00002902\00002902-RP-033.dwg FIG 2-11c

ANCHOR QEA

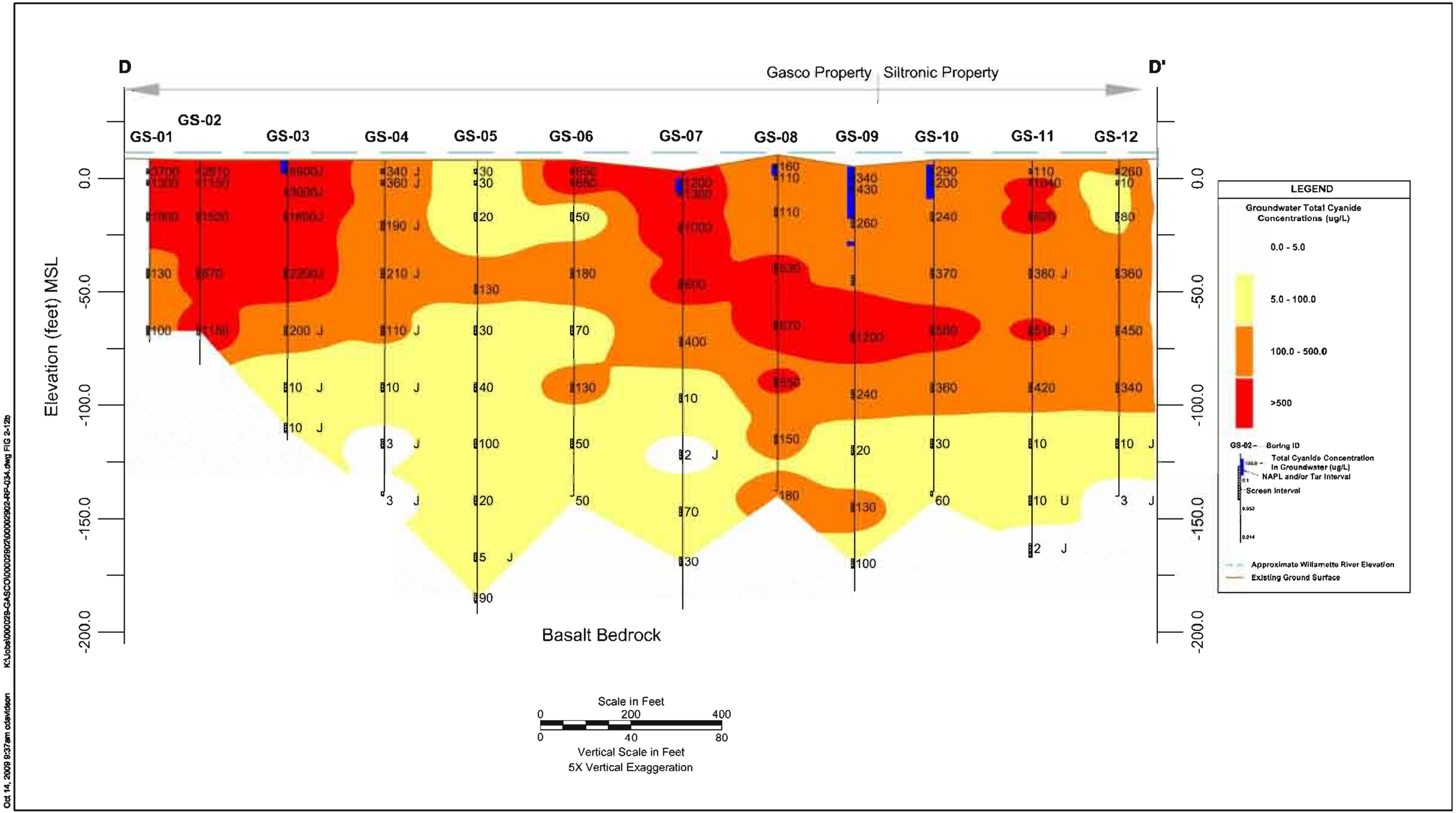
Figure 2-11c
3D MGP Plume Maps - Benzo(a)pyrene and Naphthalene
Gasco Groundwater Source Control
Interim Design Report



Oct 14, 2009 9:37am cdavidson K:\Jobs\000029-GASCO\00002802\00002902-RP-034.dwg FIG 2-12a

ANCHOR QEA

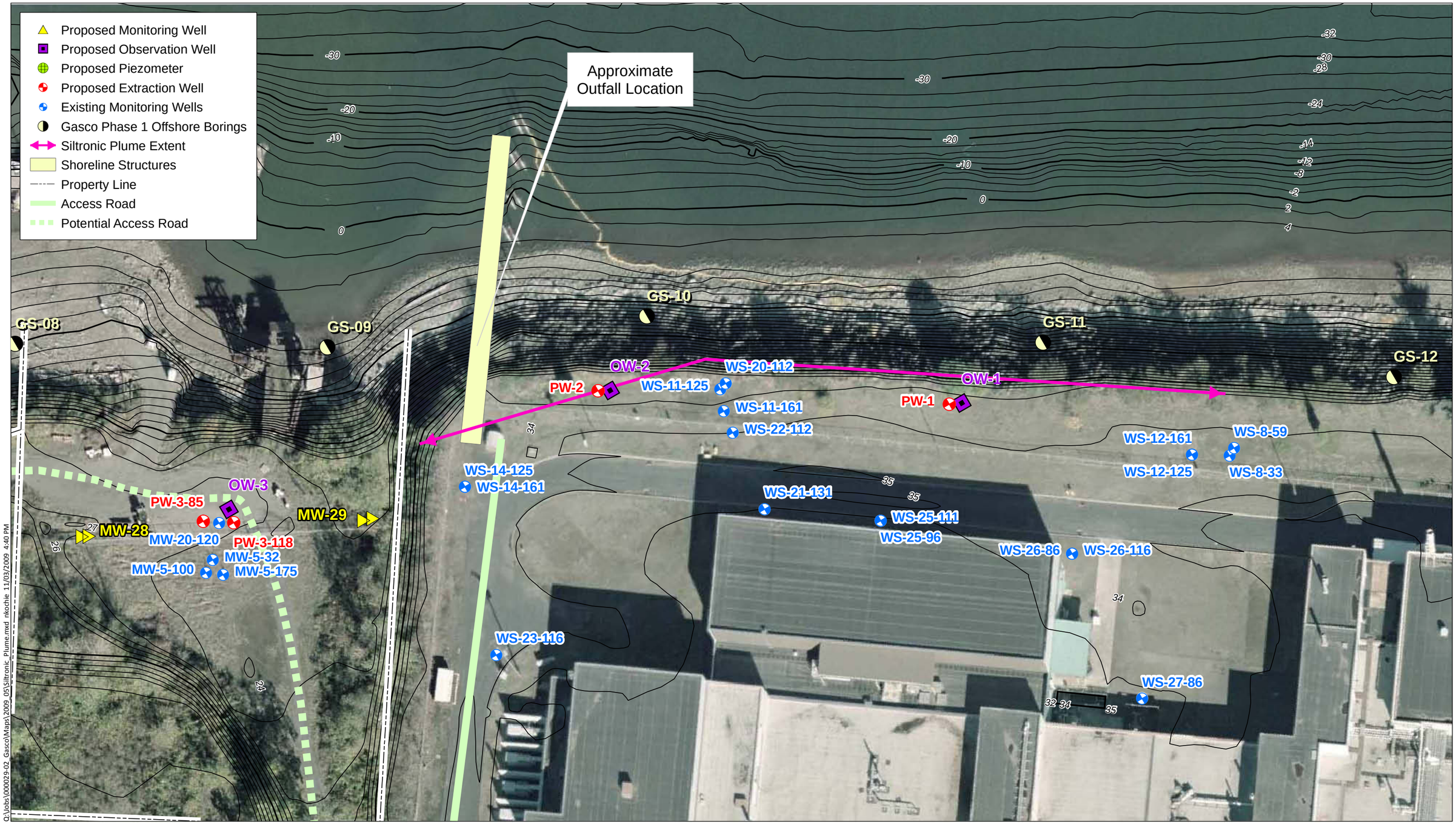
Figure 2-12a
Subsurface Profile D-D' - Free Cyanide
Gasco Groundwater Source Control
Interim Design Report



Oct 14, 2009 9:37am cdavidson K:\Jobs\000029-GASCO\00002902\00002902-RIP-G34.dwg FIG 2-12b

ANCHOR QEA

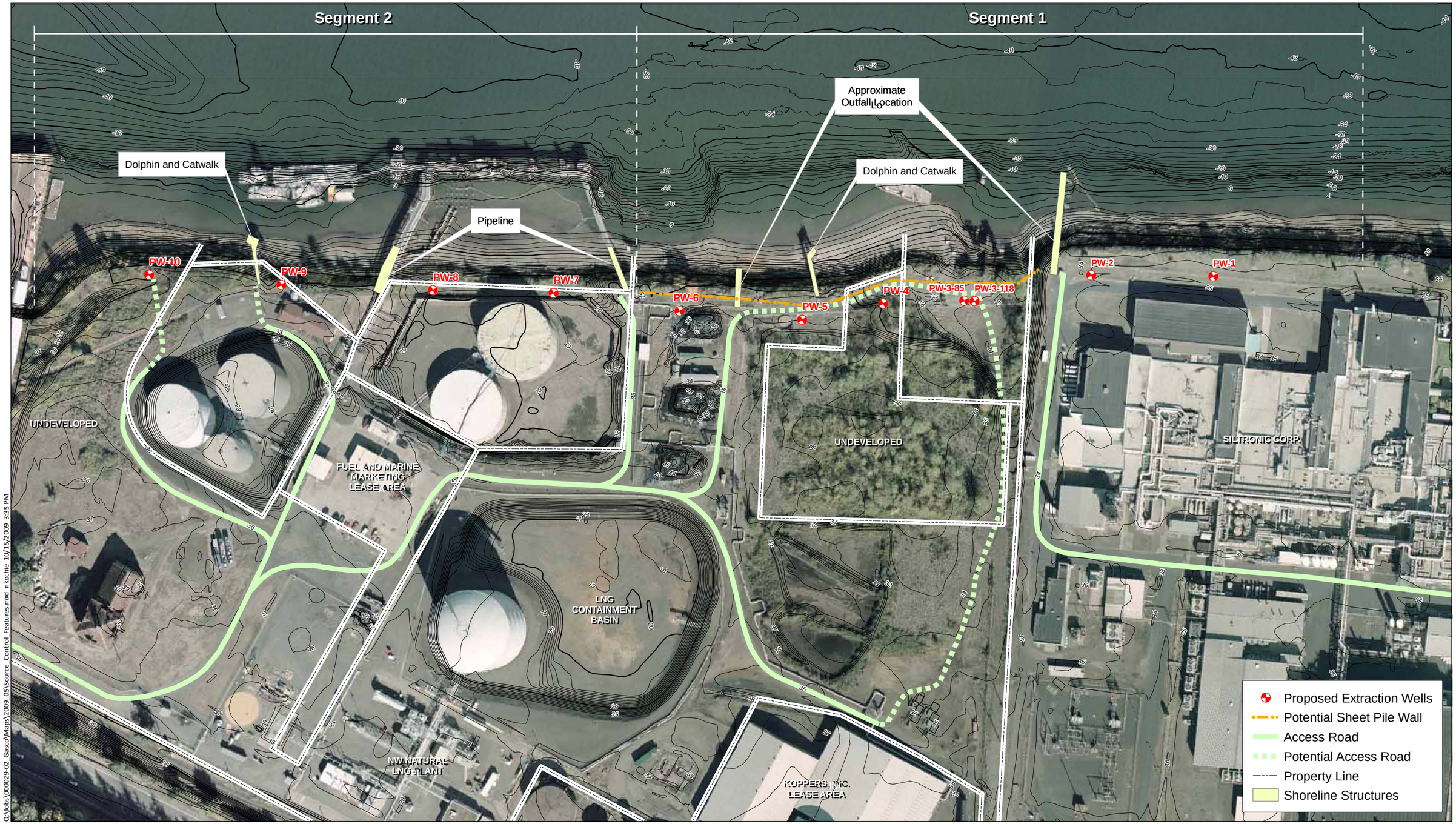
Figure 2-12b
Subsurface Profile D-D' - Total Cyanide
Gasco Groundwater Source Control
Interim Design Report



ANCHOR QEA

Feet
0 50 100

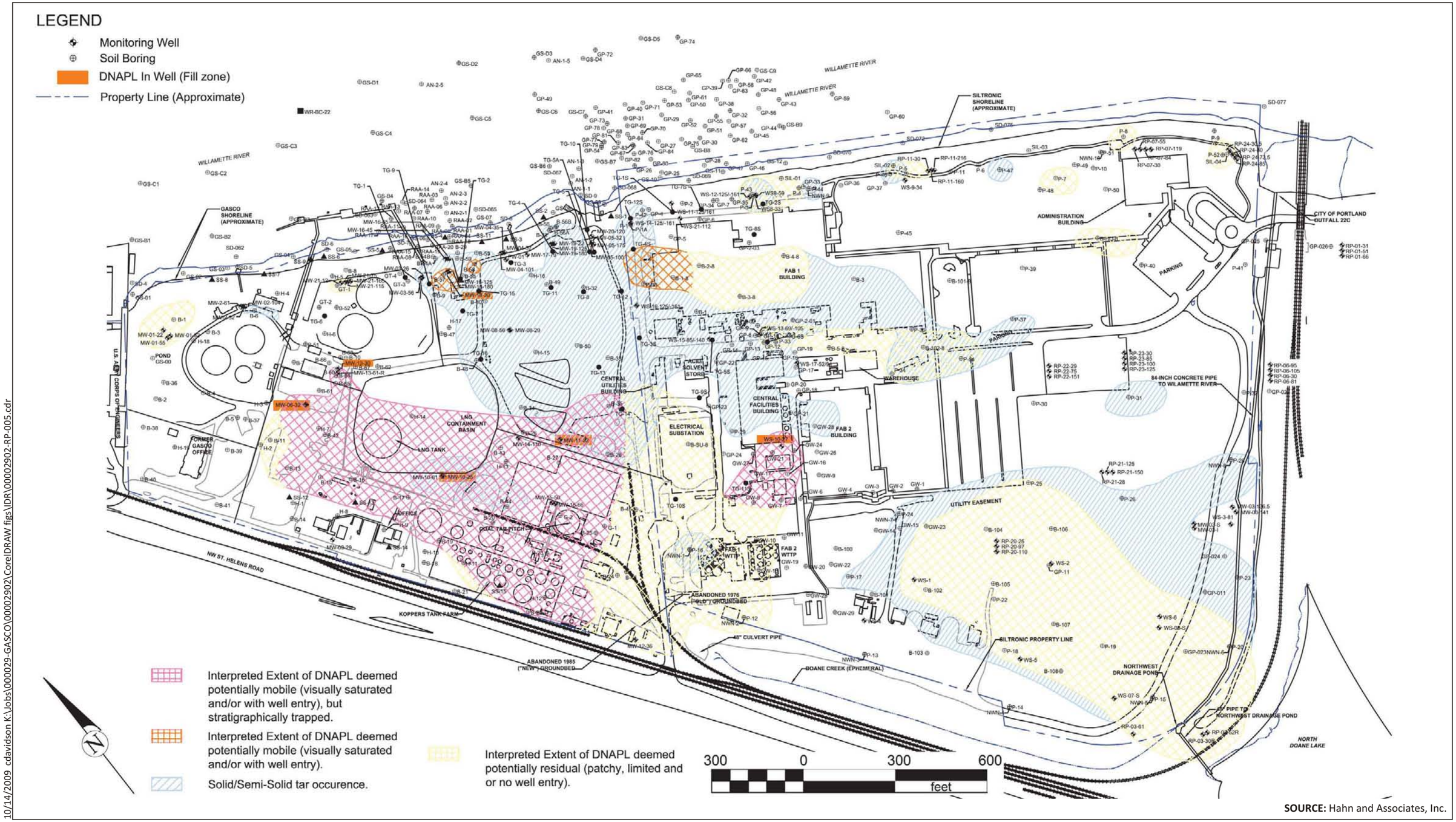
Figure 2-13
Siltronic CVOC Plume Map
Gasco Groundwater Source Control
Interim Design Report



ANCHOR QEA

Feet
0 75 150 225 300

Figure 3-1
Source Control Features
Gasco Groundwater Source Control
Interim Design Report



SOURCE: Hahn and Associates, Inc.

10/14/2009 cdavidson K:\Jobs\000029-GASCO\00002902\CorelDRAW figs\DR\00002902-RP-005.cdr

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Figure 3-2a
Estimated Distribution of Tar and DNAPL within the Fill Zone
Gasco Groundwater Source Control
Interim Design Report

Table: TarGOST DNAPL Presence
Screening Results - Gasco Property

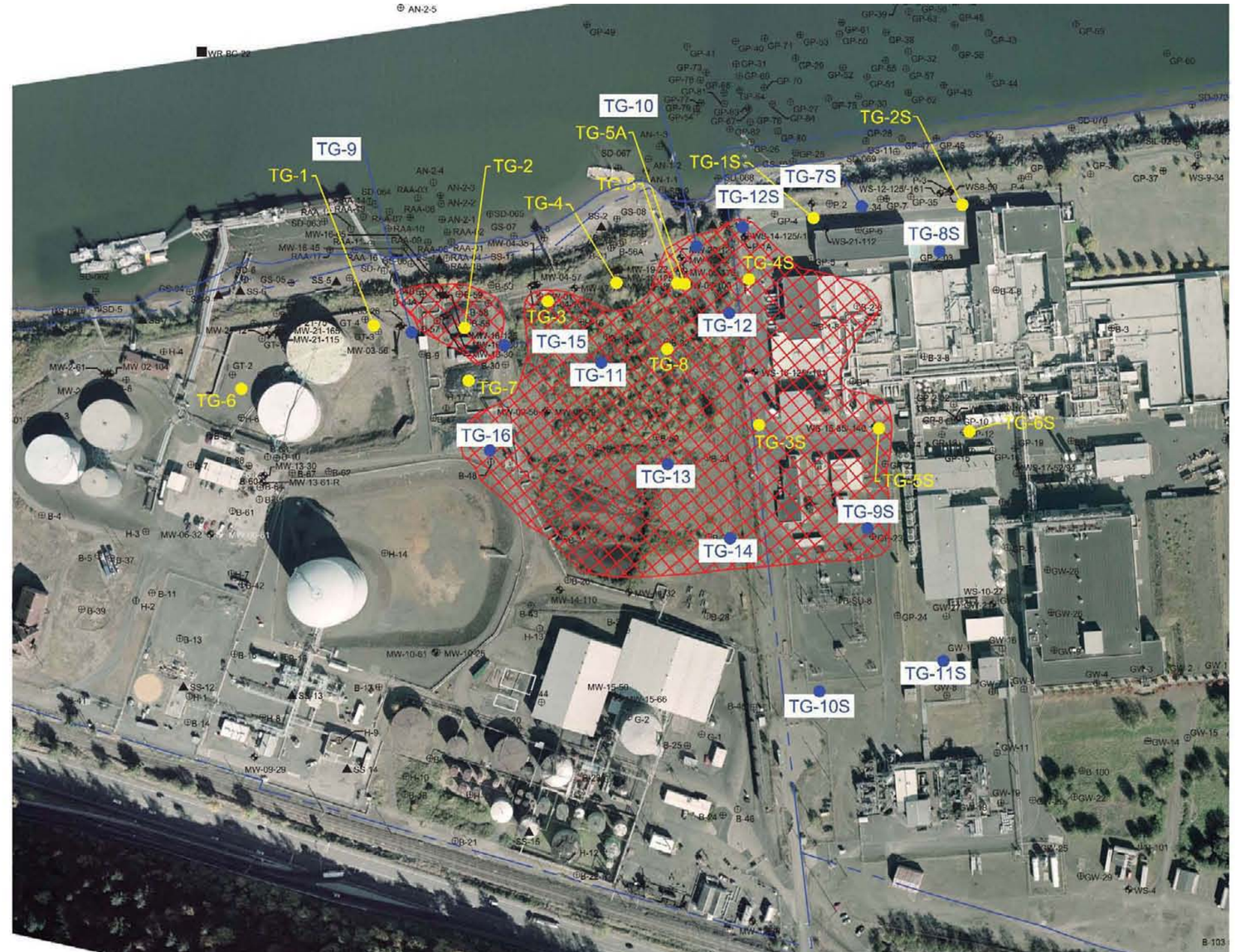
Boring ID	Boring Depth (ft bgs)	Depths of DNAPL Indication (Alluvial)
TG-1	150'	NONE
TG-2	150'	28.7'-30.6'
TG-3	150'	58.8'-60.6'
TG-4	150'	NONE
TG-5	100'	51.6'-53.3',57.8'-58.8',59.3'-63.2' 64.8'-65.1'
TG-5A	150'	51.3' ?
TG-6	125'	NONE
TG-7	150'	NONE
TG-8	150'	25'-39',41.4'-43.6',44.1'-45.3' 48.7'-48.9',51.5'-52.3',54.9'-61.1'
TG-9	148'	26',28' (MINOR)
TG-10	151'	75.5'-76.5',79.5'-86.5'
TG-11	150'	54'-56',112'?
TG-12	150'	26.5'-29.5',30'-32',32.5'-36.5', 40.5'-42.5',44.5'-48',50',52.5' ?
TG-13	102' (REFUSAL)	26.5'-36' (MINOR),36'-40',46'-50', 55'-68'
TG-14	100' (REFUSAL)	25'-34' (MINOR),36'-40',46'
TG-15	149'	144' (SHELL?) ?
TG-16	149'	42'-46',60'-61',78'-84'

Table: TarGOST DNAPL Presence
Screening Results - Siltronic Property

Boring ID	Boring Depth (ft bgs)	Depths of DNAPL Indication (Alluvial)
TG-1S	150'	116.2-118.6'
TG-2S	150'	NONE
TG-3S	150'	34'-78' in multiple intervals
TG-4S	150'	36.7'-36.9',62.8'-63.5',63.8'-65.6' 67.3'-68.6',79.0'-80.8',91.8'-93.2' 93.9'-94.5',98.6'-100'
TG-5S	150'	30'-38.6',40.2'-41.5',42.9'-44.2'
TG-6S	150'	NONE
TG-7S	150'	NONE
TG-8S	147'	NONE
TG-9S	148'	30'-42.5',44'-48',50',74'
TG-10S	91'	NONE
TG-11S	79'	NONE
TG-12S	156'	94'-96.5',110.5',113.5'-114', 115.5'-116',116.5'-120',126'-126.5',130'-131',133'-136'

NOTES:
Borings within outlined areas identified the presence of DNAPL at some depth or depth interval within the Alluvial water-bearing zone at depths shallower than 100' bgs.
Tables 2 and 3 of *Summary Report - Former MGP Operations and DNAPL Occurrence* (HAI, November 2005) provide a description of the DNAPL presence at each boring.
TarGOST ™ = Tar-Specific Green Optical Screening Tool by Dakota Technologies.

Interpreted Extent of DNAPL (visually saturated, well entry, or TarGost ID).



300 0 300 600
feet

LEGEND
- Monitoring Well
- Soil Boring
- Property Line (Approximate)
- 2007 TarGost/CPT Boring Locations (TG-Series)
- 2008 Approximate TarGost/CPT Boring Locations (TG-Series) - Not Surveyed

SOURCE: Hahn and Associates, Inc.

10/14/2009 cdavidson K:\Jobs\000029-GASCO\00002902\CorelDRAW figs\IDR\00002902-RP-005.cdr

ANCHOR QEA

Figure 3-2b
DNAPL Screening with TarGOST 2007 and 2008 Boring Locations Showing Estimated DNAPL within Alluvial - Above 100' BGS
Gasco Groundwater Source Control
Interim Design Report

Table: TarGOST DNAPL Presence
Screening Results - Gasco Property

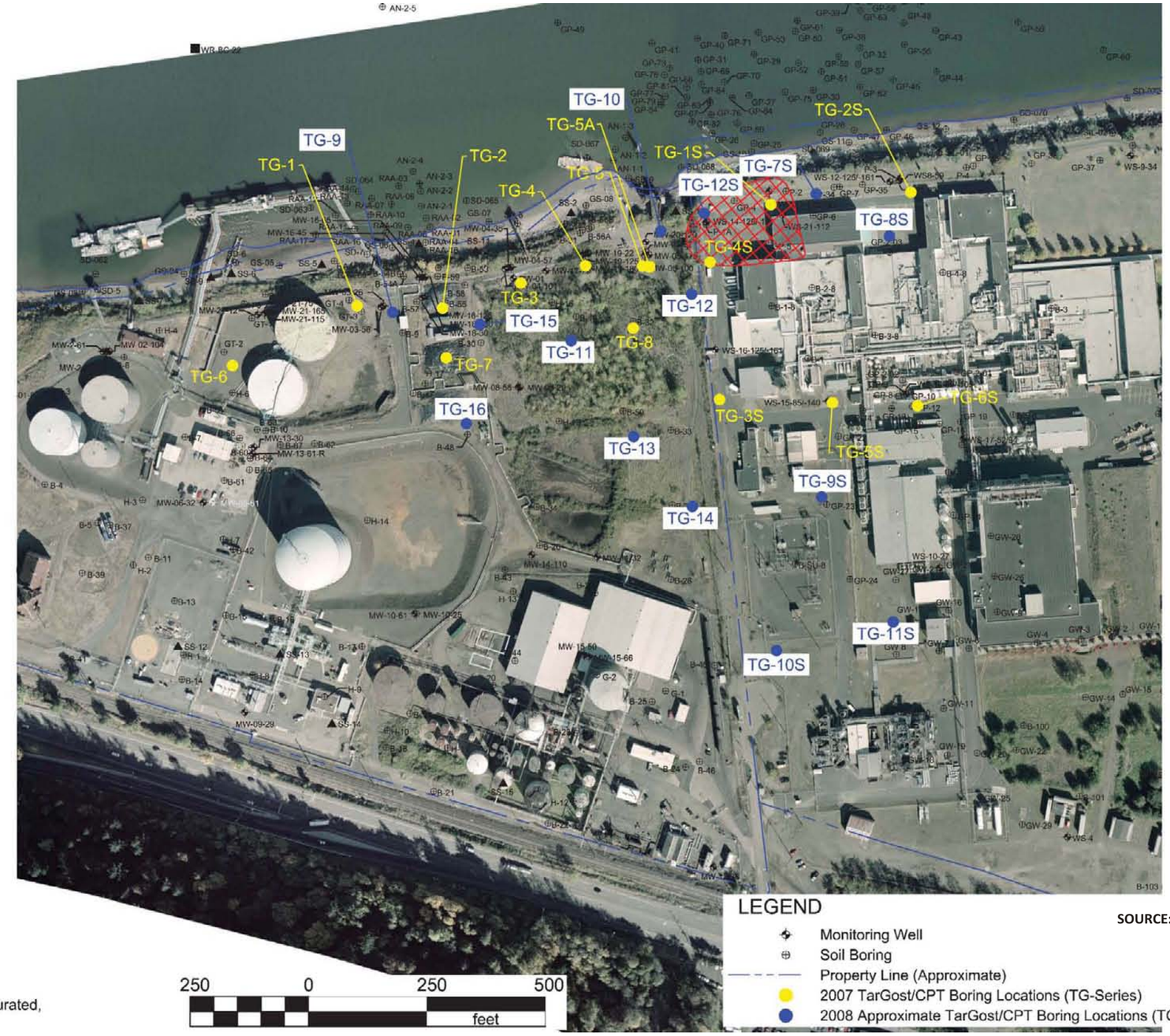
Boring ID	Boring Depth (ft bgs)	Depths of DNAPL Indication (Alluvial)
TG-1	150'	NONE
TG-2	150'	28.7'-30.6'
TG-3	150'	58.8'-60.6'
TG-4	150'	NONE
TG-5	100'	51.6'-53.3',57.8'-58.8',59.3'-63.2' 64.8'-65.1'
TG-5A	150'	51.3' ?
TG-6	125'	NONE
TG-7	150'	NONE
TG-8	150'	25'-39',41.4'-43.6',44.1'-45.3' 48.7'-48.9',51.5'-52.3',54.9'-61.1'
TG-9	148'	26',28' (MINOR)
TG-10	151'	75.5'-76.5',79.5'-86.5'
TG-11	150'	54'-56',112'?
TG-12	150'	26.5'-29.5',30'-32',32.5'-36.5', 40.5'-42.5',44.5'-48',50',52.5' ?
TG-13	102' (REFUSAL)	26.5'-36' (MINOR),36'-40',46'-50', 55'-68'
TG-14	100' (REFUSAL)	25'-34' (MINOR),36'-40',46'
TG-15	149'	144' (SHELL?) ?
TG-16	149'	42'-46',60'-61',78'-84'

Table: TarGOST DNAPL Presence
Screening Results - Siltronic Property

Boring ID	Boring Depth (ft bgs)	Depths of DNAPL Indication (Alluvial)
TG-1S	150'	116.2-118.6'
TG-2S	150'	NONE
TG-3S	150'	34'-78' in multiple intervals
TG-4S	150'	36.7'-36.9',62.8'-63.5',63.8'-65.6' 67.3'-68.6',79.0'-80.8',91.8'-93.2' 93.9'-94.5',98.6'-100'
TG-5S	150'	30'-38.6',40.2'-41.5',42.9'-44.2'
TG-6S	150'	NONE
TG-7S	150'	NONE
TG-8S	147'	NONE
TG-9S	148'	30'-42.5',44'-48',50',74'
TG-10S	91'	NONE
TG-11S	79'	NONE
TG-12S	156'	94'-96.5',110.5',113.5'-114', 115.5'-116',116.5'-120',126'-126.5',130'-131',133'-136'

NOTES:
Borings within outlined areas identified the presence of DNAPL at some depth or depth interval within the Alluvial water-bearing zone at depths shallower than 100' bgs. Tables 2 and 3 of *Summary Report - Former MGP Operations and DNAPL Occurrence* (HAI, November 2005) provide a description of the DNAPL presence at each boring.
TarGOST ™ = Tar-Specific Green Optical Screening Tool by Dakota Technologies.

Interpreted Extent of DNAPL (visually saturated, well entry, or TarGost ID).



SOURCE: Hahn and Associates, Inc.

10/14/2009 cdavidson K:\Jobs\000029-GASCO\00002902\CorelDRAW figs\IDR\00002902-RP-005.cdr

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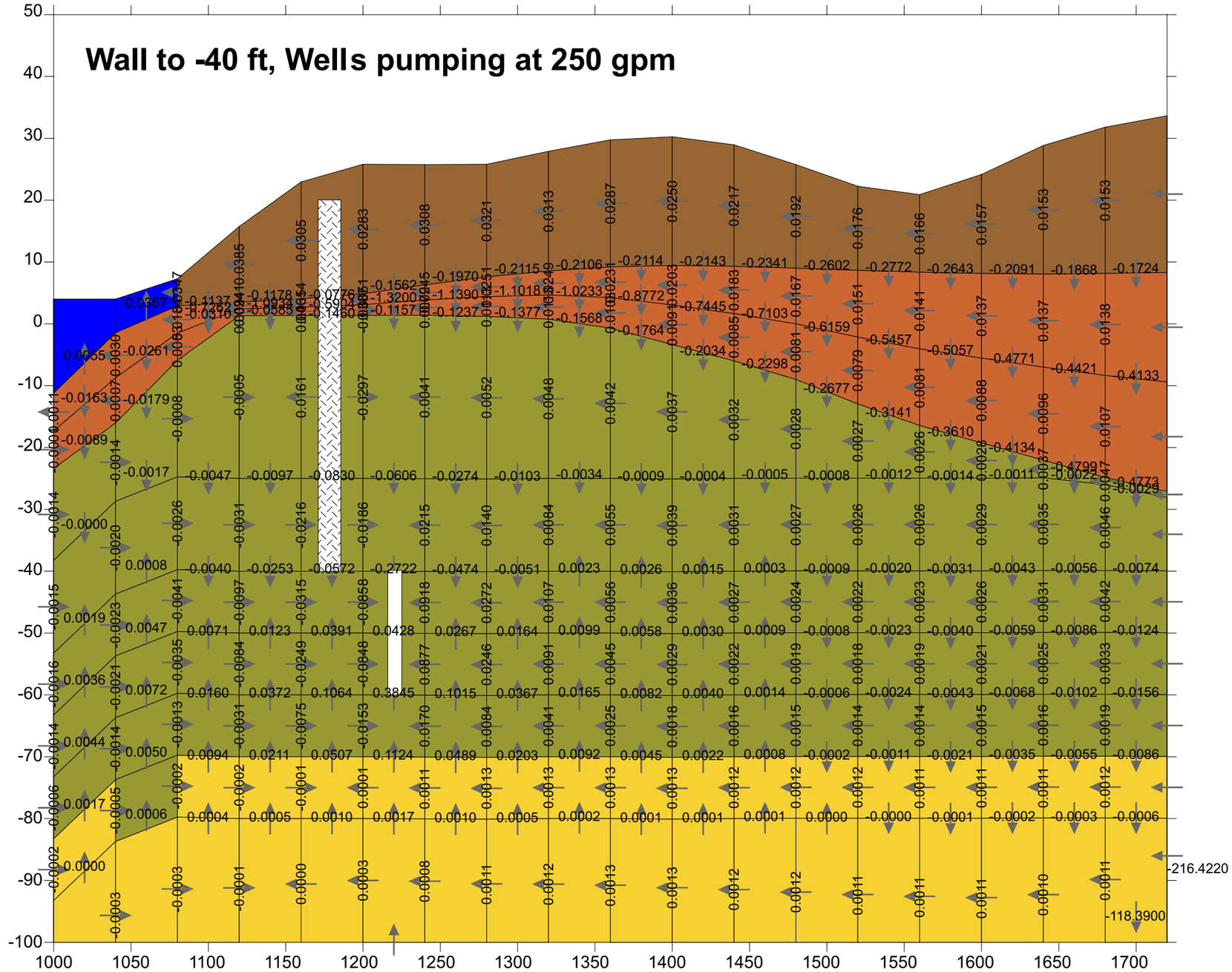
Figure 3-2c
DNAPL Screening with TarGOST 2007 and 2008 Boring Locations Showing Estimated DNAPL within Alluvial - Above 100' BGS
Gasco Groundwater Source Control
Interim Design Report



10/15/2009 cdavidson K:\Jobs\000029-GASCO\00002902\CorelDRAW figs\IDR\00002902-RP-002.cdr

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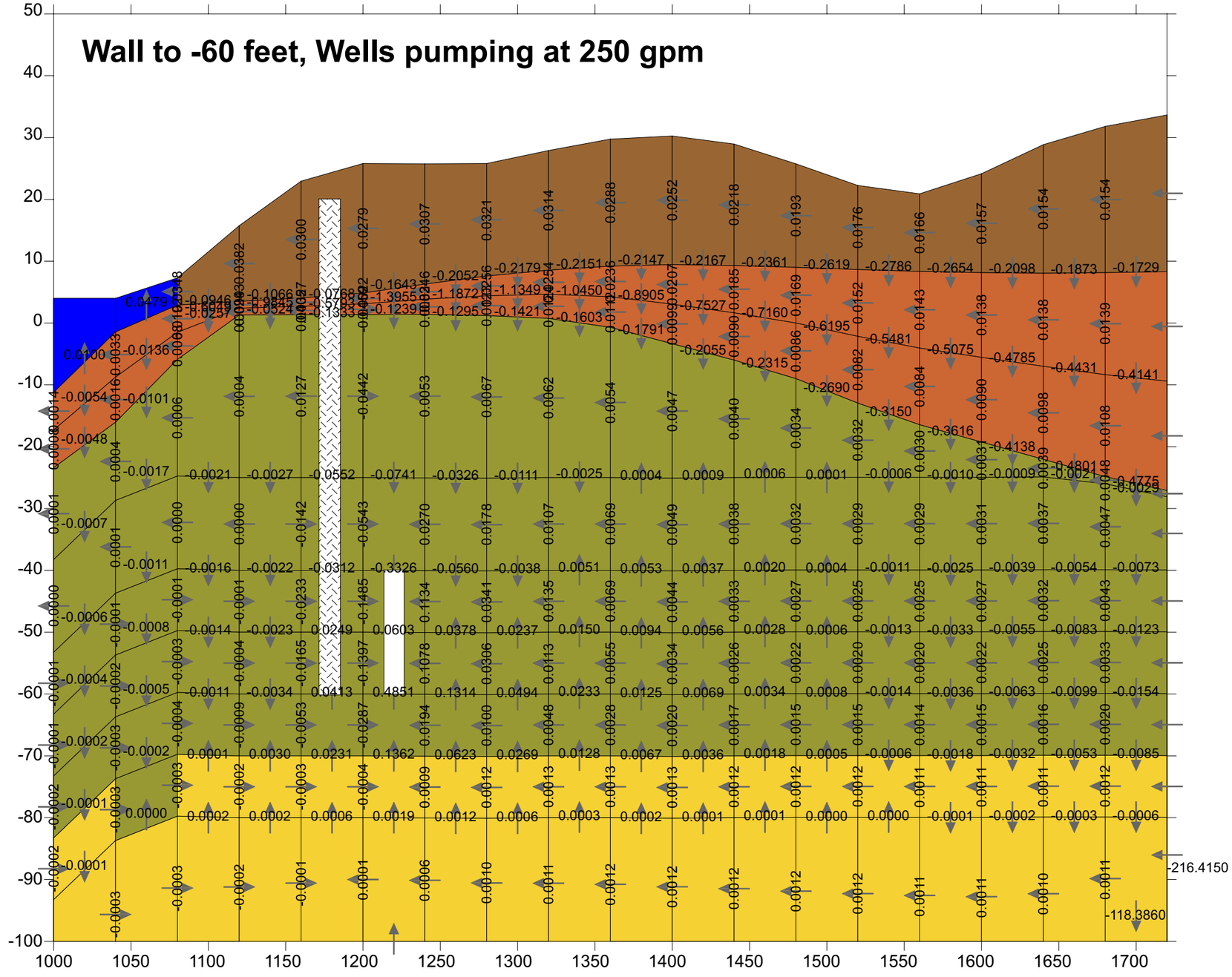
$\Sigma^2\Pi$

Figure 3-3a
Groundwater Gradient Profile, Barrier Bottom at -40ft Elevation
Gasco Groundwater Source Control
Interim Design Report

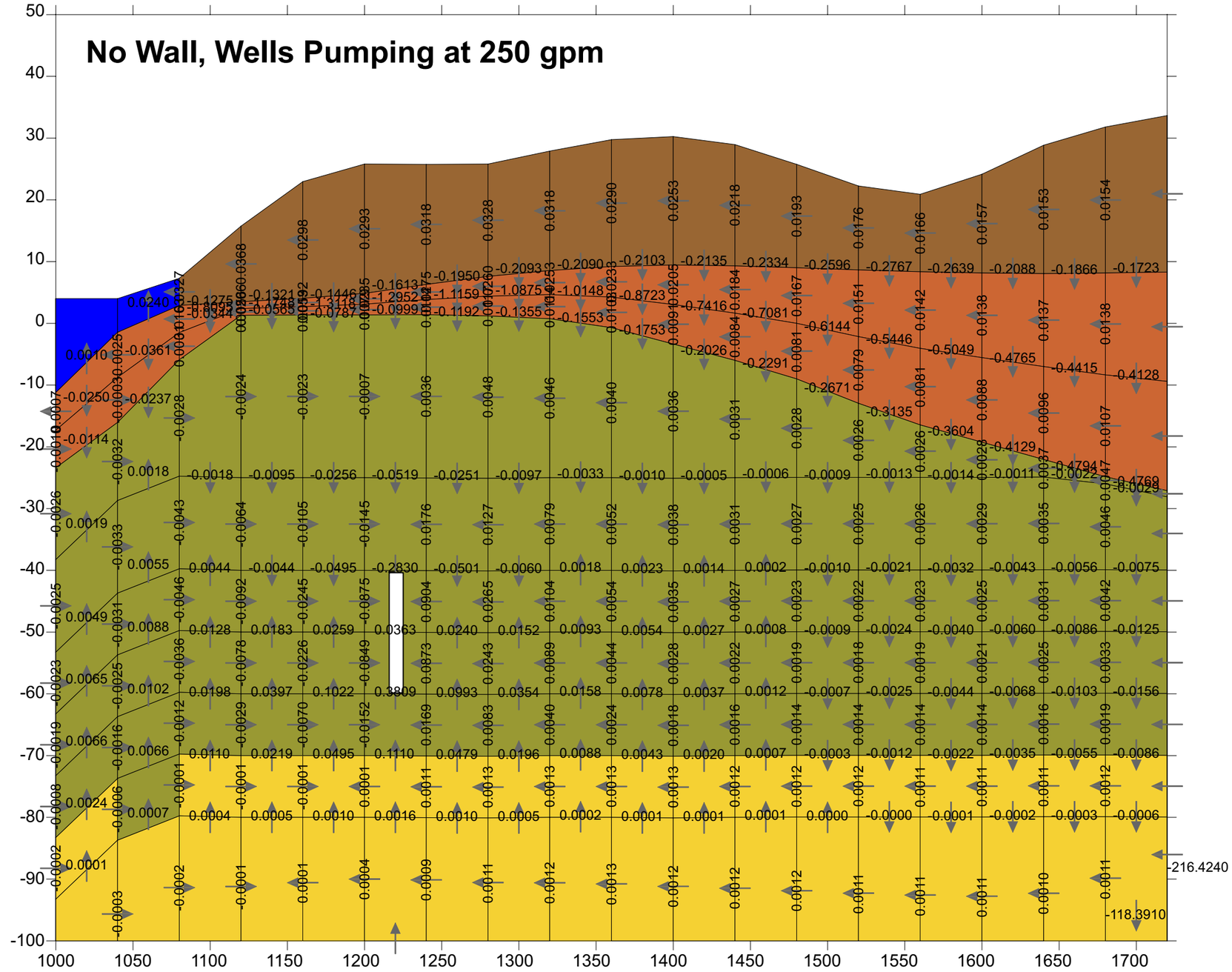


10/15/2009 cdavidson K:\Jobs\000029-GASCO\00002902\CorelDRAW figs\DR\00002902-RP-002.cdr

ANCHOR QEA

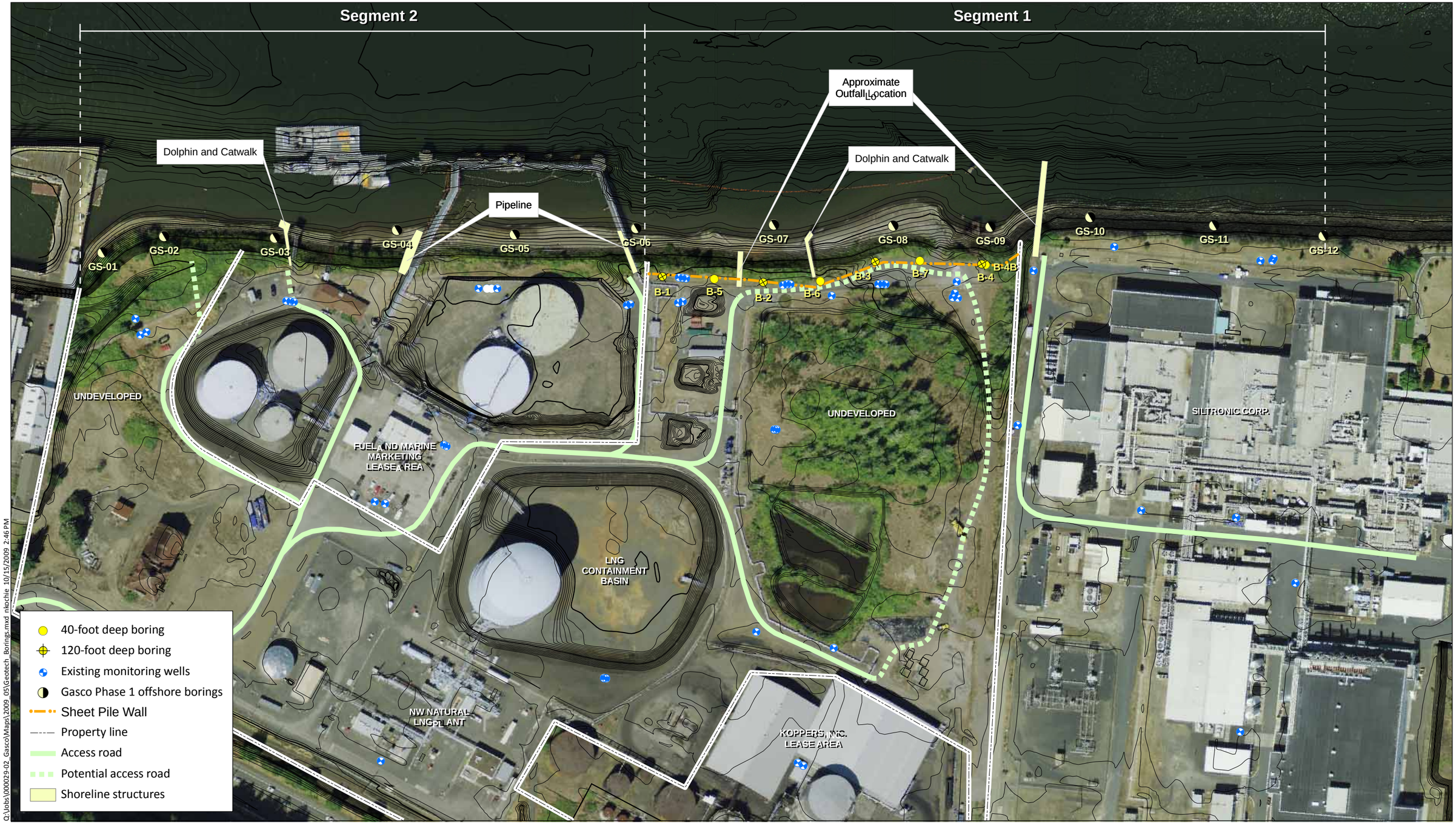
$\Sigma^2\Pi$

Figure 3-3b
Groundwater Gradient Profile, Barrier Bottom at -60ft Elevation
Gasco Groundwater Source Control
Interim Design Report



10/15/2009 cdavidson K:\Jobs\000029-GASCO\00002902\CorelDRAW figs\DR\00002902-RP-002.cdr

Figure 3-3c
Groundwater Gradient Profile, Barrier Bottom at -60ft ElevationGroundwater Gradient Profile, No Barrier
Gasco Groundwater Source Control
Interim Design Report



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Feet
0 80 160 240 320

Figure 3-4
Geotechnical Borings Along Barrier Wall
Gasco Groundwater Source Control
Interim Design Report

Junttan HHK 5A Hydraulic Impact Hammer

APE Model 250V Variable Moment Vibratory Driver

Oct 14, 2009 9:39am cdavidson K:\Jobs\000029-GASCO\00029\02\00002902-RP-031.dwg FIG 3-5

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Figure 3-5
Selected Pile Driving Equipment
Gasco Groundwater Source Control
Interim Design Report

NOTE: Vibration monitoring data acquisition system shown with one of eight accelerometers that will be placed within the Siltronic facility.

Oct 14, 2009 9:42am cdavidson K:\Jobs\000029-GASCO\00029002\00029002-RP-035.dwg FIG 3-6

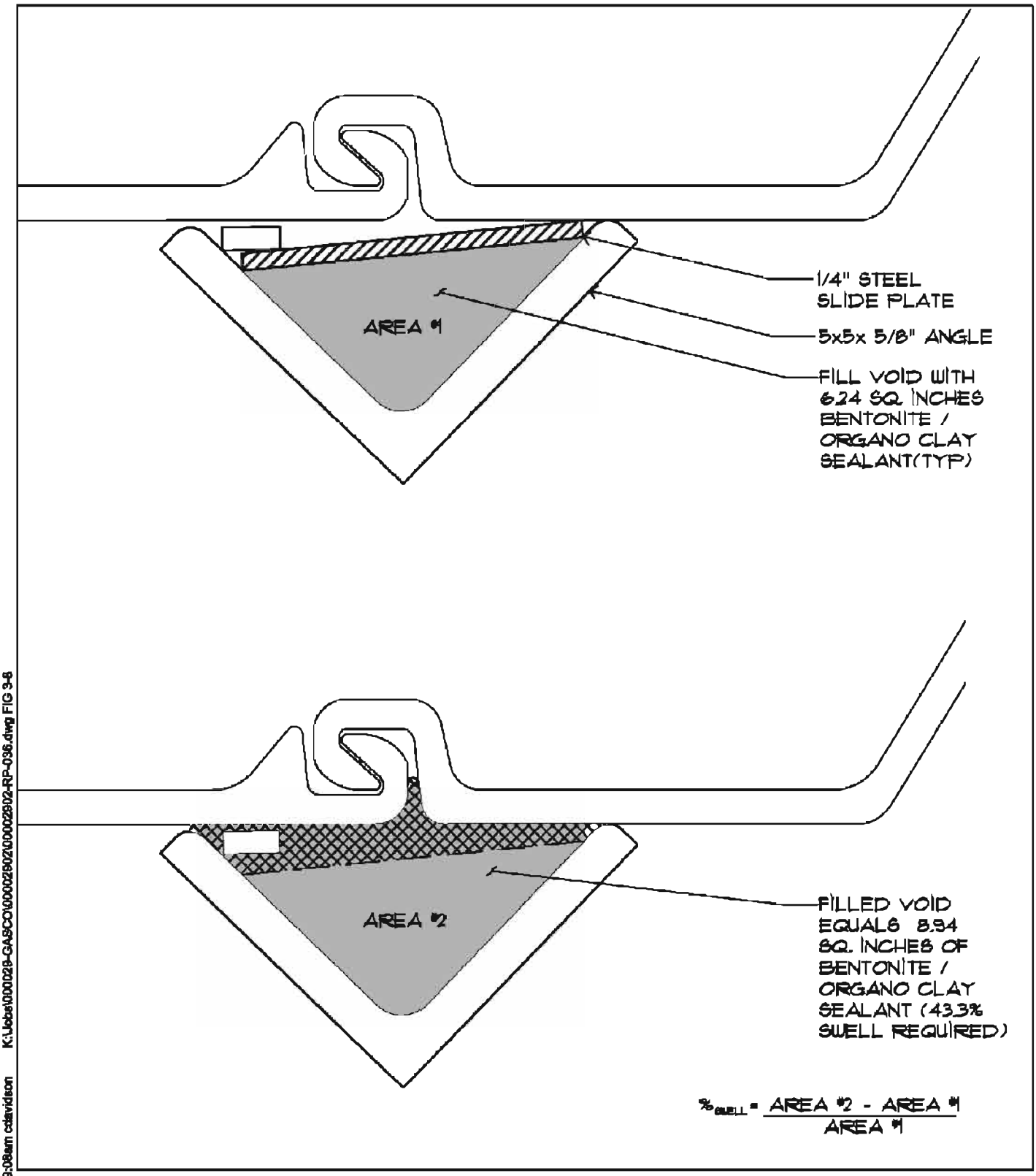
Figure 3-6
Photo of Vibration Monitoring System
Gasco Groundwater Source Control
Interim Design Report

ANCHOR QEA

ANCHOR QEA

Feet
0 150 300

Figure 3-7
Vibration Monitoring Systems Locations
Gasco Groundwater Source Control
Interim Design Report



Oct 27, 2008 9:08am cdavidson K:\Jobs\100028-GASCO\00028\02\00002802-RP-036.dwg FIG 3-8

SOURCE: Drawing prepared from pdf from Glynn Engineering Design dated 11-11-08.

Not to Scale

Figure 3-8
Seal Wall - Sealant Expansion
Gasco Groundwater Source Control
Interim Design Report

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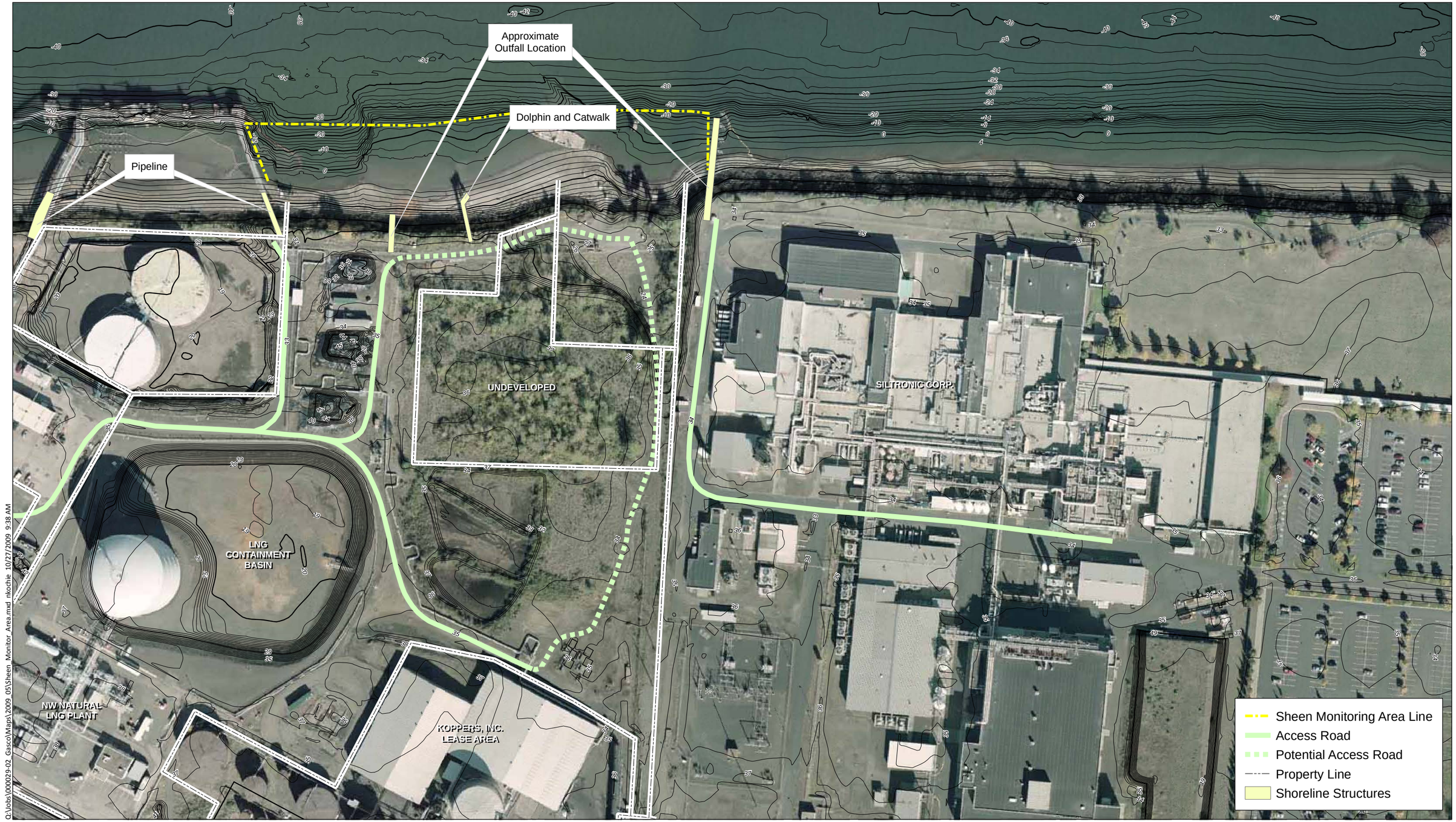
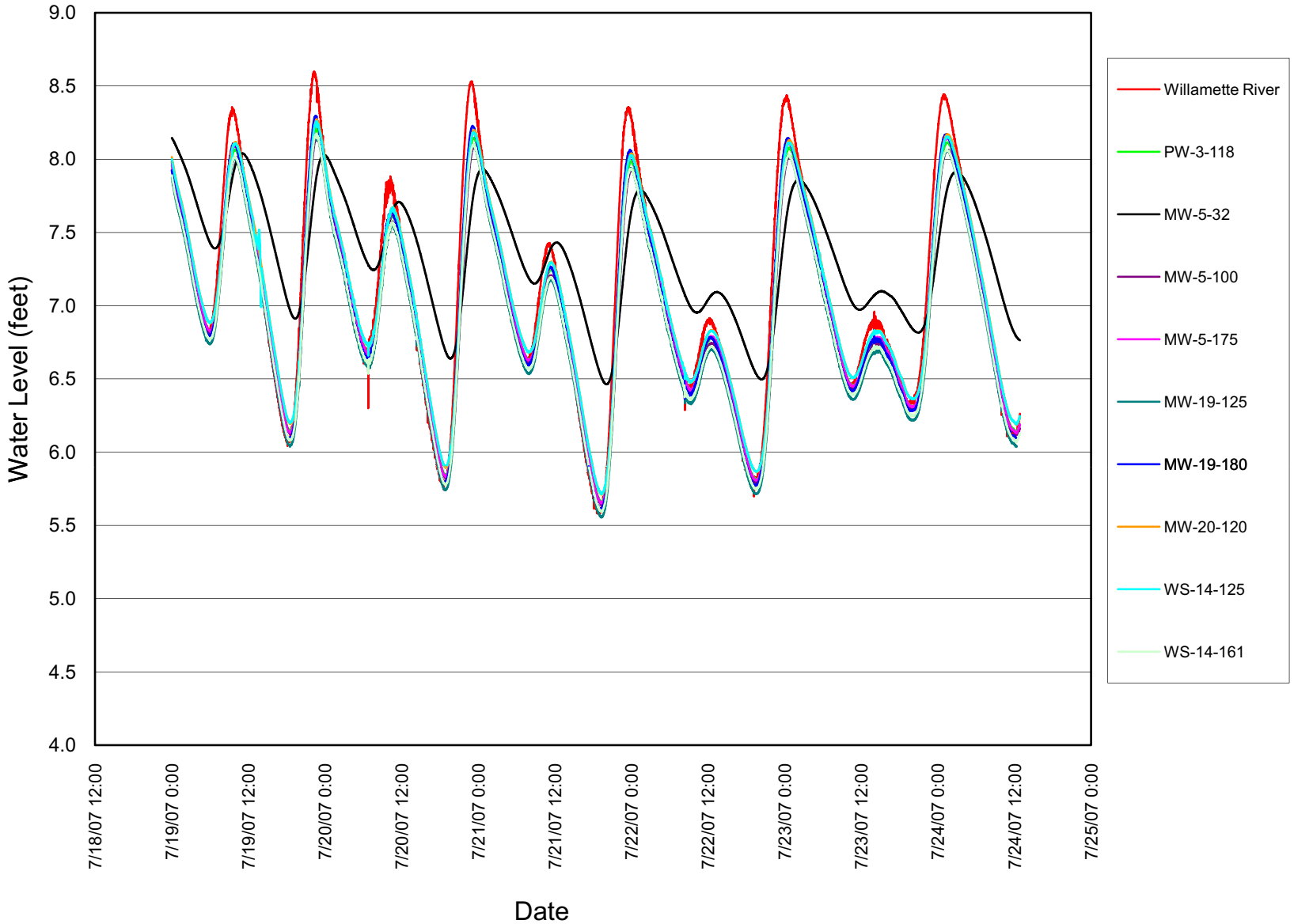


ANCHOR QEA

Feet
0 150 300

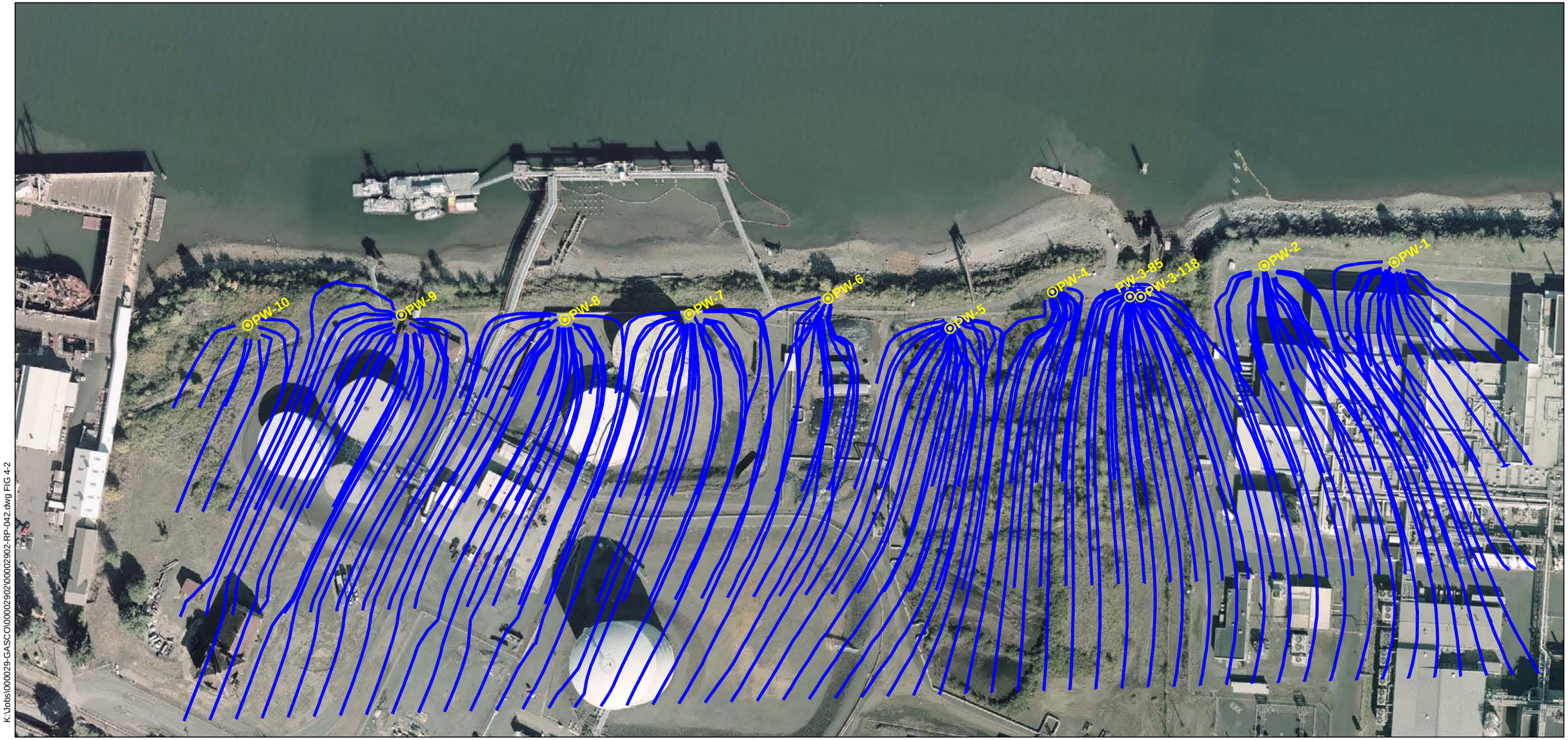
Figure 3-9
Sheen Monitoring Area
Gasco Groundwater Source Control
Interim Design Report



10/27/2009 cdavidson K:\Jobs\000029-GASCO\00002902\CorelDRAW figs\IDR\00002902-RP-007.cdr

ANCHOR QEA

Figure 4-1
River and Groundwater Tidal Fluctuations
Gasco Groundwater Source Control
Interim Design Report



LEGEND:

Pumping Well

Partical Path in Shallow Aluvium

0 150

Scale in Feet

K:\Jobs\000029-GASCO\00002902\00002902-RP-042.dwg FIG 4-2

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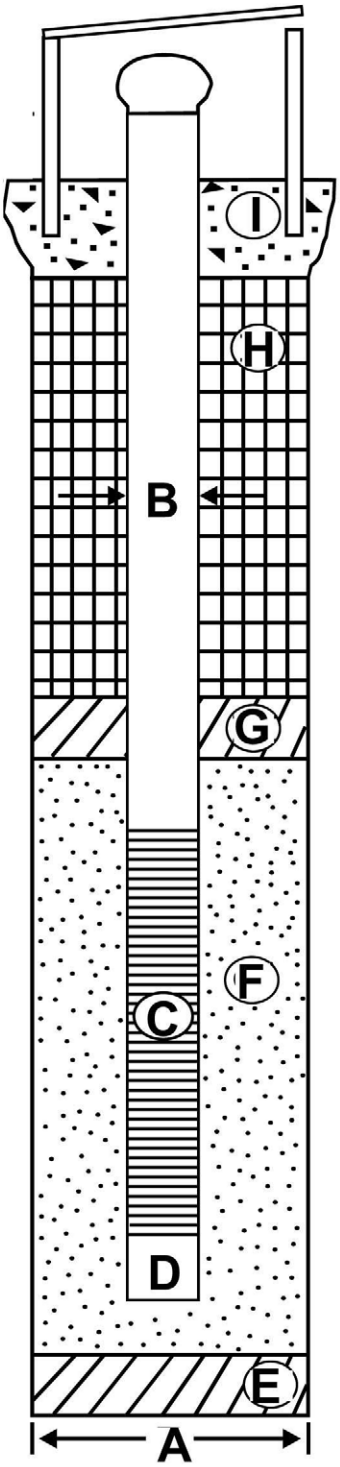
Figure 4-2
Particle Track Capture Map
Gasco Groundwater Source Control
Gasco Interim Design Report



Boring Details

A: 12" diameter casing

Well Construction

B: 8" diameter Steel Riser Pipe

C: 8" diameter Stainless Steel 0.035 slot wire-wrap screen

D: 8" diameter, 2-foot-long steel sump

E:Bentonite Grout / Organoclay if NAPL is present

F: 10x20 Silica Sand Filter Pack

G:Bentonite Chip Filter Pack Seal

H:Bentonite Grout / Organoclay if NAPL is present

I: Cement Grout Surface Seal

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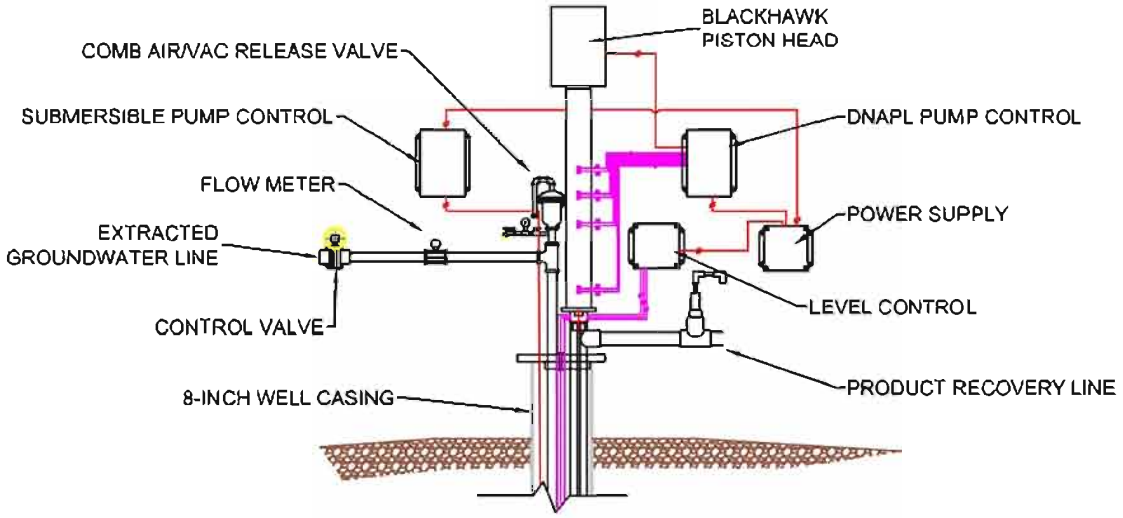
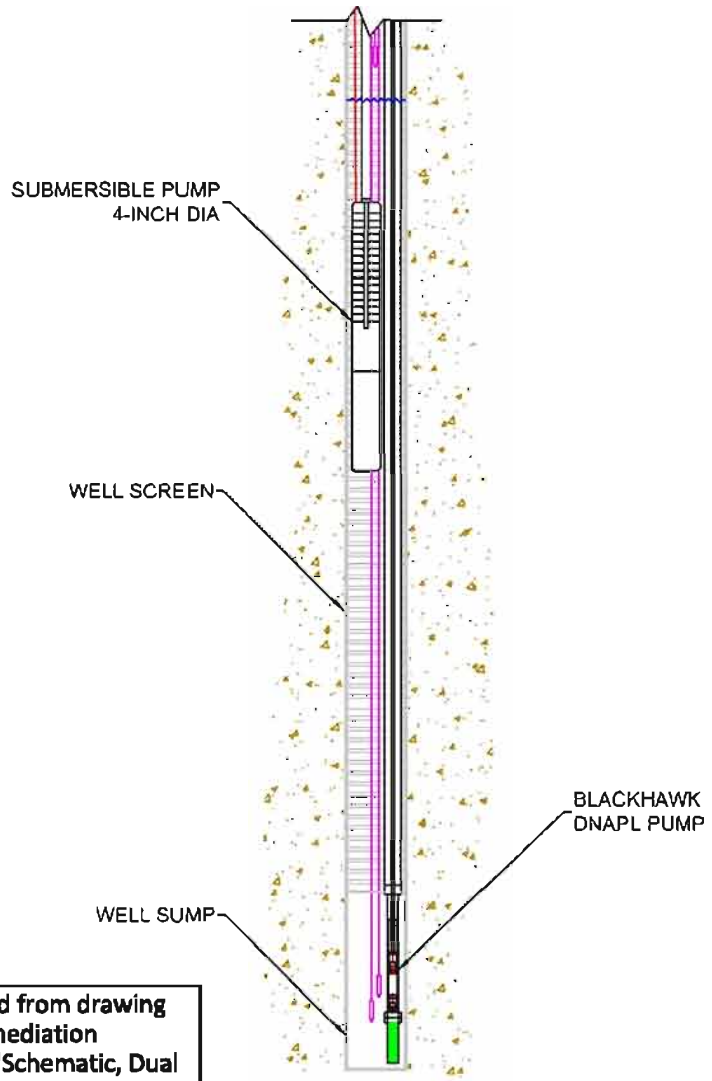
Figure 4-3
Extraction Well Construction Detail
Gasco Groundwater Source Control
Interim Design Report





SOURCE: Drawing prepared from drawing provided by Advanced Remediation Technologies Co. entitled "Schematic, Dual Pump DNAPL Recovery" dated 10/07/08.

Oct 14, 2009 9:44am cdavidson K:\Jobs\000029-GASCO\00002902\00002902-RP-035.dwg FIG 4-4

Figure 4-4
Extraction Well with DNAPL Removal System
Gasco Groundwater Source Control
Interim Design Report

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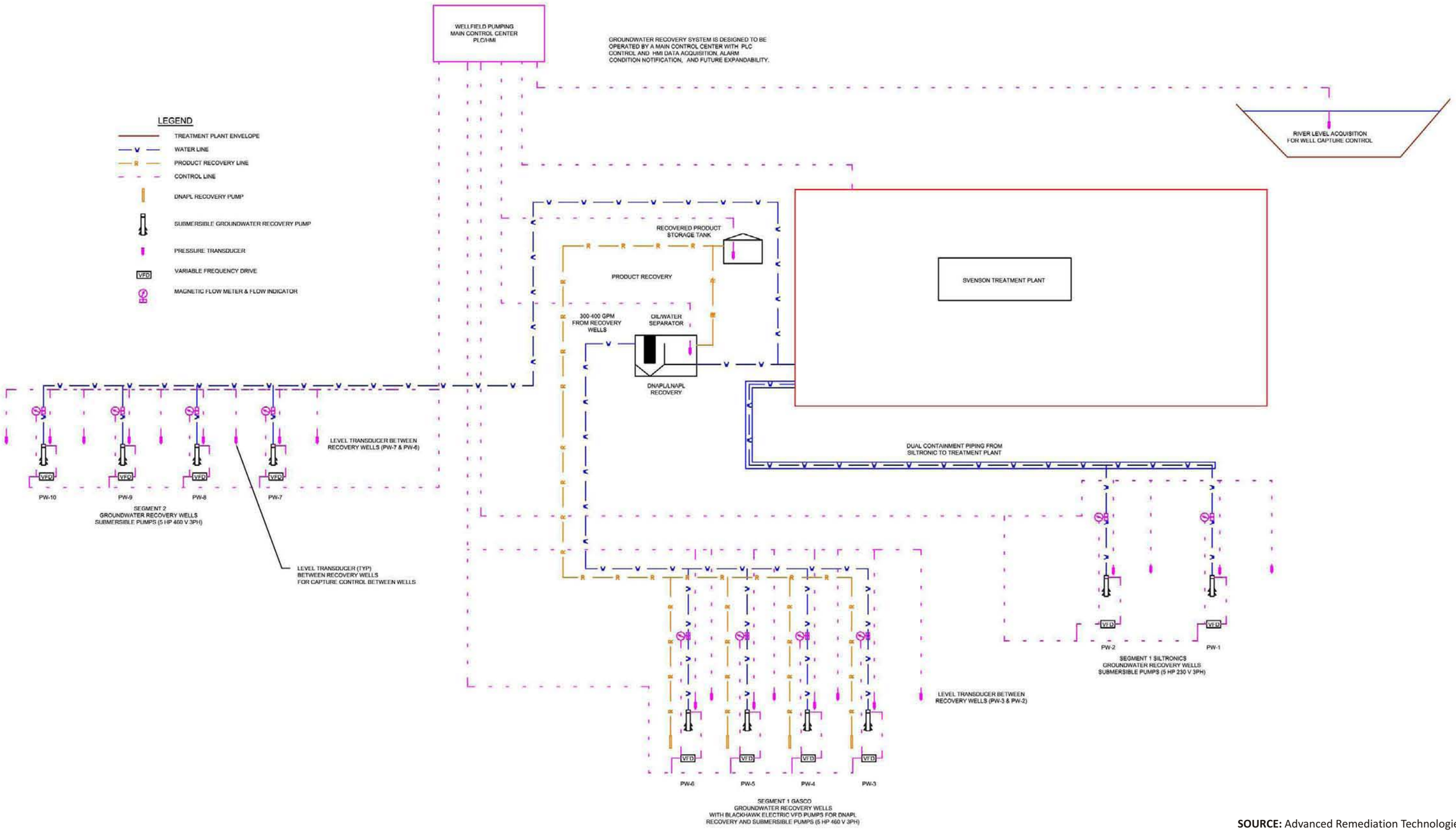

SOURCE: Advanced Remediation Technologies Co.

10/14/2009 cdavidson K:\Jobs\000029-GASCO\00002902\CorelDRAW figs\IDR\00002902-RP-003.cdr

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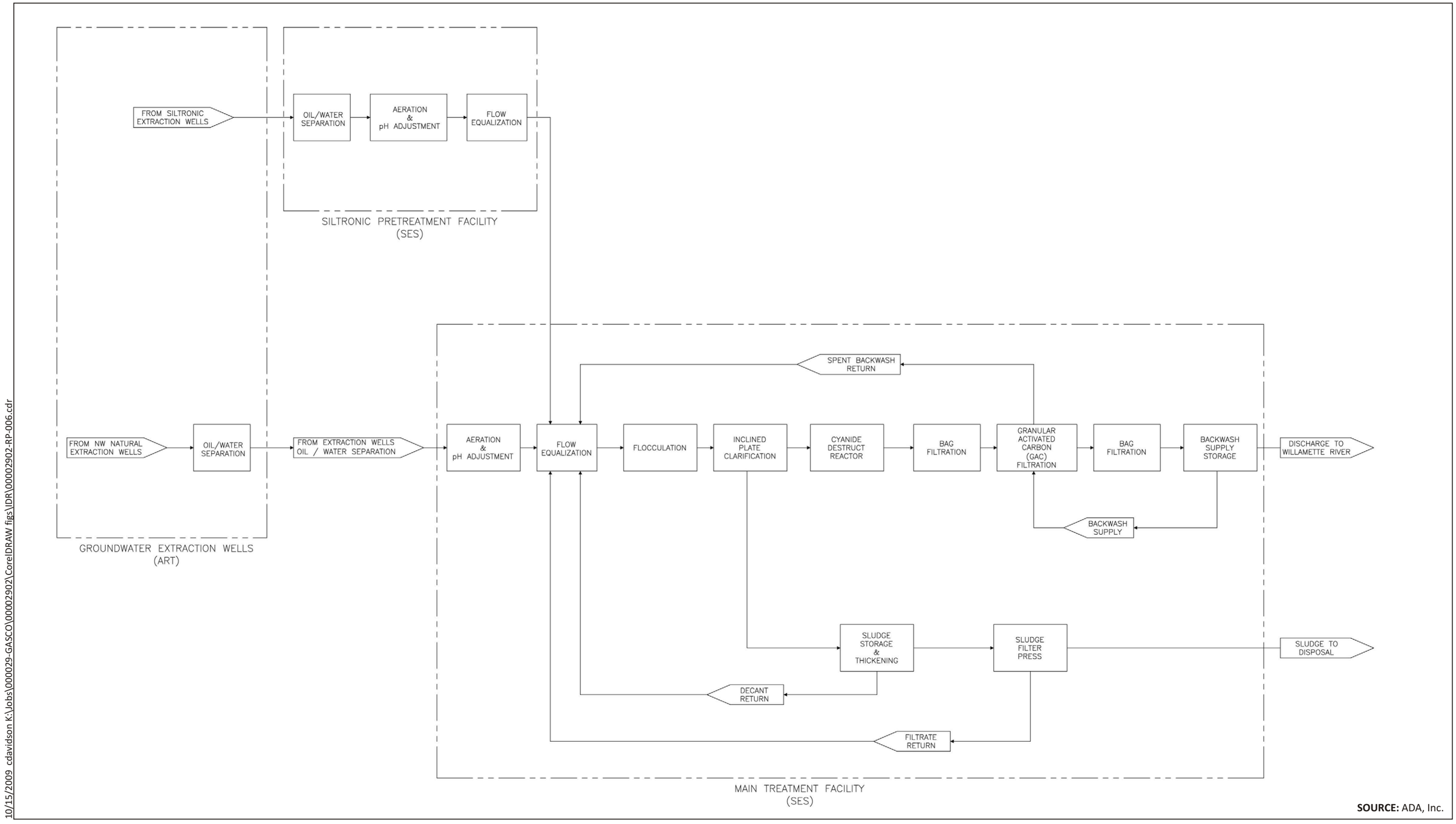
Figure 4-5
Well Field Controls and Piping
Gasco Groundwater Source Control
Interim Design Report



SOURCE: ADA, Inc.

10/15/2009 cdavidson K:\Jobs\000029-GASCO\00002902\CorelDRAW figs\IDR\00002902-RP-006.cdr

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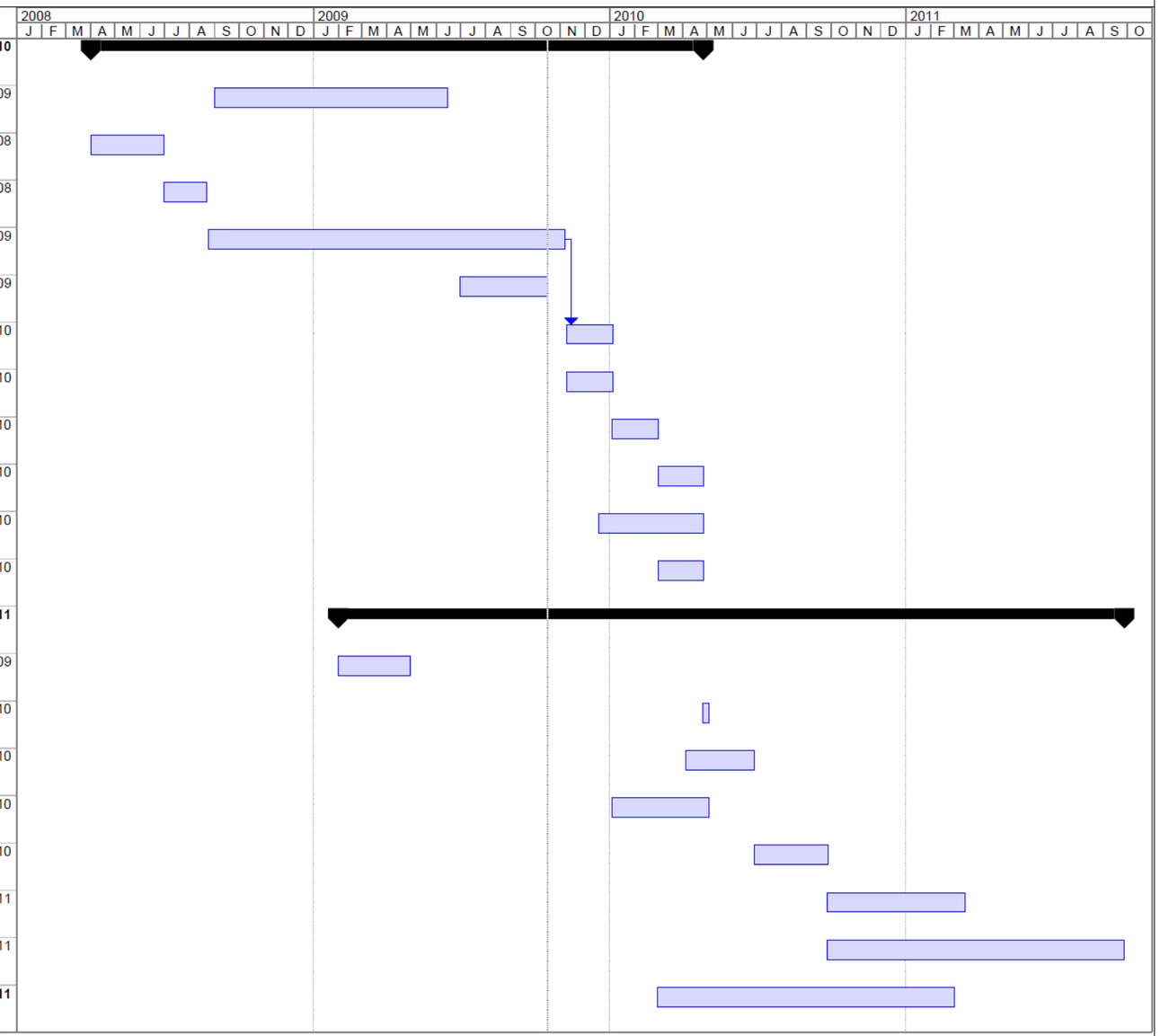
Figure 4-6
Groundwater Treatment System Process Flow Diagram
Gasco Groundwater Source Control
Interim Design Report

Gasco Site Source Control Planning Schedule 2009

ID	Task Name	Duration	Start	Finish
1	**Groundwater/DNAPL Souce Control Design**	**550 days?**	**Wed 4/2/08**	**Mon 4/26/10**
2	Conduct Design Level Studies	210 days	Mon 9/1/08	Mon 6/15/09
3	Prepare Preliminary Design	65 days?	Wed 4/2/08	Mon 6/30/08
4	DEQ/EPA Review Preliminary Design	39 days?	Tue 7/1/08	Fri 8/22/08
5	Prepare Interim Design	323 days	Mon 8/25/08	Fri 11/6/09
6	Treatment Pilot Test	80 days?	Wed 7/1/09	Fri 10/16/09
7	DEQ/EPA Review Interim Design	44 days	Mon 11/9/09	Tue 1/5/10
8	DEQ Select Alternative (wall type, length, # of wells, etc.)	44 days?	Mon 11/9/09	Tue 1/5/10
9	Revise Interim Design Report	41 days?	Mon 1/4/10	Mon 3/1/10
10	Public Notice, Comment, and DEQ Staff Report	40 days?	Tue 3/2/10	Mon 4/26/10
11	Discharge Permit and Public Notice	92 days?	Sat 12/19/09	Mon 4/26/10
12	Prepare Final Design	40 days?	Tue 3/2/10	Mon 4/26/10
13	**Construction of Groundwater DNAPL Source Controls**	**701 days?**	**Sun 2/1/09**	**Tue 9/27/11**
14	Negotiate Contractor Contract	66 days	Sun 2/1/09	Thu 4/30/09
15	Order Treatment System (Cost)	6 days	Mon 4/26/10	Mon 5/3/10
16	Mobilize Material/Equipment	62 days?	Mon 4/5/10	Mon 6/28/10
17	Obtain Construction Permits	86 days?	Mon 1/4/10	Mon 5/3/10
18	Install Pump and Treatment System	65 days?	Tue 6/29/10	Mon 9/27/10
19	DEQ Source Control Determination to EPA	122 days	Mon 9/27/10	Tue 3/15/11
20	Pump and Treat System Operation (1 Year)	262 days	Mon 9/27/10	Tue 9/27/11
21	**Site-Wide Feasibility Study (See Notes)**	**263 days?**	**Mon 3/1/10**	**Tue 3/1/11**



Project: Gasco RIFS Planning Schedu
Date: Fri 10/16/09

Task | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Milestone | Rolled Up Progress | Split | Completed Tasks | Project Summary | Group By Summary | Deadline

Line 21:
1 - Site Wide FS schedule assumes that DEQ approves the Gasco Risk Assessment and Remedial Investigations by March 1, 2010.
2 - The Site Wide FS will include evaluation of upland DNAPL Removal and shoreline vertical barrier for DNAPL remediation

Page 1

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Figure 6-1
Construction Schedule and Sequencing
Gasco Groundwater Source Control
Interim Design Report

APPENDIX A
SHEET PILE DESIGN REPORT

NW NATURAL GASCO SITE – PORTLAND OREGON OCT 16, 2009
BARRIER WALL INTERIM DESIGN REPORT

INTRODUCTION This section of the overall project design report provides the technical and logistical information that pertains to the design of the barrier wall that may be constructed along the eastern boundary of the NW Natural Gasco site in Portland, Oregon pending further evaluation as part of the site-wide Feasibility Study.

PROJECT DESCRIPTION

Wall Objectives The primary objective of the barrier wall is to prevent the migration of dense non-aqueous phase liquid (DNAPL) from the site to the Willamette River. If selected as a component of the upland remedial action, the 652.2 -foot-long steel sheet-piling barrier will be constructed after the near term source control actions (including the groundwater extraction wells) to accomplish this goal. The barrier wall will be constructed of 142 welded pairs of Skyline AZ37-700 steel sheets. Each pair of sheets will be welded for the full 60-foot length of the interlock. The scope and details of the design are shown on GGE drawings SP1 through SP4.

Performance Standards

System Permeability On an overall basis, the in-place hydraulic conductivity, or permeability, of the barrier wall is not to exceed 1.0 E -007 cm/sec as dictated by regulatory design standards. On an individual basis, the components of the barrier have a permeability that varies from essentially 0 for the welded pair of steel sheeting to the maximum rate of 1.0 E -007 cm/sec for the sealed joint between sheeting pairs. Taken collectively, the barrier wall will have a calculated permeability that is significantly less than the maximum permitted value.

Wall Depths The toe of the barrier wall will be at elevation -40 feet City of Portland (COP) datum. The top of the barrier will be at elevation +20 feet COP datum. On this basis, the total length of the sheeting is 80 feet.

Vibrations The neighboring Siltronic property and operations have been the subject of an extensive trial wall installation study. The study provided an examination of the potential vibration impact of the manufacturing process conducted at the Siltronic Plant. The proposed method of construction and equipment studied in the trial forms one component of the basis for the intended barrier wall construction.

Potential Future Actions

Well Installation A series of extraction wells will be constructed along the Willamette River, and several of these wells will be along the barrier wall. The wells will be used to extract the DNAPL from the groundwater and will therefore be on the shore side of the wall. The proposed alignment of the extraction wells is shown on the plan drawing SP1 with the wall alignment.

Wedge Excavations There is the potential that future sediment remediation may require temporary excavation adjacent to portions of the outboard side of the barrier wall. The maximum safe excavation limits consider: 1) the capability of the barrier wall to support an unbalanced soil load; and 2) the stability of the slope considering the post-excavation geometry. A series of computer program slope stability checks and sheet pile calculations were conducted to determine the safe working excavation depth of excavations on the riverside of the barrier wall. The final suggested safe excavation depth considered the site topography, barrier wall position, equipment loading and subsurface soil properties.

The barrier design allows for future excavations up to the wall and out towards the river if needed. The barrier wall is capable of supporting vertical cuts down to an elevation of +6 feet COP without any additional support measures. At this depth, the wall will behave as a cantilever. If excavations need to be deeper adjacent to the wall to complete offshore remediation, measures such as temporary shoring, narrow excavation widths or other suitable geotechnical support measures will be used, subject to additional engineering study. Once the future outboard excavation limits are known, the engineer will need to evaluate the barrier wall shoring requirements.

EXISTING CONDITIONS

Topography The site contours shown on sheet SP1 of the GGE design drawings provide an indication of the variability of grades along the alignment of the proposed barrier wall. In general, the top of the bank along the length of the barrier is at approximately elevation +30 feet COP. From the crest of the bank, the grade dips down to the river at a variable, but approximate, 2H:1V slope.

Geotechnical Multiple soil borings were advanced along the top of slope in the region where the barrier wall will be installed. These test borings were conducted in accordance with American Society for Testing and Materials (ASTM) procedures and included the measuring of resistance to a standard penetration-sampling tool, hence providing an indication of the relative density in terms of the blow counts. Below, a thick layer of man-made fill, the native soils consist of alternating layers of saturated, loose to medium dense, sand and silty sand.

Groundwater The free groundwater surface measured in the test borings was found at an average depth of 17 feet below ground surface. This equates to approximately elevation +13 feet COP, which sets the water level in the fill zone above the level of the neighboring river.

Chemistry The barrier wall will be installed into soils and groundwater that contain hydrocarbon-based contaminants. Others have studied the nature and composition of the contamination and the information provided to GGE for consideration in the evaluation of the barrier wall design. The site DNAPL consists of medium to light hydrocarbons, which tend to negate the sealing effects of bentonite; therefore, the evaluation and testing of a recipe for the sealant consisted of a blend of bentonite and

Organo clay. The selected recipe has a demonstrated permeability lower than the regulated value. See reports included as reference 1 & 2 for the permeability / compatibility study.

WALL DESIGN

Pre-trenching The man-made fill along the proposed alignment of the barrier wall consists of a significant percentage of debris including wood, concrete, boulders, riprap and brick. The debris, which extends to an average depth of 20 feet below existing grade, would preclude, or at best seriously hinder, the driving of steel sheet piling. A pre-trench operation to a depth of approximately 20 feet will be conducted in advance of the barrier wall installation. The removal and replacement of the surficial fill with a clean gravel material will have the added benefit of reducing any ground vibrations caused by the driving of sheet piling.

SES will pre-trench using a CAT 325 Excavator with a bucket width of 3-4 feet. Therefore the trench dimensions will be approximately 4 feet wide x 20 feet deep and 660 feet long. Based on the observations from the Vibration Study, no side slope or angles will be needed for the trench to maintain sidewall stability. This activity will begin 1-2 days prior to starting the installation of the sheets. At the end of each day, the trench will be backfilled with clean un-compacted material. Sheet piles will be driven through the clean material to design depths. The backfilling of the trench, prior to sheet piles being installed, will help in preventing three things from happening:

1. Surface water from collecting in the trench.
2. An individual from falling into the trench.
3. Sidewalls from collapsing

Existing borings and the Vibration Study indicate that pre-trenching may be deeper than elevation 20 (top of sheet pile wall). In-situ material and the groundwater table will determine the trench depth. The trench will be dug to a depth not greater than the groundwater table or where the strata of oversized material and undisturbed natural material transition. Soil that will be excavated, during pre-trenching, will be direct loaded into trucks and disposed of in an approved offsite landfill. A small stockpile may be needed for any material that is not shipped off site at the end of each day. The material will be covered by tarps until the following day and then loaded out for disposal.

Sheet Sections Based on the need to install long sheets (60 feet) and the associated heavy driving forces, a steel sheet, AZ37-700, was selected for the barrier wall. The high section modulus of the selected member also affords an appropriate resistance to bending required to accommodate limited excavation along the riverside of the barrier. The 142 pairs of steel sheets will be welded in pairs for a driving width of 4.5933 feet. The use of welded pairs increases the installation rate and assists in maintaining wall alignment during installation.

Cathodic Protection Corrosion of the barrier wall due to the nature of the installation environment mandates the consideration and inclusion of a system of Cathodic protection. Options considered for the barrier wall included a steel coating or

active or passive Cathodic protection. Coating can be compromised due to scratches caused by handling during installation or contact with abrasive objects buried in the ground, and the detrimental effects cannot be fully anticipated. Active or passive Cathodic protection is a relative given in terms of protection and is often the preferred selection for marine installations. Passive protection by means anodes will be incorporated into the design of the barrier wall at a later date.

Joints The sheeting sections of the barrier wall, specifically the interlocking joints, will be augmented by the inclusion of a seal material consisting of a recipe of bentonite and organo clay. The seal system will be either the Sevenson patented seal system or an equivalent alternate by de neef. The joint sealant will be installed during the barrier wall installation efforts. The joint material is placed just prior to setting and subsequent driving of a sheeting pair. QA/QC efforts are conducted as the joint sealant is installed.

Alignment In general, the barrier wall will be constructed along the top of the riverbank, set back from the top of slope a distance adequate to permit safe and efficient installation (see Sheet SP1 for barrier wall location). The exact location of the barrier wall will accommodate existing site conditions, location of existing wells, and the known underground facilities such as the Koppers pipeline and the site outfalls.

The starting point of the barrier wall is offset from the Koppers pipeline 20 feet, east / west and north / south. The offset distance, in combination with the anticipated pre-trench depth of 20 feet, provides for an approximate 1 horizontal to 1 vertical (1H:1V) slope from the bottom of the pre-trench to the grade at the pipe. This offset distance was selected to avoid undercutting the bearing soils for the pipe support foundations and to provide an adequate working distance between the barrier wall and the pipeline. The parameter was deemed appropriate for the installation work based on the vibration study efforts that proved the pre-trench excavation walls would stand nearly vertical during the pile driving.

SES will install a stormwater by-pass system during the construction of the barrier wall at the intersection of the outfall. Prior to pre-trenching, at the outfall location, the surface water underground discharge pipe will be located to prevent damage that might be caused by the excavator digging the trench. The pipe will be exposed inland of the wall and a sump will be dug (dimensions and location to be determined while on site) to maintain storage for any stormwater runoff that enters the pipeline. The sump will be lined to prevent direct contact between the storm water and soils. Two 12-inch Godwin pumps will be stationed next to the sump with sections of HDPE pipe connected to the discharge side of the pumps and run to the river. Stormwater collected in the sump will be discharged to the river using this system. Once the by-pass system is in place, sheet pile installation will continue past the outfall location. Replacement of the surface water discharge pipe will be done at the completion of installing the barrier wall sheet piling to finish grade at the discharge pipe original location. To accomplish this, an area of the barrier wall will be cut large enough to allow the discharge pipe to penetrate through the

sheet piling. The discharge pipe will be reconnected at the by-pass location and backfilled with clean borrow material. The By-pass system will then be disconnected allowing stormwater to flow through the pipe to the river.

INSTALLATION AND SCHEDULE

Equipment The equipment that will be used to install the sheetpile barrier wall is a 250 Variable Moment and a Hydraulic Impact Hammer suspended from a 100-120 ton Linkbelt Crane. Additional equipment, such as a rubber-tired loader and backhoe, will be needed for the pre-trenching prior to the sheet piles being installed. Miscellaneous equipment will be used for receiving and staging of materials such as a Pettibone Forklift. Support equipment (60' manlift, welders and generators) will be on site throughout the project.

Sequencing Installation of the sheetpile barrier wall will begin on the northeast corner of the NW Natural property adjacent to the Koppers pipeline and continue south and parallel along the Willamette River to the NW Natural-Siltronic property line.

Noise Control To mitigate sound impacts during the installation of the sheet piles, a temporary scaffolding wall will be constructed with sound boards attached and located in front Siltonic's office building (see Sheet SP1). If the soundboards do not work, acoustical blankets may be used in conjunction with the scaffolding barrier. In this case, a steel "Box" will be constructed using W4x13 I beams and a three-sided "halo" will be constructed using W8x26 beams. Acoustical blankets will be hung on all sides of the two constructed sections. The box will sit on the ground and a support crane will suspend the halo. The halo will be lowered while the sheet pile is driven to final grade. Doing so will encapsulate the sheet pile, with acoustical blankets, during installation. The box and halo can be moved as needed along the sheet pile barrier wall.

Quality Control During installation, Sevenson shall observe the alignment of the sheet piles, the condition of the steel piles, the conditions of the interlocks, and identify damage to the sheet pile during installation activities. The energy of the hammer used to drive the sheet pile shall be in accordance with the manufacturer's recommendation based on the pile weight and subsurface conditions.

Sevenson will remove and replace piles that are damaged or driven with an unacceptable deviation. Sevenson will also verify that the length of the sheet pile is appropriate for the location where the pile is being placed.

The seam in the sheet pile pair with the fabrication shop applied open angle iron will be sealed with the joint sealant selected as part of the permeability test program. (This permeability test program will demonstrate the appropriate materials for the environment of the application and characteristics of permeability not greater than $1x10^{-7}$ cm/sec. No permeability sampling or testing will be performed on the materials installed in the field.)

Production Rates and Schedules Based on the installation of the sheet piles during the Vibration Study, a linear production rate of 25-30 feet can be installed per day. The rate of installation is based on a 12-hour shift and a 5-day workweek.

REFERENCES

NW Natural – Gasco Site Compatibility / Permeability Study by GGE, dated 7-31-08

NW Natural – Gasco Site Compatibility / Permeability Study Addendum, dated 11-12-08

Appendices:

SFS Erosion and Control Plan

GGE Design Drawings: dated 9-30-09

DWG SP1 Sheet Pile Barrier Wall, Location Plan & Notes

DWG SP2 Sheet Pile Barrier Wall Sections A & B

DWG SP3 Sheet Pile Barrier Wall Sections A & B

DWG SP4 Sheet Pile Barrier Wall Details

GEOTECHNICAL
REGISTERED PROFESSIONAL
ENGINEER
80419PE
OREGON
MARK W. GLYNN
EXPIRES: 6.30.18

Soil Erosion and Sediment Control Plan

I. PROJECT SUMMARY

The Gasco site is a former oil gasification plant located at 7900 NW St. Helens Road, Portland, Oregon. The site is bounded on the northeast by the Willamette River at River Mile 6 and on the southwest by State Highway 30 (St. Helens Road). It is adjacent to the Siltronic and US Army Corp of Engineers U.S. Moorings facilities.

The scope of this phase of work is to install a sheet pile barrier wall to prevent migration of DNAPL material into the Willamette River.

II. PLAN OBJECTIVE

The objective of this plan is to state the soil erosion and sediment control measures Sevenson will implement on the NW Natural Gasco site to prevent and minimize erosion and sedimentation. Soil, water, and other natural resources will be protected from degradation and depletion that often result from land-disturbing development activities through the use of measures outlined in this Soil Erosion and Sediment Control Plan.

The soil erosion and sediment control measures described herein are designed based on the following principles:

- Minimize exposure of bare soil;
- Preserve existing vegetative cover wherever possible;
- Prevent soil from leaving the site through the use of silt fences, hay bales, and/or stone (as necessary);
- Stabilize disturbed areas soon after final grading;
- Keep runoff velocities low;
- Divert run-on water away from disturbed areas; and
- Reduce sedimentation by utilizing erosion control practices on site.

This plan is based on Oregon State Code and the requirements of the Engineer's contract drawings and specifications. A copy of the approved Soil Erosion and Sediment Control Plan, including related drawings and inspection logs, will be kept on site at all times for inspection by the Engineer's representative. Revisions to the approved plan will be submitted to the Engineer for approval.

III. PLAN IMPLEMENTATION

All erosion and sediment controls will be put into effect and functional prior to commencement of any earthwork activities. Once in place, Sevenson's Quality Control Manager, or his representative, will be responsible for the inspection of all control measures daily and after each rain event. Any items found noncompliant with this plan will either be repaired or replaced immediately.

The Quality Control Manager has the authority to stop work until these repairs are completed. He will also maintain a log of his inspections and a list of deficiencies found, and the corrective action(s) taken.

IV. PLAN COMPONENTS

Siltation and erosion control practices will be consistent with currently acceptable practices, including the placement of silt fencing and hay bales to mitigate sedimentation transport; the use of berms and trenches to re-direct surface water run-off/run-on to prevent contamination of adjacent properties; and the use of absorbent booms, where applicable, to prevent the flow of contaminated liquids from entering navigable waterways and/or storm sewer pathways.

- Surface drainage from cuts and fills within the limits of the work will be graded to control surface water flow (i.e., mitigate run-off and run-on) and mitigate soil erosion.
- Sedimentation barriers will be installed using siltation fencing and/or hay bales around the perimeter of the work area (i.e., excavation areas). All sedimentation

barriers will be inspected (inspections will be documented on the attached Environmental/Spill/Soil Erosion Protection Review Form) and maintained until interim site restoration is completed.

- Previously established grades will be maintained in a true and even condition.
- Areas of bare soil exposed by construction activities will be restricted to a minimum.
- Any piece of equipment coming into contact with contaminated soils will be decontaminated with a pressure washer at the equipment decontamination station. All equipment will be inspected prior to leaving the decontamination area and prior to authorization to leave the site.
- Sevenson or its subcontractors will immediately clean up any uncontaminated mud or soil *tracked* from the site onto roadways.
- All soil erosion and sediment control measures (silt fence, hay bales, trenches, berms, etc.) will be installed prior to any major soil disturbances, or in their proper sequence, and maintained until permanent protection is established.
- All work will be performed in accordance with the State Standards for Soil Erosion and Sediment Control in Oregon State.
- Submittal of the SESCP to the Multnomah County Soil Conservation District shall serve as notification of excavation/land disturbance activity.
- Any changes to the approved SESCP will require the submission of revised SESCPs to NW Natural and the Multnomah County Soil Conservation District. The revised plans must meet all current soil erosion and sediment control standards.

SITE SEDIMENT CONTROLS

The following control devices will be constructed as indicated below and installed in the order shown:

- **Stabilized Construction Entrances**: The site presently has one entry point for vehicular traffic, which Sevenson will use as the only means of access to and from the site. This entrance is the paved roadway leading into the site from St. Helens Rd. Sevenson may need to construct stabilized construction entrances on the existing roadways. The stabilized entrances will be constructed by placing filter fabric over the existing roadway and covered by a minimum of 4 inches of clean stone. The stabilized entrances will be at least 40 feet long and the full width of the roadway. Since the purpose of the stabilized entryways is to provide an area to remove mud and dirt from the tires of vehicles leaving the site, the entranceway stone will be cleaned or replaced when the stone becomes clogged with mud. Any mud deposited on public roadways will be removed immediately.

- **Silt Fence**: Sevenson will install wire-reinforced silt fencing along the down slope sides of the work areas. The lower edge of the silt fencing will buried a minimum of six inches and will be placed with the wire reinforcing on the upslope side. The silt fencing will be monitored daily for silt accumulation and when the silt build up causes the silt fence to either bulge, or accumulates half way up the silt fence, the silt will removed, placed on the site and re-graded.

- **Sedimentation barriers**: Pre-manufactured siltation fences will be used as sedimentation barriers and will be installed in areas where the potential of soil runoff and erosion may occur. Siltation fences will be installed on natural ground, at the bottom of fill slopes, and in ditches and other areas where siltation is a problem and will be maintained until grass is established. These fences will be embedded to prevent water from running under them. Fences will be monitored daily and maintained in satisfactory condition for the duration of the project.

- **Stockpiles:** Silt fencing will be placed to surround all stockpiles of excavated material. Sevenson will prevent the migration of surface water to the disturbed areas through use of berms, temporary swales, etc.
- **Additional Measures:** Immediately upon recognizing that unforeseen circumstances pose the potential for accelerated erosion or sedimentation, Sevenson will use appropriate best management practices to eliminate the potential for accelerated erosion and sedimentation. Sevenson will supplement the above control devices with, but not limited to, hay bales, rock dams, erosion control matting, riprap lining and/or sedimentation basins. Should the need arise to pump sediment laden water, Sevenson will use best management practices to discharge the water through sediment control devices, such as hay bales, silt fence, etc. prior to discharging the water over non-disturbed vegetative areas.
- **Final Grading and Seeding:** Upon completion of the project objectives and backfilling the site to sub-grade, four to six inches of topsoil, as specified, will spread over the disturbed areas and graded to the final design contours. Additional topsoil will be obtained from an off-site source to supplement the existing material, as required. The final surface of the topsoil areas will be "tracked in" with a bulldozer running parallel to the slopes. This operation creates cleat marks perpendicular to the slope and helps to prevent soil erosion and hold the grass seed in place. As soon as practical, the permanent seed mixture, fertilizer, and lime will be applied by hydro seeding. Straw mulch with liquid tackifier will be applied immediately following the seeding operation. All seed mixtures, fertilizer, lime, mulch, tackifier, and application rates will be as stated on contract drawings and approved by the Engineer.
- **Removal:** Removal of the erosion and sediment controls will be accomplished as the items are no longer needed. Silt fencing around stockpiles will be removed once stockpiles are depleted.

Remaining soil erosion controls will be removed upon Engineer approval and the establishment of permanent grass cover that possesses a density capable of resisting accelerated erosion and sedimentation. The last sedimentation controls to be removed are the perimeter silt fencing, and the stabilized construction entrances. Any disturbances due to the removal of the silt fence ,or other control item, will be repaired, seeded, or stabilized immediately.

V. PERMIT EQUIVALENCY REQUIREMENTS

All work will be performed in accordance with the State Standards for Soil Erosion and Sediment Control in Oregon.

VI. FINAL RESTORATION, MAINTENANCE, AND ACCEPTANCE

Following the completion of all remedial activities the site will be restored. Site restoration will include the repair of any site areas damaged or disturbed during the completion of remedial activities, as well as establishing vegetative cover at all disturbed site areas, and cleaning all work areas to remove all materials and waste.

All disturbed areas, once fine graded to final contours, will be covered with sod or hydroseeded in accordance with Contract Specification..

Sevenson will protect newly subgraded areas that cannot be top soiled/seeded right away, will remain exposed for more than 30 days, or are exposed at a time outside of the growing season. Siltation barriers, straw mulch, or soil erosion control blankets and fabric will be used to prevent siltation of areas beyond the work limit. All washed out areas will be re-graded to final grades.

All maintenance work will be performed in accordance with Contract Specifications until the Engineer grants final acceptance. At the completion of the sod or seed placement, the perimeter siltation fence (if used) will be repaired or replaced by Sevenson and will remain in place until the sod or seed (grass) stand has been established. Once the

sod or seed has been established, the sedimentation barriers will be removed and disposed of off-site.

HAUL ROADS, SUPPORT ZONE/TRAILER COMPLEX, STONE LAYDOWN/EQUIPMENT STORAGE AREAS

Temporary haul roads will be removed at the completion of construction. Topsoil placement and/or hydro seeding will improve Restoration of these areas.

HYDRO SEEDING

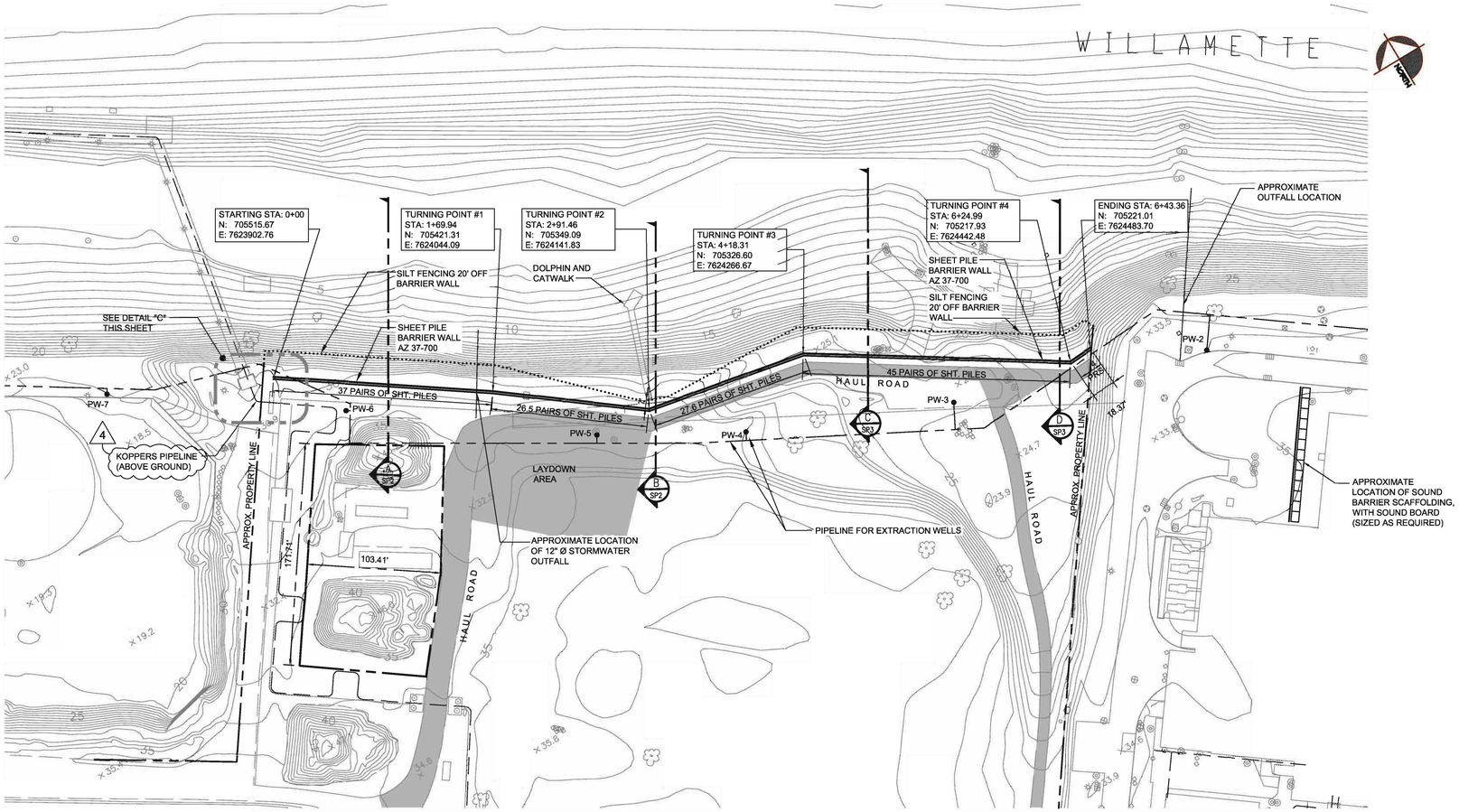
Hydro seeding will be performed by using a seed mix, mulch, fertilizer, equipment, and procedures approved by the Engineer. Hydro seeding will take place when the ground is not frozen or too dry, and as weather permits.

PRELIMINARY ACCEPTANCE OF TURF ESTABLISHMENT

Sevenson will walk the site with the Engineer's representative to inspect turf establishment. Any areas that do not meet the acceptable standard of turf will be reseeded or repaired as directed by the representative, at no additional cost to NW Natural.

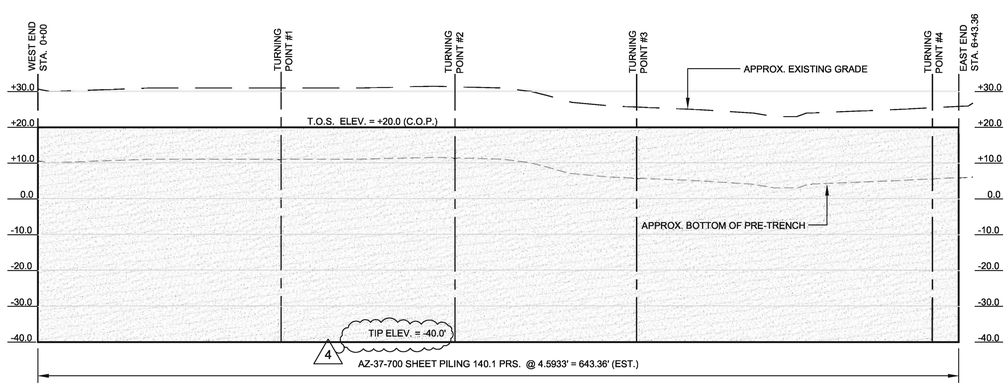
FINAL INSPECTION

After Sevenson has reseeded any areas designated by the Engineer and the new turf is established, Sevenson will request that a Final Inspection be held by the Engineer to determine that deficiencies noted in the preliminary inspection have been corrected.



A SP1 SITE PLAN

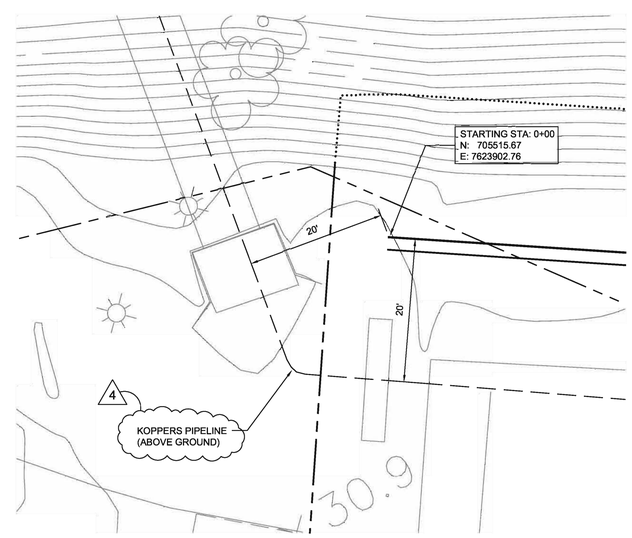
SCALE: 1" = 50'



B SP1 PROFILE - SHEET PILE BARRIER WALL - INBOARD FACE

HORIZONTAL SCALE: 1" = 50'
VERTICAL SCALE: 1" = 20'

NOTE: "C.O.P." CITY OF PORTLAND DATUM



C SP1 DETAIL "C"

SCALE: 1" = 10'

THIS GGE DRAWING USES A BASE SITE PLAN PREPARED BY ANCHOR ENVIRONMENTAL, L.L.C. AND IS INCLUDED AS A REFERENCE PLAN WITH THE EXCAVATION SHORING DESIGN PREPARED BY GLYNN GEOTECHNICAL ENGINEERING (GGE).

BARRIER WALL DESIGN & GENERAL NOTES:

DESIGN NOTES:

1. THE BARRIER WALL DESIGN AND SPECIFIED EXCAVATION GEOMETRY IS BASED ON DESIGN SOIL PARAMETERS DERIVED FROM SUBSURFACE SOILS SAMPLING AND TEST DATA PRESENTED WITHIN PROJECT INFORMATION PREPARED AND COMPLIED BY ANCHOR ENVIRONMENTAL, LLC.

2. THERE IS THE POTENTIAL THAT FUTURE SEDIMENT REMEDIATION MAY REQUIRE TEMPORARY EXCAVATION ADJACENT TO PORTIONS OF THE OUTBOARD SIDE OF THE BARRIER WALL. THE MAXIMUM SAFE EXCAVATION LIMITS CONSIDER (1) THE CAPABILITY OF THE BARRIER WALL TO SUPPORT AN UNBALANCED SOIL LOAD AND (2) THE STABILITY OF THE SLOPE CONSIDERING THE POST-EXCAVATION GEOMETRY. BASED ON THESE ANALYSES THE MAXIMUM SAFE EXCAVATION LIMIT IS ASSESSED TO TYPICALLY BE ELEVATION +6 FEET C.O.P. ONCE THE FUTURE OUTBOARD EXCAVATION LIMITS ARE KNOWN, THE ENGINEER WILL NEED TO EVALUATE THE BARRIER WALL SHORING REQUIREMENTS.

MATERIALS:

1. SHEETPILE MATERIAL SHALL COMPLY WITH ASTM A572 (Fy = 50 KSI, min.), AND SHALL BE PRODUCED BY "HOT ROLLING".

2. AZ37-700 SHEET PILE SECTIONS, BY ARCELOR MITTAL, PROVIDING A SECTION MODULUS OF 69in³/ft. ARE SPECIFIED FOR THE BARRIER WALL.

3. FULL LENGTH SHEETS SHALL BE PROVIDED TO PRECLUDE FIELD SPLICES.

4. SHEET PILING INTERLOCKS SHALL BE SEALED TO CONTROL GROUNDWATER MOVEMENT ACROSS THE BARRIER WALL.

4.1. INTERLOCKS BETWEEN SHOP PAIRED SHEETS SHALL BE SEALED USING A CONTINUOUS WELD EXTENDING THE FULL LENGTH OF THE SHEET.

4.2. FIELD INTERLOCKS SHALL BE SEALED USING SEVESON'S PATENTED SEAL SYSTEM OR OTHER FIELD APPLIED SEALANT.

5. IF REQUIRED, SUPPLEMENTAL STRUCTURAL STEEL SHALL COMPLY WITH:

5.1. WIDE-FLANGE "W" SHAPES - ASTM A992, Fy = 50 ksi,
5.2. "HP" SHAPES - ASTM A572, Fy = 50 ksi,
5.3. PIPE SECTIONS - ASTM A53, Gr. B, Fy = 35 ksi
5.4. MISC. PLATES AND CHANNELS - ASTM A36, Fy = 36 ksi

GENERAL CONSTRUCTION PROCEDURES:

1. CONSTRUCTION SHALL COMPLY WITH ALL APPLICABLE REQUIREMENTS OF OSHA CFR 29, PART 1926.

2. SHEET PILE WALL ALIGNMENT SHALL BE AS NOTED ON DRAWING SP-1 WHICH PROVIDES CALCULATED ALIGNMENT COORDINATES. ACTUAL FIELD ALIGNMENT MAY VARY, AS REQUIRED FOR ANGLE POINTS. STARTING STATION 0+00 SHALL BE MIN. 20' FROM KOPPERS PIPELINE. 4

3. COMPLETE SURFICIAL EXCAVATION AND PRE-TRENCHING ALONG THE ALIGNMENT OF THE SHEET PILE BARRIER WALL TO CLEAR THE DRIVELINE OF OBSTRUCTIONS AND FACILITATE SHEET PILING INSTALLATION.

3.1. PRE-TRENCHING: PRE-TRENCH ALONG THE DRIVELINE TO A DEPTH OF APPROXIMATELY TWENTY FEET (20') FROM EXISTING GRADE . BACKFILL THE EXCAVATED TRENCH IMMEDIATELY AND SEQUENTIALLY WITH CLEAN GRAVEL AS THE EXCAVATION PROCEEDS. THE VERTICAL LIMITS OF THE PRE-TRENCHING WILL BE ADJUSTED AS NECESSARY BASED ON THE STABILITY TRENCH SIDEWALLS IN THE INTERIM BETWEEN EXCAVATION AND BACKFILLING.

4. INSTALL BARRIER WALL SHEET PILING TO PROVIDE A TOE DEPTH CORRESPONDING TO A TIP ELEVATION OF -40.0 C.O.P. 4

5. THE ENGINEER SHALL BE NOTIFIED IMMEDIATELY IF CONDITIONS ENCOUNTERED IN THE FIELD VARY TO ANY SIGNIFICANT DEGREE, FROM THOSE CONSIDERED AND REPRESENTED IN THIS DESIGN AND/OR IF EXCESSIVE MOVEMENT OF THE SHEET PILING IS NOTED DURING CONSTRUCTION.

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VOICE (716) 625 - 6933 / FAX (716) 625 - 6983

MARK W. GLYNN, P.E.
OREGON GEOTECHNICAL
LICENSE No. 80419PE

ITEM:	DATE:	REVISION:
3	6/11/09	REVISED SHEETING TIP ELEV. TO -40.0 & CORRECTED SPELLING REVISED INTERIM DESIGN WITH CATWALK ISSUED FOR INTERIM DESIGN WITH CATWALK
2	5/28/09	ISSUED FOR INTERIM DESIGN REPORT
1	5/27/09	ISSUED FOR INTERIM DESIGN REPORT
0	5/22/09	ISSUED FOR INTERIM DESIGN REPORT

CLIENT: Sevenson Environmental Services, Inc.

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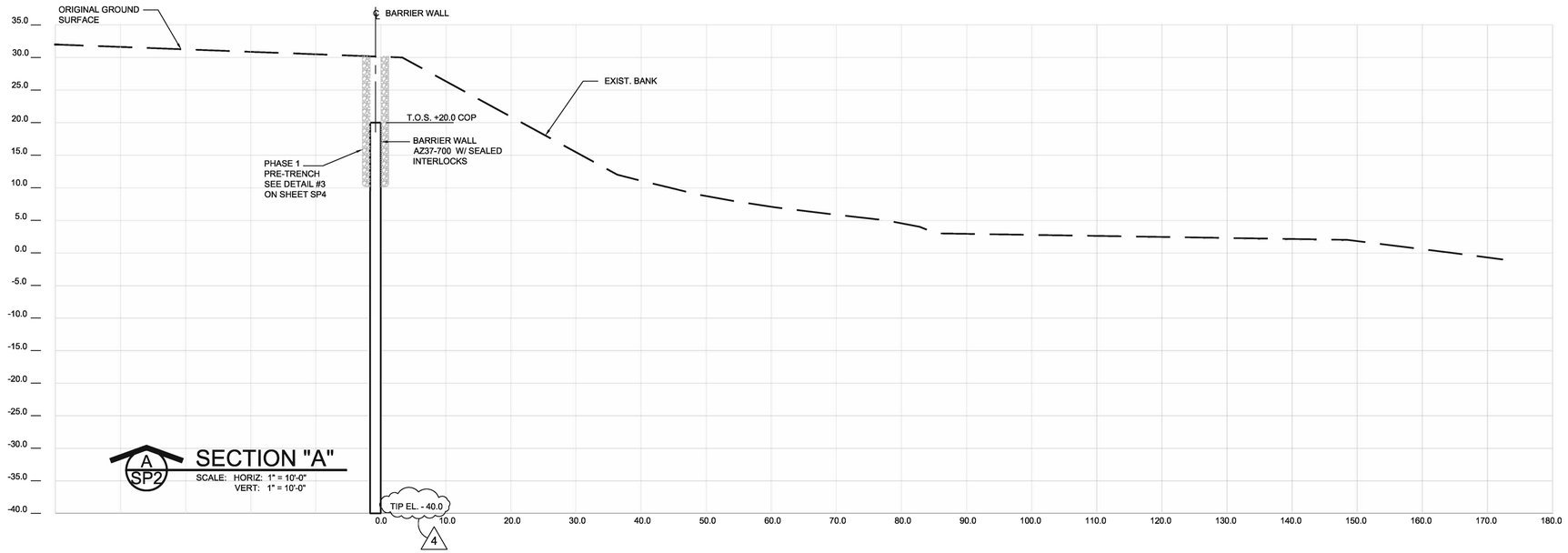
PROJECT: NW NATURAL - GASCO SITE PORTLAND, OREGON

TITLE: SHEET PILE BARRIER WALL LOCATION PLAN & NOTES

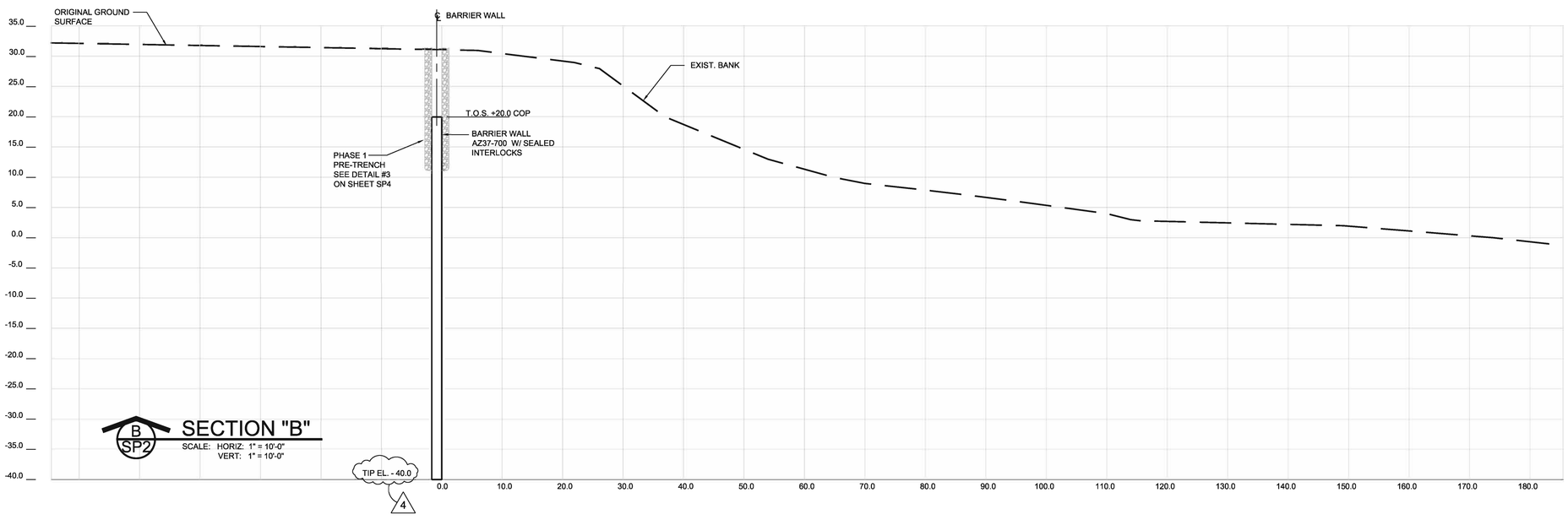
GGE PROJ #: 05-1043
GGE FILE: SP1.DWG
DRAWN BY: NMC
CHECKED BY: MWG

DWG: SP1



A SP2 SECTION "A"

SCALE: HORIZ: 1" = 10'-0"
VERT: 1" = 10'-0"



B SP2 SECTION "B"

SCALE: HORIZ: 1" = 10'-0"
VERT: 1" = 10'-0"

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MARK W. GLYNN, P.E.
OREGON GEOTECHNICAL
LICENSE No. 80419PE

ITEM:	DATE:	REVISION:
4	9/30/09	REVISED SHEETING TIP ELEV. TO -40.0
3	6/11/09	ISSUED FOR INTERIM DESIGN REPORT REVISED ALIGN. END OF DOLPHIN CATWALK
2	5/28/09	ISSUED FOR INTERIM DESIGN REPORT
1	5/27/09	ISSUED FOR INTERIM DESIGN REPORT
0	5/22/09	ISSUED FOR INTERIM DESIGN REPORT

CLIENT:
Sevenson Environmental Services, Inc.

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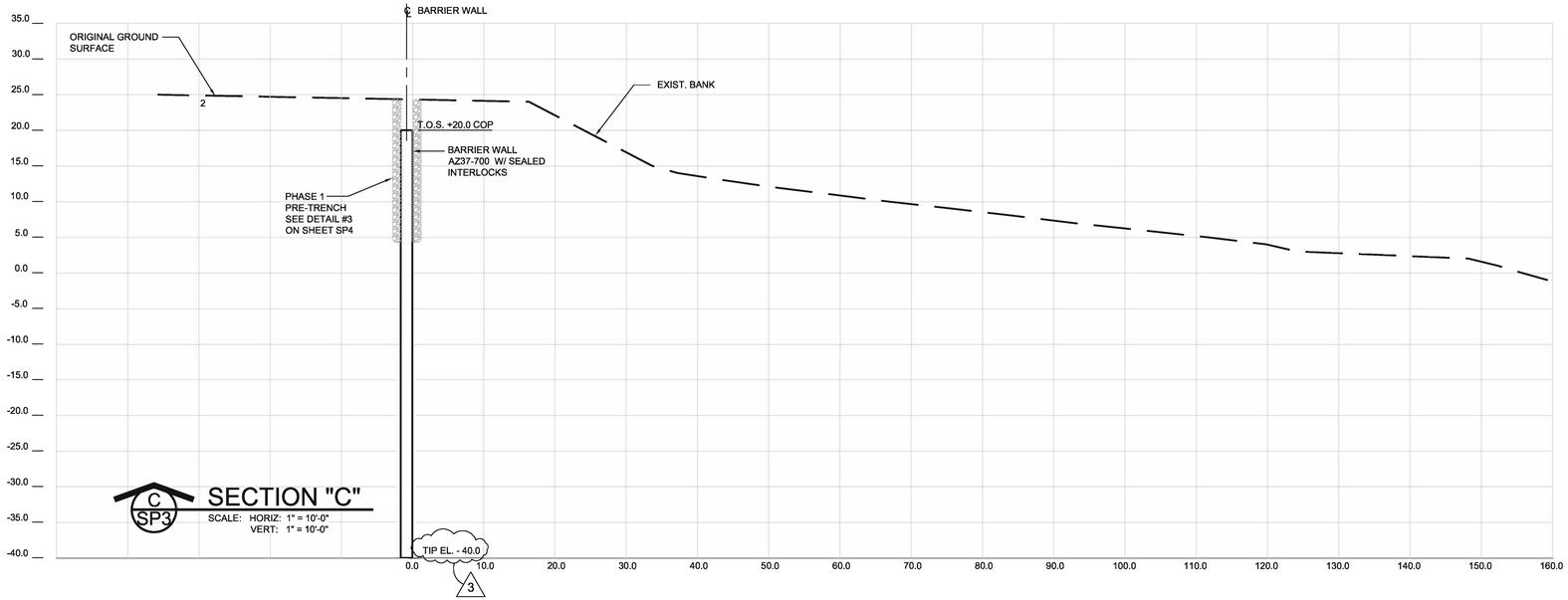
PROJECT:
NW NATURAL - GASCO SITE
PORTLAND, OREGON

TITLE:
SHEET PILE BARRIER WALL
SECTIONS A & B

GGE PROJ #: 05-1043
GGE FILE: SP2.DWG
DRAWN BY: NMC
CHECKED BY: MWG

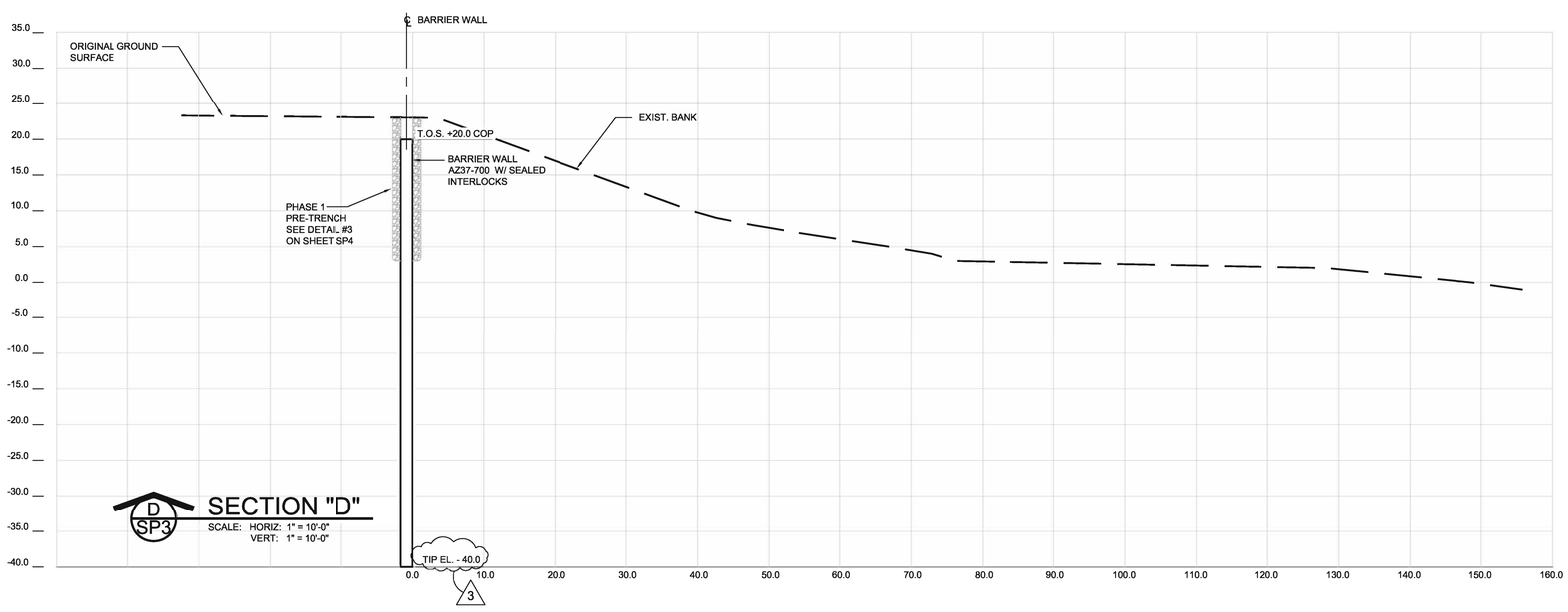
DWG: SP2



C SP3

SECTION "C"

SCALE: HORIZ: 1" = 10'-0"
VERT: 1" = 10'-0"



D SP3

SECTION "D"

SCALE: HORIZ: 1" = 10'-0"
VERT: 1" = 10'-0"

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MARK W. GLYNN, P.E.
OREGON GEOTECHNICAL
LICENSE No. 80419PE

ITEM:	DATE:	REVISION:
3	9/30/09	REVISED SHEETING TIP ELEV. TO -40.0
2	5/28/09	ISSUED FOR INTERIM DESIGN REPORT
1	5/27/09	ISSUED FOR INTERIM DESIGN REPORT
0	5/22/09	ISSUED FOR INTERIM DESIGN REPORT

CLIENT:
Sevenson Environmental Services, Inc.

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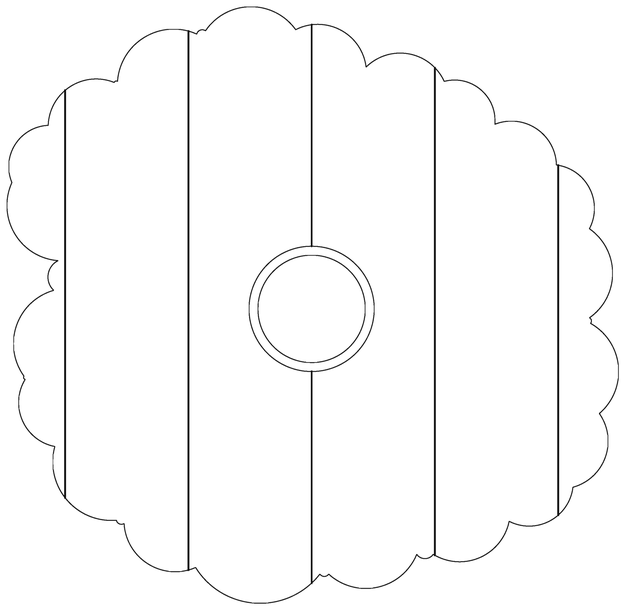
PROJECT:
NW NATURAL - GASCO SITE
PORTLAND, OREGON

TITLE:
SHEET PILE BARRIER WALL
SECTIONS C & D

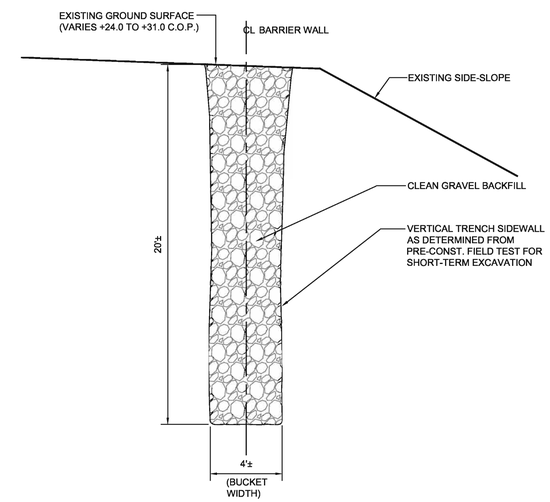
GGE PROJ #: 05-1043
GGE FILE: SP3.DWG
DRAWN BY: NMC
CHECKED BY: MWG

DWG: SP3

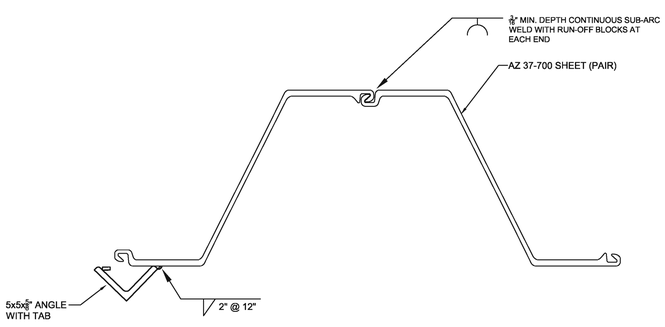


1 SP4 12" PIPE PENETRATION DETAIL
SCALE: 1-1/2" = 1'-0"

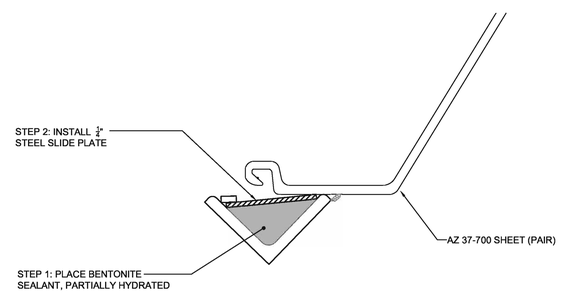
(P E N D I N G)



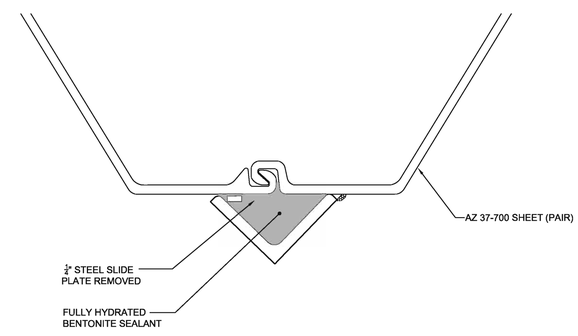
3 SP4 PRE-TRENCH DETAIL
SCALE: N.T.S.



2A SP4 INTERLOCK SEALING DETAIL (SHOP FABRICATION)
SCALE: 1-1/2" = 1'-0"



2B SP4 INTERLOCK SEALING DETAIL (FIELD PREPARATION)
SCALE: 3" = 1'-0"



2C SP4 INTERLOCK SEALING DETAIL (FIELD INSTALLED)
SCALE: 3" = 1'-0"

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LICENSE No. 80419PE

ITEM:	DATE:	REVISION:
2	9/30/09	REISSUED - NO CHANGES
1	5/28/09	ISSUED FOR INTERIM DESIGN REPORT
0	5/27/09	ISSUED FOR INTERIM DESIGN REPORT
	5/22/09	ISSUED FOR INTERIM DESIGN REPORT

CLIENT:
Sevenson Environmental Services, Inc.

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PROJECT:
NW NATURAL - GASCO SITE
PORTLAND, OREGON

TITLE:
SHEET PILE BARRIER WALL DETAILS

GGE PROJ #:
05-1043
GGE FILE:
SP3.DWG
DRAWN BY:
NWC
CHECKED BY:
MWG

DWG:
SP4

APPENDIX B
VIBRATION MONITORING AND COMMUNICATION PROTOCOLS

GROUNDWATER SOURCE CONTROL INTERIM DESIGN REPORT
NW NATURAL GASCO SITE, PORTLAND, OREGON

Prepared for

NW Natural

Prepared by

Anchor QEA, LLC

Colin Gordon & Associates

November 2009

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1 INTRODUCTION

Siltronic Corporation (Siltronic) manufactures silicon wafers for the semiconductor industry. On behalf of NW Natural, Anchor QEA, LLC (Anchor QEA), Colin Gordon and Associates (CGA), Stephen Dickenson, PhD (Dickenson), and Sevenson Environmental Services, Inc. (Sevenson) performed a vibration study to evaluate construction induced vibrations at the Siltronic facility that may be caused by construction of a vertical barrier wall. The study plan was developed in collaboration with Siltronic and was designed to evaluate the potential impacts of construction-induced vibrations on Siltronic's facility and accommodate Siltronic's production restrictions, process analysis, and feedback schedule during the testing. The Site vicinity is shown on Figure 1. General features of the Gasco and Siltronic properties are shown on Figure 2.

The vibration study was conducted between February 2, 2009 and March 10, 2009. During field testing, comprehensive vibration monitoring was conducted during all construction activities, including heavy equipment movement, backhoe pre-trenching, sheetpile driving, and pile removal. The primary goals of the construction simulation and ground motion monitoring investigation were two-fold: 1) to develop site-specific relationships for the attenuation of ground motions from the source of vibrations; and 2) to bracket the anticipated range of ground vibrations that would be generated by various construction techniques. The vibration study monitoring program was intended to characterize the range of motions that could be expected during construction options being evaluated by Anchor QEA and DEQ. It was anticipated that the ground vibrations generated during the investigation would effectively bracket the range of motions during construction; therefore, the findings from the monitoring would be used to quantitatively interpolate the vibrations that would be expected to result from multiple barrier types. The findings of the study were summarized in the *Vibration Study Data Report* (Anchor 2009) and provided to the Oregon DEQ to assist the DEQ in its selection of a groundwater DNAPL source control design for the Site.

1.1 Objectives

The objective of this appendix is to describe the vibration monitoring and communication protocols that will be used during the construction of the barrier wall. The vibration monitoring system and protocols will be based on findings from the preconstruction vibration study and conclusions summarized in the *Vibration Study Data Report*. In addition, this appendix briefly describes modifications needed to be made to select processes at Siltronic prior

to construction due to potential impacts from construction, based on the results of the vibration study.

2 VIBRATION MONITORING

2.1 Approach

2.1.1 Project Organization

Anchor QEA will manage the construction vibration monitoring and coordinate the implementation of the construction vibration monitoring with Siltronic. Signalysis will install and maintain the vibration monitoring and data acquisition system and provide technical support during construction vibration monitoring. Sevenson will manage the barrier wall construction and coordinate with Anchor QEA in the event of vibration warning level exceedances. Siltronic staff will monitor production operations during construction and provide feedback related to vibration monitoring. Siltronic equipment engineers will specify the necessary equipment or process modifications identified in the vibration study that are necessary to protect ongoing manufacturing operations during the construction phase of the barrier wall. Siltronic equipment engineers will select or approve all contractors, installations, or modification of equipment within the process areas.

2.1.2 Project/Task Descriptions

The construction vibration monitoring scope includes a ground vibration monitoring program for construction-induced vibrations associated with barrier wall construction at the Site. The protocols to be followed during construction activities are described in Section 3. All parties participating in this work, including those listed below, are required to follow the protocols described in Section 3. The following are the general responsibilities of the parties involved in activities associated with the vibration monitoring program.

Anchor QEA's tasks include:

- Working with Sevenson, Signalysis, and Siltronic to coordinate access and communication during the construction monitoring period.
- Implementing the vibration monitoring program for construction vibrations.
- Coordinating the timing of construction activities with Sevenson.
- Coordinating the implementation of response protocols in the event of a warning level exceedance and adjusting warning levels if needed.

Signalysis' tasks include:

- Installing and maintaining the vibration monitoring and data acquisition system.
- Providing technical support related to the vibration monitoring program to Anchor QEA.

Sevenson's tasks include:

- All construction activities required to install the barrier wall according to the source control Final Design approved by DEQ.
- Coordinating with Anchor QEA, Siltronic, and Signalysis in the event of vibration warning level exceedances.

Siltronic's tasks include:

- Providing staff for the implementation of the construction vibration monitoring process monitoring program.
- Providing access to allow implementation of the vibration monitoring program.
- Providing timely communication in the event of a warning level exceedance and on relevant findings from plant process monitoring during construction.
- Obtain estimates of the necessary modifications to select processes for approval by NW Natural.
- Select qualified contractors and schedule equipment modification, installation, and relocation activities.
- Schedule and supervise the modification of select processes prior to construction due to potential impacts from construction, based on the results of the vibration study. These modifications include:
  - Operating the scanning electron microscope when construction is not occurring.
  - Placing one laser mark microscope on a new vibration mount.
  - Relocating one laser mark microscope to a location with less vibration impacts.
- Providing long-term continuous monitoring of process tools and providing timely communication and feedback related to the long term continuous monitoring results.

2.2 Monitoring Locations

The locations where vibration monitoring equipment will be placed within the Siltronic fabrication (FAB) buildings are depicted in Figure 2. The construction vibration monitoring locations will be the same locations that were used during the preconstruction vibration

monitoring testing. Table 1 provides details related to what activities occur at each of the locations and the orientation of each of the 8 accelerometers that will be installed.

Long term continuous monitoring of impacts on tools will be conducted by Siltronic. Higher Order Statistical Process Control will be applied to metrology data produced by continuous monitoring of wafer production activities.

Siltronic will compare the yield or capability from normal production lots processed during the entire construction period with the baseline yield or capability for similar materials. Tolerance levels for changes in each of the parameters listed below are based on historical capability for each process. Tolerance levels have been selected based on the defect rates for 97.7% of lots produced, plus 25% of the difference in defect rates for 97.7% and 99.8% of lots produced. Production lots that exceed the selected tolerance from baseline yield or capability will be evaluated to determine if the cause may be from vibration or from other identifiable causes.

Higher Order Statistical Process Control data evaluation methods will be applied to the following yield and capability parameters:

Multi-Wire Sawing

- Potential Effects - Wire movement during slicing or catastrophic wire break
- Parameters – Warp, Total Thickness Variation (TTV), Sawmarks

Edge Grinding

- Potential Effects – Edge quality
- Parameters – Chips, Sparkle

Lapping

- Potential Effects – Loss of slurry film during lapping
- Parameters – Scratches

Backside Deposition (Poly Silicon; LTO: APCVD, LPCVD, PECVD)

- Potential Effects – Particle contamination (airborne or in-tool)
- Parameters – Pinholes, Dimples

Geometry Sorting

- Potential Effects – Measurement Stability
- Parameters – Thickness, Resistivity

Wax Mounting

- Potential Effects – Particle contamination (airborne or in-tool)
- Parameters – Dimples

Polishing

- Potential Effects – Final Polisher cylinder vibration
- Parameters – LLS

Polishing Geometry Measurement

- Potential Effects – Measurement Stability
- Parameters – Thickness, GBIR, GFLR, STIR

Final Cleaning and Inspection

- Potential Effects – Airborne Particles
- Parameters – LLS, airborne particle counters

Automatic Inspection, Laser

- Potential Effects – Measurement Stability (lasers, lenses, & mirrors)
- Parameters – LLS, Nanotopography

Epitaxy

- Potential Effects – Airborne Particles
- Parameters – Spikes, LLS

Laser Marking

- Potential Effects – Stability of laser, lenses, & mirrors
- Parameters – Dot depth, readability of marked wafer

Spreading Resistance Profile (SRP)

- Potential Effects – Measurement stability
- Parameters – Dopant profile of epitaxial layer (concentration and thickness)

Analytical Laboratory

- Potential Effects – SEM stability
- Parameters – Distortion of images

Deviation from the above defect toleration will be evaluated by FMEA to determine if the root cause was attributable to vibration induced impacts from barrier wall construction.

2.3 Initial Warning Levels

Warning levels to be used in Fab 1 during construction vibration monitoring will be the same as the last warning levels defined during the preconstruction vibration study. The last warning levels defined during the preconstruction vibration study are provided on Table 2.

Deviations from the last warning limits defined include adjustments to the warning limits in FAB 2. The last warning limits defined during preconstruction monitoring in FAB 2 were due to velocities recorded during the Step 4 ambient phase of the preconstruction vibration study, showing that there are vibration sources other than construction impacts which would likely cause warning level exceedances in FAB 2. For this reason, the warning levels for all frequencies in FAB 2 have been adjusted such that the minimum warning level is 500 micro inches per second, which corresponds to one vibration criterion (VC) higher than the FAB 2 design VC based on the recommendation of CGA. The warning levels for the majority of the frequencies in FAB 2 were already in exceedance of 500 micro inches per second following the preconstruction vibration study. The proposed initial FAB 2 warning levels are provided on Table 3. Warning levels that have been increased from the final warning level defined in the preconstruction vibration study are subject to ongoing discussions between NW Natural and Siltronic.

Vibration data is collected over four second time windows. As recommended by CGA, in order for a warning level to be triggered, velocities must be exceeded for three consecutive time windows, or 12 seconds.

3 VIBRATION MONITORING PROTOCOLS

The vibration monitoring system will be installed and tested before barrier wall construction begins. Signalysis will provide Anchor QEA with instructions related to restarting the system (if needed), adjusting alarm levels, and ensuring that monitoring data is stored and maintained securely. In addition Signalysis will coordinate with Anchor QEA to ensure that contingencies related to the vibration monitoring system operation are in place so that the construction schedule is not impacted by vibration monitoring system failure.

3.1 Communication Protocols

The planned construction work hours are 7:00 am though 7:30 pm, Monday through Friday. Siltronic does not currently have a plan for staffing process engineers during all of the planned construction work hours. Either funding for extended daily hours for process engineers will be obtained or construction hours will be restricted to times when process engineers are normally available. Prior to the start of sheet pile installation there will be a communication check between the Project Manager (PM; Anchor QEA Designee), the Plant Process Monitoring (PPM; Siltronic Designee) Lead, the Construction Management (CM; Sevenson Designee) Lead. The actual designees will be identified in the construction work plans. The purpose of this check is to confirm that the communication devices are working reliably between all parties. Two-way radios will be utilized as the primary communication device. Cell phones will be utilized as the back-up communication device. Repeated communication checks should also be made between all parties at least hourly during construction to confirm that the communication systems are functional.

Each day prior to start of sheet pile installation there will be a meeting between the PM, the PPM Leads, and the CM Lead. During that meeting the group will review the work planned for that day and the communication protocols to be sure that all parties understand the process. Meeting notes from each meeting will be summarized and distributed to the project team to provide documentation of attendees, discussions, and agreements made.

3.2 Warning Level Exceedance Protocols

Warning levels will be set as described in Section 2.3. These warning levels may be adjusted by mutual agreement between NW Natural and Siltronic during the course of construction. If a

warning level is exceeded the PM will receive notification via automatic text message from the vibration monitoring system:

- The PM will notify the CM Lead and direct the CM Lead to pause construction immediately.
- The CM Lead will halt all operations and movement of large equipment until cleared by the PM.
- The PPM Lead will check Siltronic's processes and alert the PM of any catastrophic failures or other identified issues. The exact timing of feedback from Siltronic after an exceedance will be determined through ongoing discussions between NW Natural and Siltronic.
- The PM and PPM Lead may adjust the warning level after performing process monitoring review protocols, as described in Section 3.4.

3.3 Protocols Related to Long Term Continuous Impact Monitoring

The following protocols related to long-term continuous impact monitoring will be followed:

- Siltronic intends to use higher order statistical process control data collected from process monitoring stations. Review and correlations of this data may take up to two weeks.
- The PM will authorize the CM Lead to resume construction.

In the event that the Siltronic PPM does not authorize a resumption of construction and it is determined that modifications to the design may be needed due to vibration issues, DEQ will be contacted for consultation. The design already includes contingencies for mitigating vibration sound related impacts. Any changes to the design beyond the contingencies already specified will be reviewed with and approved by DEQ.

4 REPORTING

Daily logs will be maintained by Sevenson and Anchor QEA during construction. Information related to pile driving starts and stops, warning level exceedances, warning level adjustments, and authorization by Siltronic to proceed in the event of a warning level exceedance will be recorded.

Any modifications to the design on the sheetpile wall that are needed due to vibration issues will be summarized in the Gasco Groundwater Source Control Remedial Action Completion Report. If modifications are needed, the summary will include vibration and process feedback data, as well as the rational for making the modifications to the design. Siltronic will provide the results of process monitoring data under the terms of the Non-Disclosure Agreement between NW Natural and its Contractors and Subcontractors and Siltronic related to any decision leading to modifications to the design to NW Natural for inclusion in the report. A draft report will be submitted to Siltronic for review. The report will then be submitted to DEQ. The version submitted to DEQ may have some information redacted to remove material designated by Siltronic as confidential business information.

5 REFERENCES

Anchor QEA 2009. Vibration Study Data Report. Gasco Siltronic Construction. Prepared for NW Natural. May 2009.

TABLES

Table 1
Monitoring Locations and Related Information

Location	FAB Facility	Specific Location	Orientation	Activities At Location
1	2	Room 6D113 1st Floor Ceiling	Vertical	FAB 2 Production
2	2	Room 6D113 1st Floor Ceiling	North-South	FAB 2 Production
3	2	Room 6D113 1st Floor Ceiling	East-West	FAB 2 Production
4	2	Room 6D113 Concrete Floor	Vertical	Equipment Maintenance
5	1	Room A120 Concrete Floor	Vertical	Scanning Electron Microscope
6	1	Room A120 Concrete Floor	East-West	Scanning Electron Microscope
7	1	Room E180 Concrete Floor Below Raised Access Floor	Vertical	FAB 1 Final Cleaning
8	1	Room H138 Concrete Floor Below Raised Access Floor	Vertical	FAB 1 Epitaxy

Table 2
Final Warning Levels Defined During the Preconstruction Vibration Monitoring Study

	Accelerometer							
	FAB 2				FAB1			
Frequency (Hz)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
4	1115	400	400	918	2000	400	1000	1000
5	1415	400	492	1101	2320	400	2000	2000
6.3	1200	400	400	1560	2080	300	2000	2000
8	1200	400	400	1000	3000	400	2000	2000
10	1200	500	700	1000	5000	1200	4000	4000
12.5	1000	280	500	900	6000	1200	4000	8000
16	1000	800	600	900	7000	1200	9000	8000
20	1520	970	*600*	900	8000	3000	9000	5000
25	2596	1866	1193	278	8000	1400	9000	4000
31.5	1000	1573	911	100	6000	600	3000	1000
40	900	*500*	*400*	75	10000	3000	3000	1000
50	*643*	*500*	*800*	59	10000	3000	3590	1000
63	643	362	641	240	10000	3000	2576	3000
80	518	*362*	225	39	10000	3000	2450	3000

Notes:

In microinches per second.

Bold red = warning level increase from previous day or time.

Italic red = warning level increase as a result of non-construction related activity.

Table 3
Proposed Warning Levels for Barrier Wall Construction Vibration Monitoring

	Accelerometer							
	FAB 2				FAB 1			
Frequency (Hz)	1	2	3	4	5	6	7	8
4	1115	**500**	**500**	918	2000	400	1000	1000
5	1415	**500**	**500**	1101	2320	400	2000	2000
6.3	1200	**500**	**500**	1560	2080	300	2000	2000
8	1200	**500**	**500**	1000	3000	400	2000	2000
10	1200	500	700	1000	5000	1200	4000	4000
12.5	1000	**500**	500	900	6000	1200	4000	8000
16	1000	800	600	900	7000	1200	9000	8000
20	1520	970	600	900	8000	3000	9000	5000
25	2596	1866	1193	**500**	8000	1400	9000	4000
31.5	1000	1573	911	**500**	6000	600	3000	1000
40	900	500	**500**	**500**	10000	3000	3000	1000
50	643	500	800	**500**	10000	3000	3590	1000
63	643	**500**	641	**500**	10000	3000	2576	3000
80	518	**500**	**500**	**500**	10000	3000	2450	3000

Notes:

In microinches per second.

Bold red = warning level increase from final warning level defined during preconstruction vibration monitoring study.

FIGURES

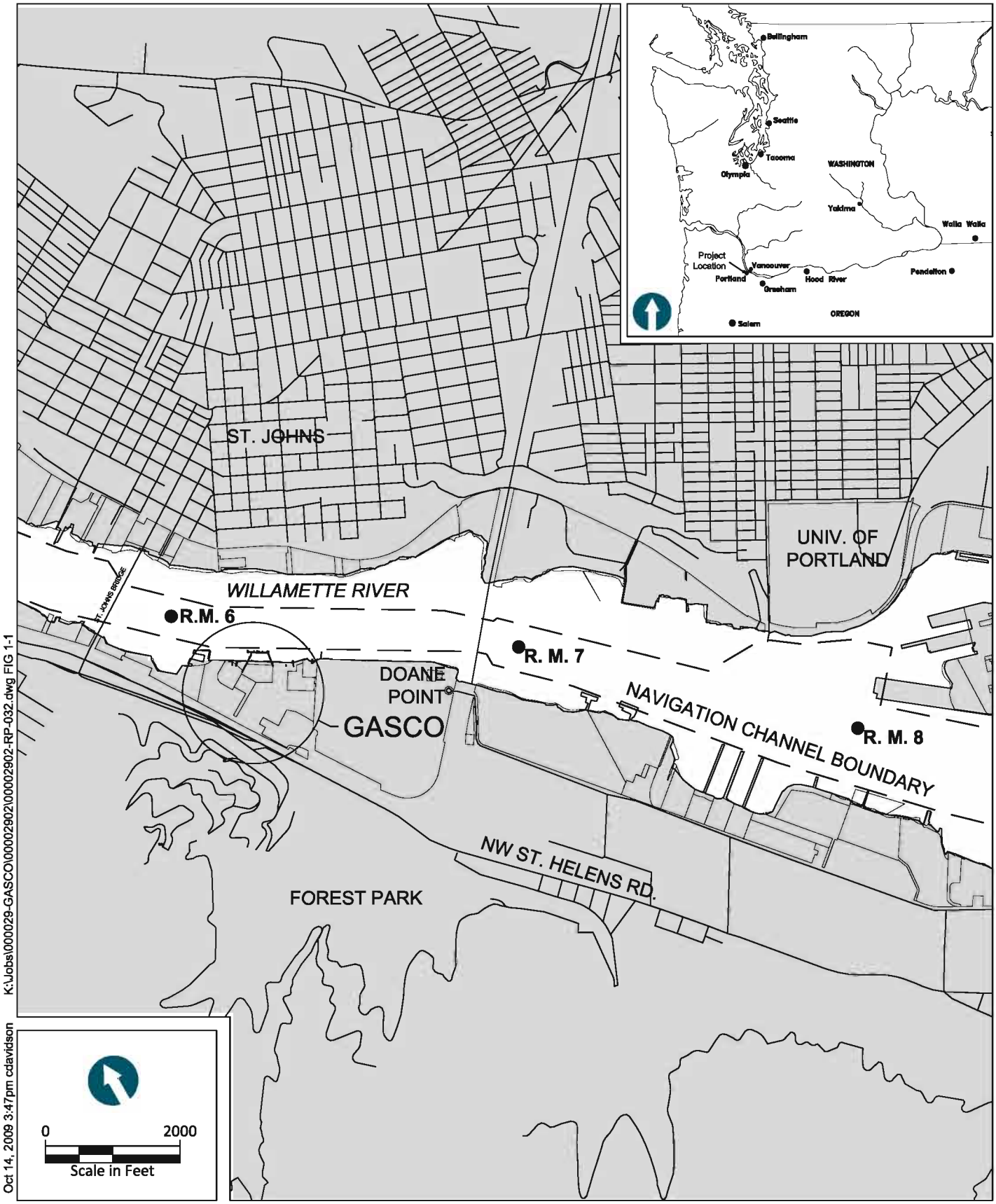


Figure 1-1
Site Vicinity Map
Gasco Groundwater Source Control
Interim Design Report

ANCHOR QEA

ANCHOR QEA

Feet
0 150 300

Figure 2
Vibration Monitoring Systems Locations
Gasco Groundwater Source Control
Interim Design Report, Appendix B

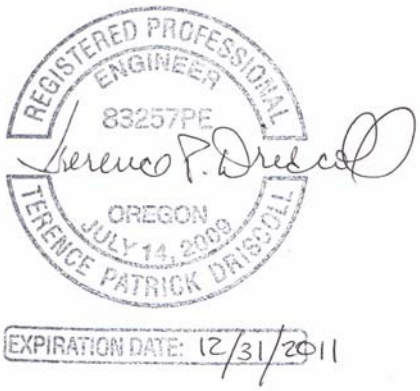
APPENDIX C
GROUNDWATER TREATMENT SYSTEM DESIGN (SEVENSON)

NW Natural Gas Company

NW Natural and Siltronic
Wastewater Treatment Interim Design Report

October 2009

Sevenson Environmental Services, Inc.



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Process Design—NW Natural Site

The proposed treatment process is largely designed to remove iron and manganese, cyanide, heavy metals, VOCs and SVOCs. The plant will be situated inside a secondary containment area containing crushed stone over a 40-mil liner, with berms around the entire site to contain wastewater, residual, or chemical spills. The facility will be operated under a site-specific Health and Safety Plan (HASP), submitted under separate cover. The site-specific HASP will address spill prevention and countermeasures to be taken and emergency contacts in the event of a spill.

The NW Natural plant is designed to operate at an average daily influent flow rate of 300 gpm. Treated effluent from the Siltronic plant (100 gpm) will be blended into the NW Natural plant for a total projected influent flow rate of 400 gpm, operating on a continuous basis. Discharge will be to the Willamette River.

All backwash water will be recirculated to the influent equalization tanks for re-treatment. All plant residuals (bag filters, sedimentation tank solids, and spent carbon) will be properly disposed of to a permitted facility.

Process Design—Siltronic Site

The proposed treatment process is largely designed to remove iron and manganese, cyanide, heavy metals, and chlorinated solvents including vinyl chloride. The oil-water separator, air stripping tank, equalization tank and influent pump will be situated inside a secondary containment area on the NW Natural site at the NW Natural-Siltronic property line. The containment area will contain crushed stone over a 40-mil liner, with berms around the entire plant site to contain wastewater, residual, or chemical spills.

The preliminary Siltronic treatment train will be located approximately 500 feet away. All piping between the containment areas will be dual-contained, HDPE pipe. The dual-contained piping will be pitched toward lowest point on the line, and possible leakage captured and monitored at a valve and nipple located on the exterior pipe.

Basis of Design and Impact of Pilot Testing

Sevenson has prepared this design document following the completion of a 6-week pilot plant test, completed in September 2009, and a 1-week air stripping pilot on site wastewater conducted in Sevenson's Wastestream laboratory. The Wastewater Pilot Plant Testing Plan (Sevenson, April, 2009) was provided to DEQ on May 4, 2009. DEQ provided a preliminary comment letter on October 13 and Sevenson prepared a May 21 response letter addressing DEQ's comments. The findings from operating the pilot treatment plant have been incorporated into the final design of the treatment system. The Pilot Plant report will be submitted to DEQ subsequent to this report.

The approach and sizing data contained in this interim design report are based upon the Pilot Plant, Wastestream air stripping studies, and prior treatability studies that established the processes as effective in cost-effectively meeting Oregon DEQ's discharge standards.

Sevenson has included its wastewater treatment plant design and materials balance in Attachment A for both the NW Natural and Siltronic sites. The interim design drawings for the plant are included in Attachment B.

Influent Wells Location

In the full scale extraction system the NW Natural treatment plant will draw from eight wells on the NW Natural Site, and two wells from the Siltronic site, as shown on Figure 1.

It is anticipated that flow from the well pumps will be controlled from the central Supervisory Control and Data Acquisition (SCADA) system to replenish the treatment plant influent equalization tanks.

Water level transducers in the river and key monitoring wells will be used for real time measurement of river and groundwater elevations. The well discharge rates will be adjusted to maintain average groundwater elevation below average river elevation and thereby achieve containment of groundwater at the shoreline.

Because of daily river tidal influences on the near shore groundwater levels, the well flow rates will be adjusted concurrently with groundwater level fluctuations through the use of

variable frequency drives which will control the well pumping rates. The system will be constructed for remote monitoring of groundwater elevations and well discharge rates. The extraction well pumping rates will be monitored from the SCADA control panel. Flow from each well will be indicated and totalized within the SCADA system.

Sodium Hydroxide Feed Pumps

Two sodium hydroxide feed pumps, pH meters and controllers will be installed on the incoming well lines to increase the influent pH to 9.5-10.0 in the flow to the air stripping tanks. The rates of iron and manganese oxidation are both greatly accelerated at higher pH.

NW Natural Air Stripping Tanks

Each NW Natural well pump will pump into a common oil-water separator, before being pumped to the NW Natural Air Stripping Tanks. Prior to entering the air stripping tanks, the wastewater pH will be adjusted to 9.5-10.0 to facilitate the ultimate precipitation of iron, manganese, and other metals in the downstream settling process.

Two 12,000-gallon tanks will be provided to handle all NW Natural flows. The purpose of the air stripping tanks is twofold:

1. To volatilize the small quantity of VOCs present, and to provide partial stripping of SVOCs; and
2. To oxidize incoming iron and manganese which are both in their soluble, reduced forms.

Two 600 standard-cubic-feet-per-minute (scfm) positive-displacement blowers will be provided, one per tank. The blowers will be constant speed, and have been designed to provide a minimum air: water ratio of 30: 1 at the maximum influent flow rate. At lower flows, the air: flow ratio will be higher. Laboratory data from the Wastestream results (to be submitted in the Pilot Plant Report) indicated that virtually complete removal of VOCs and 50% removal of SVOCs were achievable at the design air: water ratio.

The tanks are designed with baffles to also collect any floating light solids and oil that may be present. The accumulated solids and floatables in the tanks will be periodically removed as required using a trash pump.

Siltronic Air Stripping Tank

The Siltronic well pumps will pump into an oil-water separator, before being pumped to the Siltronic Air Stripping Tank. Prior to entering the air stripping tank, the wastewater pH will be adjusted to 9.5-10.0 to facilitate the ultimate precipitation of iron, manganese, and other metals in the downstream settling process.

One 12,000-gallon tank will be provided to handle all NW Natural flows. The purpose of the air stripping tank is twofold:

3. To volatilize the various chlorinated solvents (vinyl chloride, trichloroethylene, and the various forms of dichloroethylene) present in the Siltronic wells, and to provide partial stripping of SVOCs; and
4. To oxidize incoming iron and manganese which are both in their soluble, reduced forms.

One 300 standard-cubic-feet-per-minute (scfm) positive-displacement blowers will be provided. The blower will be constant speed, and has been designed to provide a minimum air: water ratio of 30: 1 at the maximum influent flow rate. At lower flows, the air: flow ratio will be higher. Laboratory data from the Wastestream results (to be submitted in the Pilot Plant Report) indicated that virtually complete removal of VOCs and 50% removal of SVOCs were achievable for the Siltronics wastewater at the design air: water ratio.

The tank is designed with baffles to also collect any floating light solids and oil that may be present. Any accumulated solids and floatables in the tank will be periodically removed as required using a trash pump.

NW Natural Influent Equalization Tanks

An inflow routing analysis (Rippl diagram) has been prepared for the NW Natural wells to optimize the sizing of the equalization tanks, to provide the required storage to minimize

downstream flows to the remainder of the plant. As indicated, the influent flows are expected to vary with tidal and other factors affecting river levels, and the resulting river: groundwater differential.

Analyses were prepared for the "normal" condition, as modeled by Anchor Environmental, and the so-called maximum-day flow (a total of 400 gpm). These analyses are shown in Appendix C for NW Natural. The results of the analyses show a required equalization storage capacity as summarized in Table 1:

Table 1: Summary of NW Natural Equalization Storage

Required Storage, gals	**Average Day Flow Condition**	**Maximum Day Flow Condition**
MW-1	10,800	14,400
PW-1	10,800	14,400
Total Required Storage, gals	**21,600**	**28,800**

Two 6,000-gallon, in-line equalization tanks will be provided, for a total in-line storage capacity of 12,000 gallons. The tanks will be interconnected. In addition, a separate 21,000-gallon tank will be piped to the in-line tanks to provide off-line equalization storage, to handle additional peak flows. Thus, a total of 33,000 gallons of storage is provided, which is more than sufficient.

Besides well water, the off-line equalization tank will also receive spent backwash water from the downstream GAC vessels.

Siltronic Influent Equalization Tank

An inflow routing analysis (Rippl diagram) was prepared for the Siltronic wells to optimize the sizing of the equalization tank, to provide the required storage to minimize downstream flows to the remainder of the plant. As indicated, the influent flows are expected to vary with tidal and other factors affecting river levels, and the resulting river: groundwater differential.

Analyses were prepared for the "normal" condition, as modeled by Anchor Environmental, and the so-called maximum-day flow (a total of 400 gpm). These analyses are shown in Appendix D for Siltronic. The results of the analyses show a required equalization storage capacity as summarized in Table 2:

Table 2: Summary of Siltronic Equalization Storage

Required Storage, gals	Average Day Flow Condition	Maximum Day Flow Condition
Siltronic Wells	**5,400**	**8,400**

One 6,000-gallon, in-line equalization tank will be provided, for the average day condition. In addition, a separate 3,000-gallon tank will be piped to the in-line tank to provide off-line equalization storage, to handle additional peak flows. Thus, a total of 9,000 gallons of storage is provided, which is more than sufficient.

Inclined-Plate Clarifier (IPC) Feed Pump

One 259-gpm centrifugal IPC feed pump will be provided, tied to a pipe system with the equalization tanks. The pump has a variable frequency drive (VFD) adjustable speed control, to allow for pumping different flow from each well to the plant. A 4-inch flow meter will be provided to control the downstream polymer feed unit.

An uninstalled spare pump will be stored on site to permit quick replacement of any part, or the entire pump.

Siltronic Process Addition Point

Following the air stripping and equalization processes at the Siltronic site, a transfer pump will pump the Siltronic flow to the Inclined-Plate Clarifier to remove iron, manganese, and other metals.

The pilot plant and Wastestream studies consistently showed that air stripping easily exceeded Oregon DEQ's requirements for minimum levels of chlorinated solvents. As a result, the effluent from the air stripping is not a "listed" waste and may be introduced into the NW Natural process flow stream without further issue.

IPC Flow Meter

A 4-inch flow meter will be provided to control the downstream polymer feed unit. The flow meter will read both NW natural and Siltronic flows.

Polymer Addition

A polymer addition system will be installed to feed polymer to the wastewater prior to introduction into the downstream inclined-plate clarifier to facilitate settling. The polymer will be injected into the IPC flash-mix chamber, and paced by the flow meter to the clarifier.

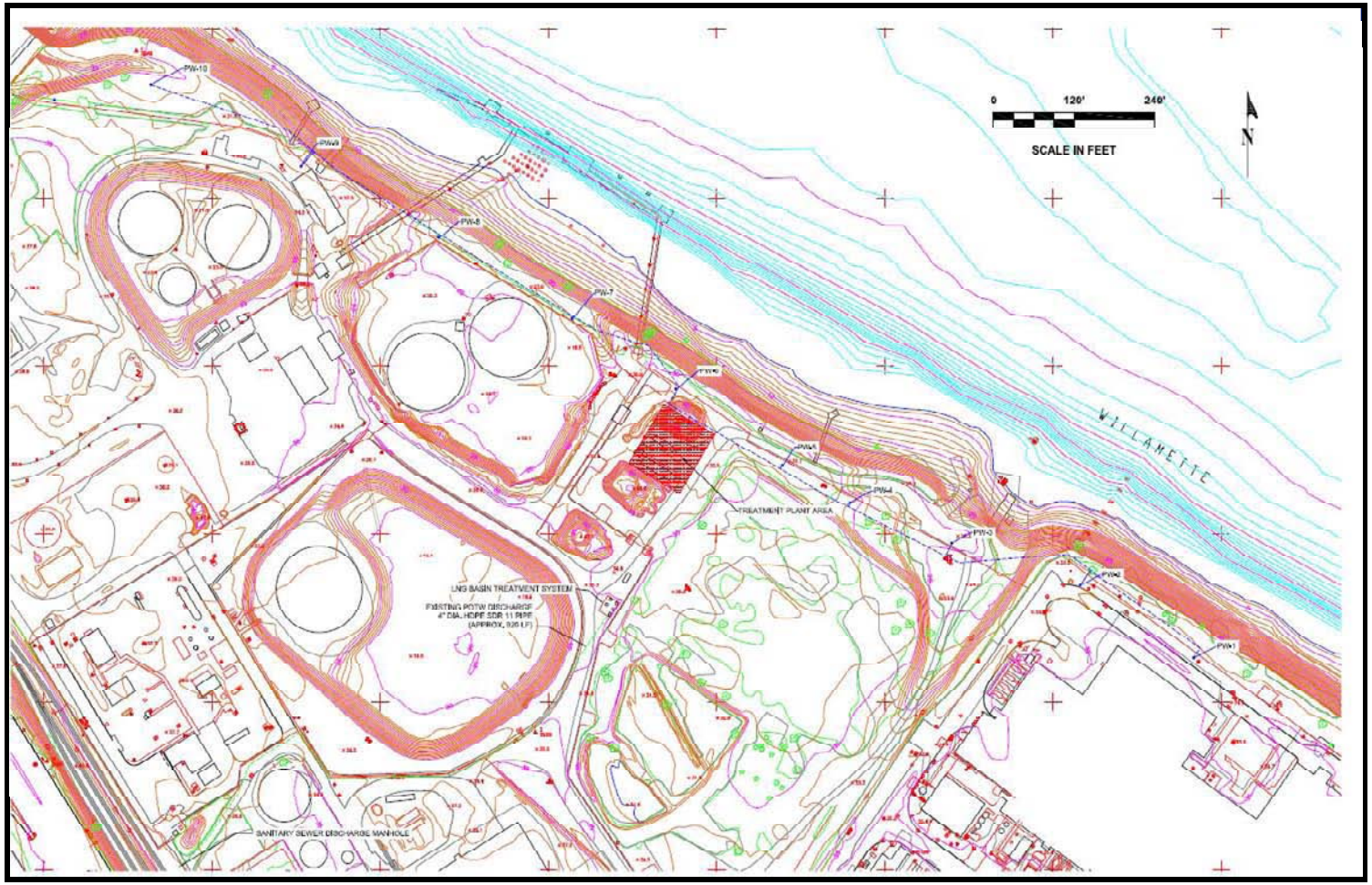
Inclined-Plate Clarifier (IPC)

A single inclined-plate clarifier (IPC) will receive the flow from the equalization tanks of both NW natural and Siltronic. The principal purpose of the IPC is to remove the oxidized iron and manganese generated in both upstream processes.

In addition, heavy metals will be removed via iron co-precipitation in the clarifier. The tank will have a mechanical flash-mix chamber, and a mechanical flocculation to facilitate settling of the chemical flocs. The tank will be equipped with 1,500 square feet of settling area.

Settled sludge will be removed via a single air-operated diaphragm pump located under the IPC and designed to work off an adjustable timer programmed in the SCADA system. The pump will discharge to two gravity thickener tanks for storage, thickening, and ultimate dewatering via a filter press. The resulting filter cake will be stored in a proper container within the containment area and properly disposed of periodically.

Figure 1: Location of NW Natural and Siltronic Wells for Treatment Plant



Cyanide Destruct Chemical Feed System

A chemical feed system will be supplied to provide for cyanide destruction. The chemical feed pump and control system will be capable of feeding either 50% hydrogen peroxide or 12.5% sodium hypochlorite, both of which proved to be effective in reducing cyanide in previous pilot and bench-scale tests. An ORP meter and controller will be installed on the cyanide destruct reactor to destroy cyanide as described below. The feed pumps will take suction from a chemical tote containing approximately 260 gallons of either 50% hydrogen peroxide solution or 12.5 % sodium hypochlorite solution.

Cyanide Destruct Reactor

A 21,000-gallon reactor tank will be used for cyanide destruction via the alkaline oxidation process. The alkaline oxidation process uses either hydrogen peroxide (H_2O_2) or sodium hypochlorite (NaOCl) to break the cyanide bond at high pH in two steps.

1. Cyanide (CN-) oxidized to cyanate (CNO-);
2. Cyanate is further oxidized to carbon dioxide and nitrogen gas,

Both of these reactions will occur in the cyanide destruct tank. The addition of either hydrogen peroxide or sodium hypochlorite (both strong oxidizers) is made ahead of the destruct tank. The oxidizer feed rate is automatically controlled by Oxidation-Reduction Potential (ORP), measured in millivolts by a probe in the tank. Adding the oxidant raises ORP in the wastewater. An ORP controller will control the addition of the oxidant to the desired level to destroy cyanide.

The tank will be sized for a minimum detention time of 60 minutes, based upon the results in the treatability and pilot tests. A constant water level will be maintained in the tank via level controls and variable-speed pumping.

Sulfuric Acid Feed System

A sulfuric acid feed pump, a pH meter and a controller will be installed on the pipe from the cyanide destruct tank to reduce the wastewater pH to approximately 8.5. The sulfuric

acid feed pump will take suction from a tote, containing approximately 260 gallons of sulfuric acid. The acid will be injected upstream of a 4-inch in-line static mixer.

Filter Feed Pumps

Following the cyanide reactor tank will be a 259-gpm electric centrifugal pump. The pump will be automatically controlled, using a set level in the cyanide destruct tank. The flow rate will be adjusted with the use of a variable-frequency drive.

The Filter Feed Pumps will pump the combined flows through the bag filters, and the granular activated carbon (GAC) vessels, before discharging to the Willamette River, or into the Backwash Storage Tank.

Primary Bag Filters

Four pressure bag filters (2 trains of 2 filters) will be provided to remove remaining particulates from the wastewater prior to the GAC units. The two trains of bag filters will be set up to operate in series to filter iron and other solids prior to introduction into the GAC vessels. Each bag filter has a capacity of 500 gpm.

The upstream and downstream filters will be fitted with 10-micron and 5-micron bags, respectively. The vessels are fitted with inlet and outlet pressure transmitters. When the selected pressure differential is reached, the train will automatically shift to the other train and the SCADA system will alert the operator to changes filter bags before putting the train back on line.

Granular Activated Carbon Vessels

The waste stream then flows through two, 10-foot diameter Granular Activated Carbon (GAC) vessels, piped in series, with differential pressure measured across each vessel. The GAC units will remove volatile organics and semi-volatile organics in the effluent from the filter units. Ten thousand pounds of carbon will be loaded into each vessel, for an overall total of 20,000 pounds of carbon.

The system design is intended to continue to remove all organics in the lag vessel after breakthrough in the lead vessel. Breakthrough will be determined by frequent sampling

of volatile and semi-volatile organics between the columns. After breakthrough, volatile and semi-volatile organics will be monitored from the lag column. No work will continue if the lag vessel becomes exhausted. The amount of carbon in each vessel has been calculated to give the process water adequate contact time at a maximum equalized flow rate of 259 gallons per minute.

The GAC filters will be provided with backwashing capability to allow continuous operation. A single unit will be shut down for backwashing and the other unit will continue during the backwashing. Spent backwash water will be returned to the Spent Backwash Tank for re-processing through the plant.

Effluent Bag Filters

A final filtration step will be accomplished using two bag filters arranged in parallel. The filters are intended to remove any carbon fines and adsorbed organics escaping the GAC vessels.

The bag filters will be equipped with either 1.0-micron or 0.5-micron bags. The vessels are each sized for 500 gpm, are fitted with inlet and outlet pressure transmitters. The bags will be changed at an appropriate pressure differential.

Effluent Discharge

The effluent will continue under pressure past the Effluent Bag Filters to the discharge point to the river. As an alternative, flow may be diverted to the Backwash Storage Tank as necessary.

Backwash Storage Tank

Treated effluent will be discharged as required into one 21,000-gallon backwash storage tank. The tank will serve clean water holding tank for backwash water.

Backwash Pump

An electric centrifugal pump will be provided, with a capacity of 942 gpm, to allow for a suitable backwash rate for the GAC vessels and will carry the spent backwash flow to the Spent Backwash Tank.

Flow Meter Rate/Totalizer

All treated wastewater discharged from the plant will pass through a 4-inch flow meter. Discharge flow rates and totalized volumes will be recorded by the SCADA system.

In addition, a 4-inch backwash flow meter will be installed on the backwash line. Backwash flow and duration will be controlled by SCADA.

Effluent Sampler

A refrigerated composite effluent sampler will be provided to provide a representative effluent sample for monitoring and compliance. The sampler will obtain a flow-proportioned effluent sample controlled off the outputs of the effluent flow meter and totalizer.

Combined Plant Residuals Handling and Disposal

All residuals from both the NW Natural and Siltronic treatment plants: settled solids, GAC media, and spent bag filters, will be properly disposed of.

Gravity Sludge Thickeners

Settled sludge from the NW Natural IPC will be pumped to two gravity thickeners via an air-operated diaphragm pump. The purpose of the gravity thickeners is to concentrate the sludge to the maximum extent possible prior to dewatering with a filter press.

Two 8,000-gallon storage tanks will be provided and piped either in common or individually. The tanks allow for up to 3.7 days of storage of sludge, to accommodate weekend and holiday periods. Each tank will be equipped with steep, cone bottoms and decanting valves to permit thickening.

The decanted water from the thickeners will be piped to a recycle pump station for return to the head of the plant.

Filter Press, Feed Pump and Polymer Addition

One electric filter press feed pump will be provided to pump thickened sludge from the gravity thickeners to the filter press. The pump is sized at 50 gpm, to handle the required sludge flow at nominal pressure up to the maximum filter press pressure of 100 psi. A polymer feed system will be used to pump polymer into the pump discharge prior to the filter press to improve the press' dewatering performance.

The filter press is sized at 40 cubic feet. With an estimated cycle time of 2 hours, this allows for approximately 3 drops per day. The filter press is expected to produce a cake with a solids content of 50-60%. Filtrate from the filter press will be returned under pressure to the influent equalization tanks.

Dried filter cake will be analyzed for heavy metals, cyanides and organics and a determination made as to its nature, whether hazardous or nonhazardous. An appropriate disposal site for the sludge cake will be selected after the determination.

Air Compressor and Storage Tank

An air compressor and storage tank will be provided to operate the sludge pump, the filter press pneumatic valves, the filter press system, and to blow down the filter press.

Instrumentation

Supervisory Control and Data Acquisition

A Supervisory Control and Data Acquisition (SCADA) system provides overall monitoring and control of the treatment facilities. The SCADA system comprises Programmable Logic Controllers (PLC), a Personal Computer (PC) and Variable Frequency Drives (VFD) interconnected by an Industrial EtherNet/IP™ Local Area Network (LAN). The SCADA system LAN is shown on Drawing M-3.

Operation of the Siltronic Pretreatment Facility (SPTF) is monitored and controlled by a remote PLC. This PLC communicates over fiber-optic data communication cables with a central PLC and a PC in the NW Natural Treatment Facility (NWNTF). The SCADA system for the groundwater extraction wells communicates with the treatment system SCADA system by an EtherNet/IP™ link. There are also several discrete, i.e. point-to-point, interlocks for critical functions such as a well field shutdown required by a treatment system process shutdown.

Field instruments and process control components within the treatment facilities are shown on the Process Piping and Instrumentation Diagrams (P&IDs) included as Drawings M-4, M-5, M-6 and M-7. Field instruments, such as tank level transmitters and flow meters, are connected directly to PLC analog input modules. Pump control VFDs are monitored and controlled digitally by EtherNet/IP™ connections to the SCADA LAN.

Siltronic Pretreatment

Drawing M-5 shows the P&ID for Siltronic pretreatment facility located at the northeast corner of NW Natural property adjacent to the Siltronic property line. Groundwater is pumped from two extraction wells on the Siltronic property into an oil-water separator and then flows by gravity into an aeration tank with underflow baffle and overflow weir discharging into flow equalization wetwell.

A pH probe in the pipeline between the separator and aeration tank measures the pH and controls the output of a chemical metering pump feeding sodium hydroxide to raise the process pH to a predetermined set point.

The aeration blower is controlled manually by start-stop pushbuttons in the locally mounted combination motor starter. Blower operational status, i.e. on or off, is monitored by the SCADA system.

An ultrasonic transducer and level transmitter system measures the liquid level in the flow equalization wetwell. The level transmitter output signal is the process variable input to a loop controller in the SCADA PLC. The PLC will be programmed to provide proportional band control of the flow equalization discharge pump. The pump speed will increase as the liquid level increases and will decrease as the level decreases. The controller gain will be selected to provide maximum attenuation of influent flow rate variations.

Pretreatment discharge flow rate will be measured and communicated to the main plant. Provision will be made for intermittent addition of hydrogen peroxide to the pretreatment discharge force main. An insertion-type oxidation-reduction potential (ORP) probe will be available to control the peroxide feed in a proportional plus integral (PI) control loop.

Flow Equalization and Aeration

The Siltronic pretreatment facility discharges to the main plant Spent Backwash Storage Tank as shown on Drawing M-5. The Spent Backwash Storage Tank is hydraulically connected to equalization wetwell compartments of the two aerated weir tanks collecting flow from the NW Natural Wells. Filtrate discharge from the filter press and the sump pump discharge from the sludge storage/decant tanks are returned to this storage/equalization tank along with backwash from the carbon filters.

An influent flow meter measures flow from the NW Natural extraction wells. This transmitter output is summed with the pretreatment flow meter in the SCADA system for a total plant flow.

If the pretreatment flow is combined with the NW Natural extraction wells, the well flow is computed by subtracting the pretreatment flow from the influent flow meter flow. This well flow is a check on the sum of the flows from the individual wells.

A pH probe controls a sodium hydroxide chemical metering pump to raise the well flow pH to a predetermined set point suitable for metal hydroxide precipitate formation. The aeration blowers are controlled manually by start-stop pushbuttons in the locally mounted combination motor starters. Blower operational status, i.e. on or off, is monitored by the SCADA system.

A level transmitter in one of the equalization wetwells controls the clarifier feed pump. A second transmitter in the other wetwell is a backup. Discharge rate of the clarifier feed pump is measured by a magnetic flow meter.

Flocculation and Settling

Flocculation and settling processes are shown on Drawing M-5. The feed pump discharge flow meter output flow-paces a chemical feed pump that feeds polymer necessary for flocculation/coagulation and settling.

The flocculation basin is integral to the Inclined Plate Clarifier (IPC). Energy input for flocculation and coagulation is controlled by an adjustable-speed flocculator drive motor. The operator manually adjusts the mixer speed at the VFD.

Precipitated solids settled in the IPC are removed by a gravity blow-off to either of two sludge storage tanks. A solenoid valve controlled by the SCADA PLC will actuate a pneumatic-body pinch valve to regulate sludge wasting.

IPC Effluent Clearwell and Cyanide Destruction

Drawing M-5 also diagrams the cyanide destruction process. Overflow from the IPC flows by gravity to the Cyanide Destruct Reactor. An ORP probe in the reactor controls a chemical metering pump, feeding either hydrogen peroxide or sodium hypochlorite.

The cyanide reactor also serves as a clarifier effluent clearwell. An ultrasonic level transmitter system in the reactor tank controls the filter feed pump discharging to the bag filters and GAC filters in order to maintain adequate hydraulic residence time (HRT) in the cyanide destruct reactor.

Bag Filters

Suspended solids remaining after the IPC and suspended solids formed by oxidation reactions in the cyanide destruction process are removed in a series of bag filters. Pressure transmitters ahead, after and between the bag filters transmit line pressures to the SCADA system. The gauge pressures at these points are used to continuously calculate differential pressure across the filters and indicate when cleaning is required.

Sludge Thickening and Dewatering

The clarifier sludge thickening and dewatering system is also shown on Drawing M-6. Two cone-bottom sludge storage/decant tanks are manually alternated for gravity sludge thickening and storage. Ultrasonic transmitters in each tank will alarm before overfilling. The filter press dewatering system is operated manually from a local control panel. The PLC in the dewatering control panel is networked to the SCADA system.

Granular Activated Carbon Filtration

Drawing M-7 diagrams the Granular Activated Carbon (GAC) filters. Operation and cleaning (backwashing) of the GAC filters will be controlled manually. The GAC filters are normally operated in parallel. Pressure transmitters on the influent and effluent piping allow the SCADA system to compute differential head-loss across the GAC system.

The SCADA system will use a supplemental pressure transmitter between the GAC filters to determine individual head losses when the filters are operated in series. A final bag filter system is provided after the GAC filters to capture any charcoal fines that may be flushed through. A pressure transmitter downstream of the final bag filters allows the SCADA system to compute headloss and indicate when the bag filters need cleaning.

Final Effluent Filter Backwash System

Effluent from the GAC filters and final bag filters is discharged to Backwash Supply Storage Tank. This tank accumulates enough clean water for occasional backwashing of the GAC filters. GAC filter backwashing is an entirely manual operation. The operator manual closes valves around the selected filter to isolate it from production and opens the backwash supply and drain valves. He then manually operates the adjustable-speed backwash pump at the VFD to provide the appropriate backwash flow rate for the prescribed duration. Waste backwash flow is returned to the Spent Backwash Storage flow equalization tank. Overflow from the Backwash Supply storage tank is discharged to the Willamette River. Effluent instrumentation includes a flow meter, temperature sensor and pH probe.

Electrical

Primary Service

The existing high-voltage (34.5kV) three-phase Portland General Electric (PGE) power distribution line long the Siltronic-NW Natural property line will be tapped and extended overhead northwest to the treatment plant site as shown on Drawing E-1. The high-voltage primary distribution power will be “stepped-down” to 480 Volt, 3-phase, 4-wire utilization “secondary service” at the treatment plant site. The service transformers will be either pole-mounted or mounted on an “H-frame”. The transformers will be located outside the containment berm southeast of the building as shown

The primary service extension and service transformers will be furnished and installed by PGE.

Utility Metering

PGE requires current transformer instrument metering for three-phase services greater than 200 Ampere capacity. An exterior post-mounted instrument metering cabinet with

meter socket will be installed near the service transformers so that entry into the containment area by utility personnel is not required.

The post mounted instrument metering cabinet and meter socket will be provided by the contractor. The current transformers (CTs) and meter will be furnished and installed by PGE.

Secondary Service

Secondary 480V service from the post-mounted metering to the treatment building will be installed in underground conduit. Special details will be incorporated to pass pipelines and conduits through or over the berm so that the containment integrity is not compromised.

The metered secondary service will enter an electrical/control room at the southeast corner of the building. A wall-mounted main circuit breaker comprises the service entrance.

The preliminary size of the secondary service is between 400 and 800 Amperes.

Secondary Distribution

The single-line diagram (Drawings E-2 and E-3) show the secondary power distribution for the treatment system and groundwater extraction wells. After the main circuit breaker power is distributed and overcurrent protection is provided by a power panelboard (PP1).

Branch circuits for process motors and other utilization equipment within the main treatment building are provided directly from PP1.

A 100 Ampere feeder in PP1 is provides power for groundwater extraction wells PW-6 through PW-10 as shown on Drawing E-3

A 200 Ampere feeder provides power for extraction wells PW-1 through PW-5 and also provides a 100 Ampere subfeed for the Siltronic pretreatment system.

Power for lighting, convenience receptacles, instrumentation, etc. is derived from step-down transformers and 120/240 Volt lighting and appliance panelboards or load centers as shown on the single-line diagram.

Motor Branch Circuits

Motor controllers, such as variable frequency drives for adjustable-speed motors and combination starters for constant-speed motors, will be stanchion or wall mounted at the process equipment.

Motors will be connected to the controller with motor plugs and receptacles such as the Meltric Decontactor Motor Plug that will also serve as a safety disconnect means.

Spare process pump and other process motors will be inventoried on-site to facilitate a replacement with only a few hours down time. This downtime will be accommodated by influent equalization storage and short-term suspension of well pumping if required.

Buildings and Other Appurtenances

The facilities will be enclosed within a “sprung” structure building to shield the facilities and the operators from cold and rainy weather. The building will be equipped with inside and outside lighting, and will be provided with heating and ventilation systems.

A standard construction trailer will be provided to house an operator’s office including the central SCADA control panel for both plants and all feed wells. The trailer will be located outside of the containment area. The trailer will be equipped with additional office systems to permit the operators to prepare the necessary reports documenting process and effluent performance.

A Connix™ box will be used to store the uninstalled spare pumps, blowers, chemical feed system, and assorted spare parts.

An electrical substation will be located within the “sprung” structure.

The chemical storage and feed structure will also be located within the sprung structure. The chemical facility will be equipped with a chemical shower and eyewash, with a drain for both to the recycle pump station.

Four-inch hose will be used for the conveyance of the process water between the process tankage in the plant. Hose is used instead of hard piping because it provides a degree of flexibility and shock absorption that is critical in the field. The proposed hose is a hard rubber 150-psi suction type hose with a spiral wound steel reinforcement running through its length.

Storage, Handling and Disposal of Hazardous Chemicals and Wastes

All site personnel working at the treatment plant will have required OSHA training and certification for management of potentially hazardous chemicals and waste materials. The minimum training for onsite personnel is described in the Sevenson HASP to be submitted under separate cover.

A decon area will be provided within the lined, bermed area to permit decontamination of equipment, vehicles, etc.

Attachment A: Plant Design and Materials Balance

16-Oct-09				
NW NATURAL DESIGN DATA AND MATERIALS BALANCE				
DESIGN DATA --400 GPM	**mg/L**	**AVERAGE DAY**	**MAXIMUM DAY**	**COMMENTS/ ASSUMPTIONS**
NW INFLUENT FLOW-MW-1, GPM		80	150	Does not include Siltronic or LNG flows
VOLATILE ORGANIC COMPOUNDS, LBS/DAY	0.001	0.001	0.002	
SEMI-VOLATILE ORGANIC COMPOUNDS, LBS/DAY	0.060	0.058	0.108	
TOTAL SUSPENDED SOLIDS, LBS/DAY	185	178	333	
FREE CYANIDE, LBS/DAY	0.01	0.010	0.018	
TOTAL IRON, LBS/DAY	270	259.6	486.7	
TOTAL MANGANESE, LBS/DAY	10.0	9.6	18.0	
NW INFLUENT FLOW-PW-1, GPM		80	150	Does not include Siltronic or LNG flows
VOLATILE ORGANIC COMPOUNDS, LBS/DAY	8.5	8.2	15.3	
SEMI-VOLATILE ORGANIC COMPOUNDS, LBS/DAY	10.0	9.6	18.0	
TOTAL SUSPENDED SOLIDS, LBS/DAY	150	144.2	270.4	
FREE CYANIDE, LBS/DAY	0.01	0.010	0.018	
TOTAL IRON, LBS/DAY	16	15.4	28.8	
TOTAL MANGANESE, LBS/DAY	1.8	1.73	3.24	
SILTRONIC INFLUENT FLOW, GPM		40	70	
VOLATILE ORGANIC COMPOUNDS, LBS/DAY	5.0	2.4	4.2	
SEMI-VOLATILE ORGANIC COMPOUNDS, LBS/DAY	0.25	0.12	0.21	
TOTAL SUSPENDED SOLIDS, LBS/DAY	70	33.6	58.9	
FREE CYANIDE, LBS/DAY	0.01	0.005	0.008	
TOTAL IRON, LBS/DAY	36	17.3	30.3	
TOTAL MANGANESE, LBS/DAY	1.8	0.87	1.51	
CAUSTIC FEED PUMPS				pH Adjustment as required
TYPE		Diaphragm		
CONTROL		pH		
NUMBER OF UNITS		3		
PROJECTED USAGE, GALS/DAY		115	216	Treatability using 25%
PROJECTED USAGE, LBS/DAY		1,498	2,808	
, GALS/HOUR		4.8	9.0	
UNIT CAPACITY, GALS/HR		0-20	0-20	
TOTAL CAPACITY, GALS/HOUR		0--60	0--60	
STORAGE PROVIDED, GALS		5,000	5000	
STORAGE PROVIDED, DAYS		43.4	23.1	
NW NATURAL MW-1 AIR STRIPPER				
NUMBER OF TANKS		1	1	
UNIT VOLUME, GALS		12000	12000	
TOTAL VOLUME GALS		12000	12000	
DETENTION TIME, MINS		150	80	
AIR: WATER RATIO	**30: 1**	56	30	Wastestream results

MW-1 BLOWER				
NUMBER OF UNITS		1		per 2 tanks
TYPE		Positive Displacement		
CONTROL		Constant Speed		
AIR FLOW RATE, SCFM		602		
ESTIMATED STATIC HEAD, PSI		3.0		7-foot submergence
ESTIMATED DYNAMIC LOSSES, PSI		1.5		
TOTAL BLOWER TDH, PSI		4.5		
EST BHP		15		
NW NATURAL PW-1 AIR STRIPPER				
NUMBER OF TANKS		1	1	Baffled over/under tank
UNIT VOLUME, GALS		12000	12000	
TOTAL VOLUME GALS		12000	12000	
DETENTION TIME, MINS		150	80	
AIR: WATER RATIO	**30: 1**	56	30	Wastestream results
NW NATURAL PW-1 BLOWER				
NUMBER OF UNITS		1		per 2 tanks
TYPE		Positive Displacement		
CONTROL		Constant Speed		
AIR FLOW RATE, SCFM		602		
ESTIMATED STATIC HEAD, PSI		3.0		7-foot submergence
ESTIMATED DYNAMIC LOSSES, PSI		1.5		
TOTAL BLOWER TDH, PSI		4.5		
EST BHP		15		
SILTRONIC AIR STRIPPER				
NUMBER OF TANKS		1	1	Baffled over/under tank
UNIT VOLUME, GALS		12000	12000	
TOTAL VOLUME GALS		12000	12000	
DETENTION TIME, MINS		300	171	
AIR: WATER RATIO	**30: 1**	56	32	Wastestream results
SILTRONIC BLOWER				
NUMBER OF UNITS		1		per tank
TYPE		Positive Displacement		
CONTROL		Constant Speed		
AIR FLOW RATE, SCFM		301		
ESTIMATED STATIC HEAD, PSI		3.0		7-foot submergence
ESTIMATED DYNAMIC LOSSES, PSI		1.5		
TOTAL BLOWER TDH, PSI		4.5		
EST BHP		15		

NW MW-1 AIR STRIPPING EFFLUENT, GPM		80	150	
VOLATILE ORGANIC COMPOUNDS, LBS/DAY @ REMOVAL =	99%	0.00001	0.00180	Wastestream results
SEMI-VOLATILE ORGANIC COMPOUNDS, LBS/DAY @ REMOVAL =	50%	0.0288	0.1050	Wastestream results
TOTAL SUSPENDED SOLIDS, LBS/DAY		177.9	333.5	
FREE CYANIDE, LBS/DAY @ REMOVAL =		0.010	0.018	
TOTAL IRON, LBS/DAY		259.6	486.7	
TOTAL MANGANESE, LBS/DAY		9.6	18.0	
NW PW-1 AIR STRIPPING EFFLUENT, GPM		80	150	
VOLATILE ORGANIC COMPOUNDS, LBS/DAY @ REMOVAL =	99%	0.1	0.2	Wastestream results
SEMI-VOLATILE ORGANIC COMPOUNDS, LBS/DAY @ REMOVAL =	50%	4.8	9.0	Wastestream results
TOTAL SUSPENDED SOLIDS, LBS/DAY		144.2	270.4	
FREE CYANIDE, LBS/DAY		0.010	0.018	
TOTAL IRON, LBS/DAY		15.4	28.8	
TOTAL MANGANESE, LBS/DAY		1.7	3.2	
SILTRONIC AIR STRIPPING EFFLUENT, GPM		40	70	
VOLATILE ORGANIC COMPOUNDS, LBS/DAY @ REMOVAL =	99%	0.024	0.042	Wastestream results
SEMI-VOLATILE ORGANIC COMPOUNDS, LBS/DAY @ REMOVAL =	50%	0.060	0.105	Wastestream results
TOTAL SUSPENDED SOLIDS, LBS/DAY		33.6	58.9	
FREE CYANIDE, LBS/DAY		0.0048	0.0084	
TOTAL IRON, LBS/DAY		17.3	30.3	
TOTAL MANGANESE, LBS/DAY		0.865	1.514	
EQUALIZATION TANKS				From Equalization Analysis
NW NATURAL EQUALIZATION TANKS				
NW NATURAL ON LINE				
TYPE		OVER/UNDER WEIR	OVER/UNDER WEIR	
NO OF UNITS INSTALLED		2	2	
UNIT AIR STRIPPER VOLUME, GALS		6,000	6,000	
TOTAL AIR STRIPPER VOLUME, GALS		12,000	12,000	
NW NATURAL OFF LINE (ALSO SPENT BACKWASH STORAGE)				FOR MAXIMUM DAY FLOW
TYPE		FRAC	FRAC	
NO OF UNITS INSTALLED		1	1	
UNIT AIR STRIPPER VOLUME, GALS		21,000	21,000	
TOTAL AIR STRIPPER VOLUME, GALS		21,000	21,000	
TOTAL NW NATURAL EQUALIZATION (ON LINE AND OFFLINE), GALS		33,000	33,000	
SILTRONIC				
TYPE		OVER/UNDER WEIR	OVER/UNDER WEIR	
NO OF UNITS INSTALLED		1	1	
UNIT AIR STRIPPER VOLUME, GALS		6,000	6,000	
TOTAL AIR STRIPPER VOLUME, GALS		6,000	6,000	

EQUALIZED FLOW AND LOADS TO PLANT				
NW NATURAL MW-1, GPM		48	90	From Equalization Analysis
NW NATURAL PW-1, GPM		48	90	From Equalization Analysis
SILTRONIC, GPM		24	42	From Equalization Analysis
LNG BASIN		30	30	
RECYCLE PUMP STATION		2	3	
FILTER PRESS FILTRATE		2	3	
TOTAL FLOW, GPM		**153**	**259**	
VOLATILE ORGANIC COMPOUNDS, LBS/DAY		0.106	0.197	
SEMI-VOLATILE ORGANIC COMPOUNDS, LBS/DAY		4.90	9.22	
TOTAL SUSPENDED SOLIDS, LBS/DAY		481.1	896.9	Incl solids fm recycle pump station & FP filtrate
FREE CYANIDE, LBS/DAY		0.024	0.044	
TOTAL IRON, LBS/DAY		292.3	545.8	
TOTAL MANGANESE, LBS/DAY		12.2	22.8	
IPC FEED PUMP				Controlled off reactor level
TYPE		CENTRIFUGAL		
NO OF UNITS		1		Uninstalled spare
UNIT CAPACITY, GPM		259		
TDH, FT		20		
UNIT HP		5		with VFD
INFLUENT FLOW METER				
TYPE		MAGNETIC		
NO OF UNITS		1		
SIZE, INCHES		4		
ANIONIC POLYMER FEED PUMP				Settling Aid
TYPE		Diaphragm		
CONTROL		FLOW PACED		
NUMBER OF UNITS		1		With uninstalled spare
PROJECTED USAGE @ 8.6 LBS/GAL, LBS/DAY		9.59	16.15	@ 5 mg/L
PROJECTED USAGE @ 8.6 LBS/GAL, GALS/DAY		1.11	1.88	20-Gallon Carboy
, GALS/HOUR		0.09	0.16	
UNIT CAPACITY, GALS/HR		0-1		
TOTAL CAPACITY, GALS/HOUR		0-2		
DILUTION WATER @ 0.25%, GALS/DAY		446	751	
, GALS/HOUR		37	63	
, GALS/MIN		0.31	0.52	
FLASH MIX TANK				
NUMBER		1		
TYPE		MECHANICAL		
MIXER HP		1.0		
DIMENSIONS, FT				
LENGTH		3.0		
WIDTH		3.0		
DEPTH		4.0		
VOLUME, GALS		269		
DETENTION TIME, MINS		1.8	1.0	

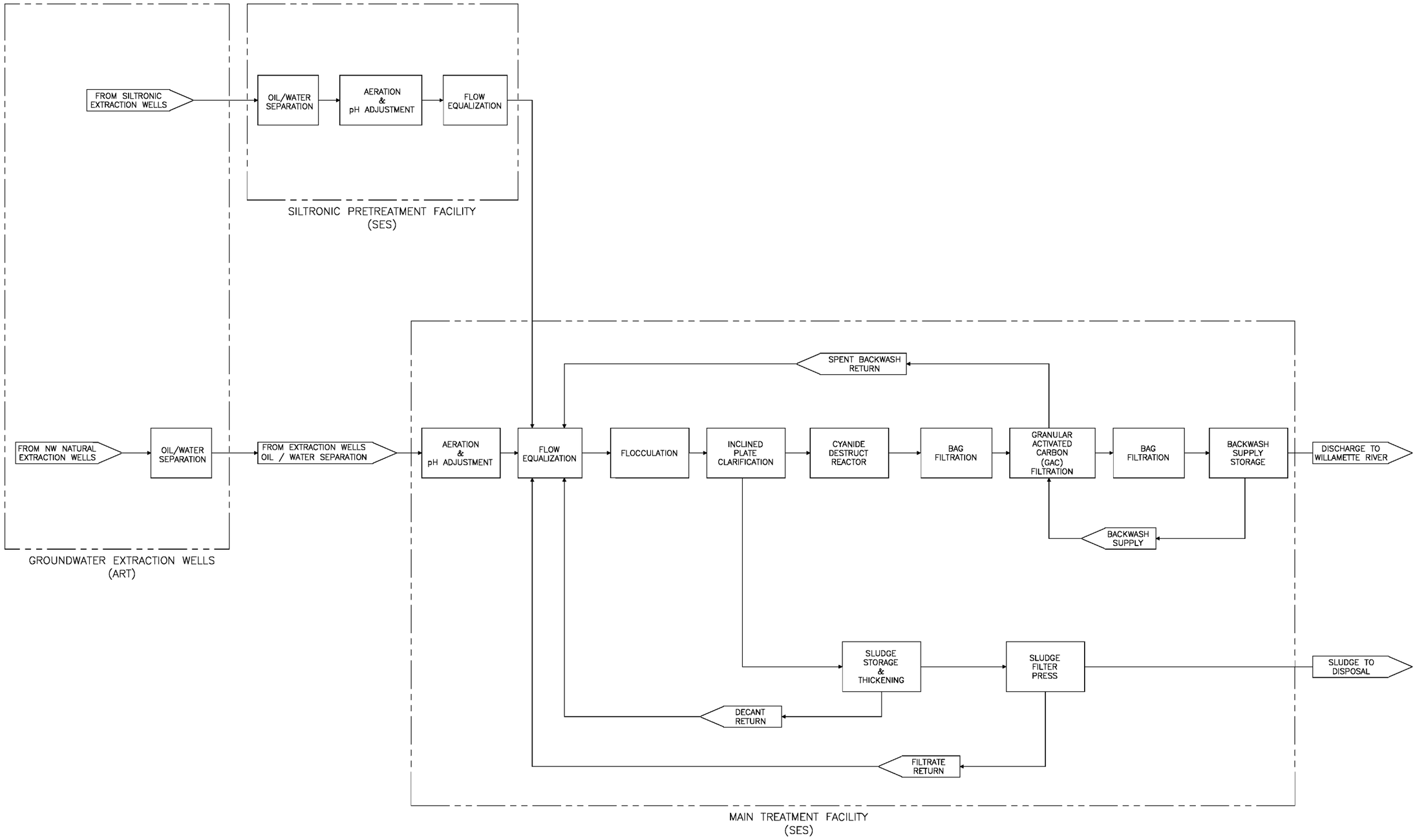
FLOCCULATION TANK				
NUMBER		1		
TYPE		MECHANICAL		
MIXER HP		3.0		
DIMENSIONS, FT				
LENGTH		8.0		
WIDTH		8.0		
DEPTH		8.0		
VOLUME, GALS		3830		
DETENTION TIME, MINS		25.0	14.8	
INCLINED-PLATE CLARIFIER				
TYPE		INCLINED PLATE		
NUMBER		1		
DIMENSIONS, FT				
LENGTH		14		
WIDTH		6		
HEIGHT		12		
PROJECTED SETTLING AREA, SQ FT		1,500		
LOADING RATE, GPM/SQ FT		0.10	0.17	
SOLIDS PRODUCTION				
INFLUENT SOILIDS,		263	491	@ 90% Removal of Influent
CHEMICAL SOLIDS		1,023	1,910	@ 3.5 X Influent Iron
TOTAL SOLIDS, LBS/DAY		1,286	2,402	
, CONCENTRATION @		3%	3%	
, GALS/DAY		5,039	9,411	
, GALS/MIN @ 10 MINS/HR		21.0	39.2	
SLUDGE PUMP				
TYPE		DIAPHRAGM		
NUMBER		1		
CAPACITY, GPM		50		
REQUIRED AIR, CFM		25		
AIR COMPRESSOR				
CAPACITY, CFM		50		
PRESSURE, PSI		125		
HYDROGEN PEROXIDE FEED PUMPS				CYANIDE OXIDATION
TYPE		Diaphragm		pH = 10.5
CONTROL		Paced off ORP		ORP = 250 mv
NUMBER OF UNITS		1		
PROJECTED USAGE, GALS/DAY		88	149	Treatability & Estimate
PROJECTED USAGE, LBS/DAY		884	1,489	Estimate
, GALS/HOUR		4	6	
UNIT CAPACITY, GALS/HOUR		0-40		
TOTAL CAPACITY, GALS/HOUR		0-80		
STORAGE PROVIDED, GALS		260		
STORAGE PROVIDED, DAYS		2.9	1.7	

FLASH MIX				
TYPE		IN-LINE STATIC		
SIZE, IN		3		
CYANIDE REACTOR				
DESIRED DETENTION TIME, MINS		60		Oxidation to Cyanate
TYPE		FRAC		
NUMBER OF UNITS		1		
UNIT VOLUME, GALS		21,000		
TOTAL VOLUME, GALS		21,000		
DETENTION TIME, MINS		137	81	
SULFURIC ACID FEED PUMPS				pH Adjustment 8-8.5
TYPE		Diaphragm		
CONTROL		Paced off pH		
NUMBER OF UNITS		2		
PROJECTED USAGE @ 28 mg/L, LBS/DAY		77	130	Estimate
, GALS/HOUR		0.2	0.4	
, GALS/DAY		6.0	10.0	
UNIT CAPACITY, GALS/HOUR		0-4		
TOTAL CAPACITY, GALS/HOUR		0-8		
STORAGE PROVIDED, GALS		240		Tote
STORAGE PROVIDED, DAYS		40.3	23.9	
FILTER/GAC FEED PUMPS				
TYPE		CENTRIFUGAL		
NO OF UNITS		1		With uninstalled spare
UNIT CAPACITY, GPM		259		
TDH, FT		185		80 psi
UNIT HP		25		
BAG FILTERS				Metals/solids removal
NO OF UNITS		4		Two trains In series
BAG MEDIA, MICRONS		10-->5		

GRANULAR ACTIVATED CARBON VESSELS				Organics Removal
DESIGN PARAMETERS				
CONTACT TIME, MINS		15		
LOADING RATE, GPM/SQ FT		4		
NO OF UNITS		2		In Series
UNIT DIAMETER, FT		10		
UNIT HEIGHT, FT		12		
CARBON DEPTH, FT		4		
UNIT AREA, SQ FT		78.5		
TOTAL AREA, SQ FT		157		
EFFECTIVE UNIT VOLUME, CU FT		314		
TOTAL EFFECTIVE VOLUME, CU FT		628		
HYDRAULIC LOADING, GPM/SQ FT		1.0	1.6	
LBS CARBON/UNIT @ 32 LBS/CU FT		10,048		
TOTAL AVAILABLE CARBON, LBS		20,096		
EMPTY BED CONTACT TIME , MINS		30.6	18.2	
TOTAL ORGANICS TO CARBON UNITS, LBS/DAY		5.0	9.4	
% TOTAL ORGANICS REMOVAL		99%	99%	
EFFLUENT ORGANICS, LBS/DAY		0.05	0.09	
, mg/L		0.03	0.03	
UTILIZATION RATE, LBS TOCr/LB CARBON		0.15	0.15	
UTILIZATION RATE, LBS/CARBON/DAY		33	62	
, LBS/YEAR		12,049	22,693	
EFFECTIVE BED LIFE, DAYS		609	323	
BACKWASH HOLDING TANK				
TYPE		FRAC TANK		
NO OF UNITS INSTALLED		1		
VOLUME, GALS		21,000		
TOTAL VOLUME, GALS		21,000		
SINGLE BACKWASH VOLUME, GALS		14,130		15 minutes/backwash
STORED BACKWASHES		1.5		
GAC BACKWASH PUMP				
TYPE		CENTRIFUGAL		
NO OF UNITS INSTALLED		1		With uninstalled spare
UNIT CAPACITY, GPM		942		Backwash Rate = 12 gpm/sq ft
TDH, FT		50		
UNIT BHP		25		

BAG FILTERS				Carbon fines removal removal
NO OF UNITS		2		In parallel
BAG MEDIA, MICRONS		1		
EFFLUENT FLOW METER				
TYPE		MAGNETIC		
SIZE, INCHES		3		
RESIDUALS HANDLING (NW NATURAL & SILTRONIC)				
NW NATURAL SILTRONIC SLUDGE THICKENER/STORAGE				
NO OF UNITS		2		
UNIT VOLUME, GALS		8,000		
TOTAL VOLUME, GALS		16,000		
SLUDGE FEED, GALS/DAY		5,039	9,411	
STORAGE CAPACITY, DAYS		3.2	1.7	
THICKENED SLUDGE, LBS/DAY		1,222	2,282	@ 95% Solids capture
THICKENED SLUDGE, 2 x INFLUENT		6%	6%	
THICKENED SLUDGE, GALS		2,370	4,427	
RECYCLE PUMP STATION				Also collects chemical spills
SUPERNATANT SOLIDS, LBS/DAY		64	120	
SUPERNATANT RETURN, GALS/DAY		2,669	4,984	
, GPM @ 15 MINS		89	166	2 decants per day
ASSUMED RETURN RATE, GPM (SHORT DURATION) @ 24 HRS		2	3	
TYPE		PACKAGE		
NUMBER OF PUMPS		2		
RETURN PUMP STATION, GPM		200		
TDH, FT		25		
EST BHP		3		
NW NATURAL SILTRONIC SLUDGE FILTER PRESS & PUMP				
TOTAL SLUDGE TO PRESS, LBS/DAY		1,222	2,282	
, GALS/DAY		2,370	4,427	
PUMP TYPE		CENTRIFUGAL		
NO OF UNITS		1		
PUMP OUTPUT, GPM		26	49	30 minute fill
PUMP PRESSURE PSI AT MAX PUMP FLOW, PSI		15		35 feet
PUMP OUTPUT AT MAX PRESSURE, PSI		4.9		
MAX PUMP PRESSURE, PSI AT MIN FLOW		100		231 feet
EST BHP		5		Worst case is high flow - lower pressure
SLUDGE PRESS				
ESTIMATED CYCLE TIME, HRS		2	2	
EST CYCLES/DAY		3	3	
DEWATERED CAKE, DRY LBS/DAY		1,161	2,167	
, WET LBS/DAY @ 60%		1,934	3,612	
, CU FT/DAY		55	103	@ 35 LBS/CU FT
, CU FT/CYCLE		18	34	
PRESS VOLUME, CU FT		40		
ASSUMED SOLIDS CAPTURE, %		95%	95%	
FILTRATE, LBS/DAY		61	114	
, GALS/DAY		2,363	4,413	
, GALS/MIN		7	12	
ASSUMED RETURN RATE, GPM (SHORT DURATION) @ 24 HRS		2	3	

Attachment B: Treatment Plant Design Drawings



PROCESS FLOW DIAGRAM (PFD)

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10/13/2009

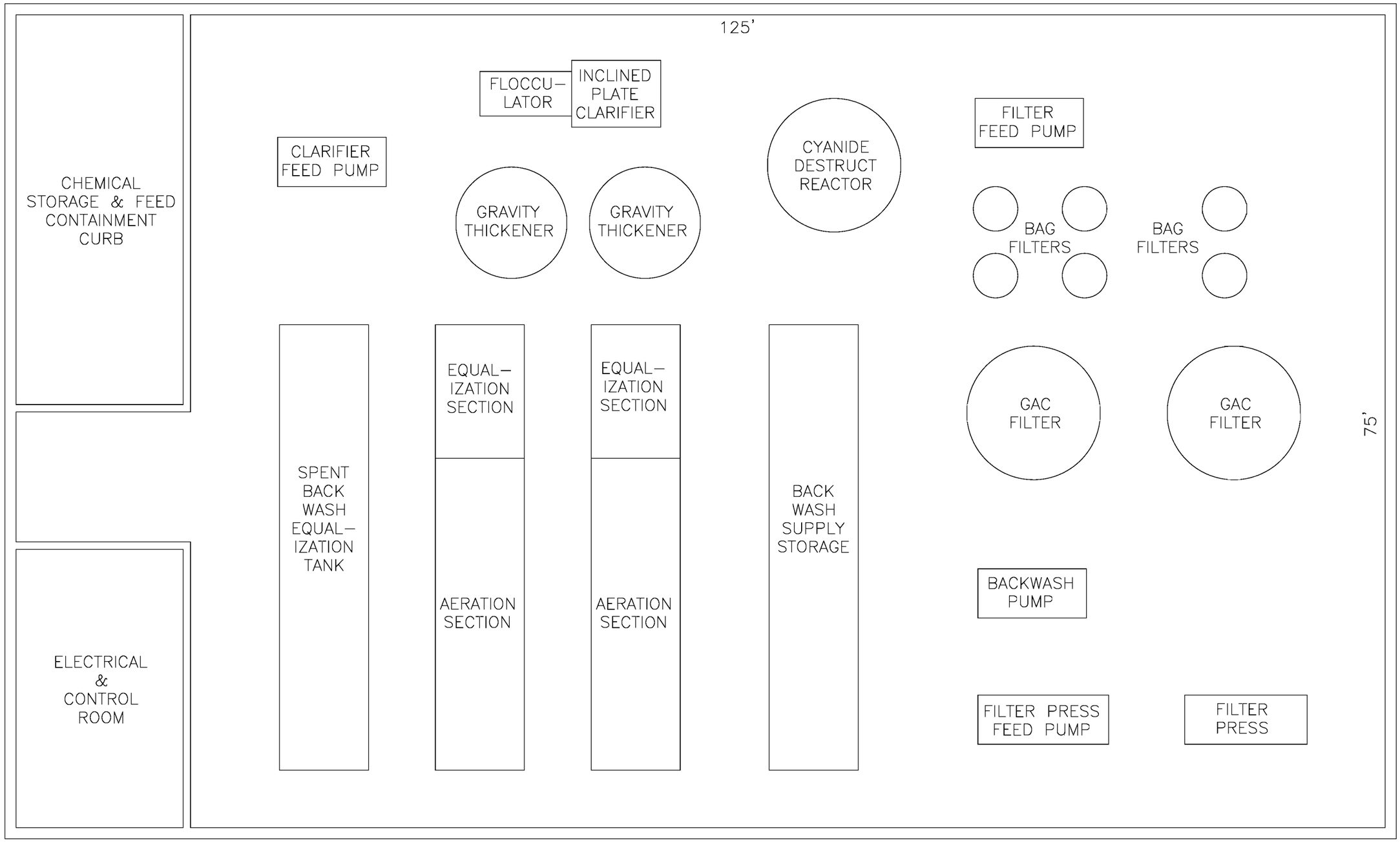
NW NATURAL GASCO SITE SOURCE CONTROL

INTERIM DESIGN REPORT
GROUNDWATER TREATMENT FACILITY
PROCESS FLOW DIAGRAM (PFD)

APP.BY	MDC
CHK.BY	TPD
DSN.BY	TPD/TSJ
DRN.BY	TSJ
JOB NO.	SES-E975
CONTRACT:	–
SCALE:	
CADD NO.	NW GASCO DR (REV 7)
FILE NO.	

M-1

SHEET 1 OF 1



TREATMENT BUILDING LAYOUT

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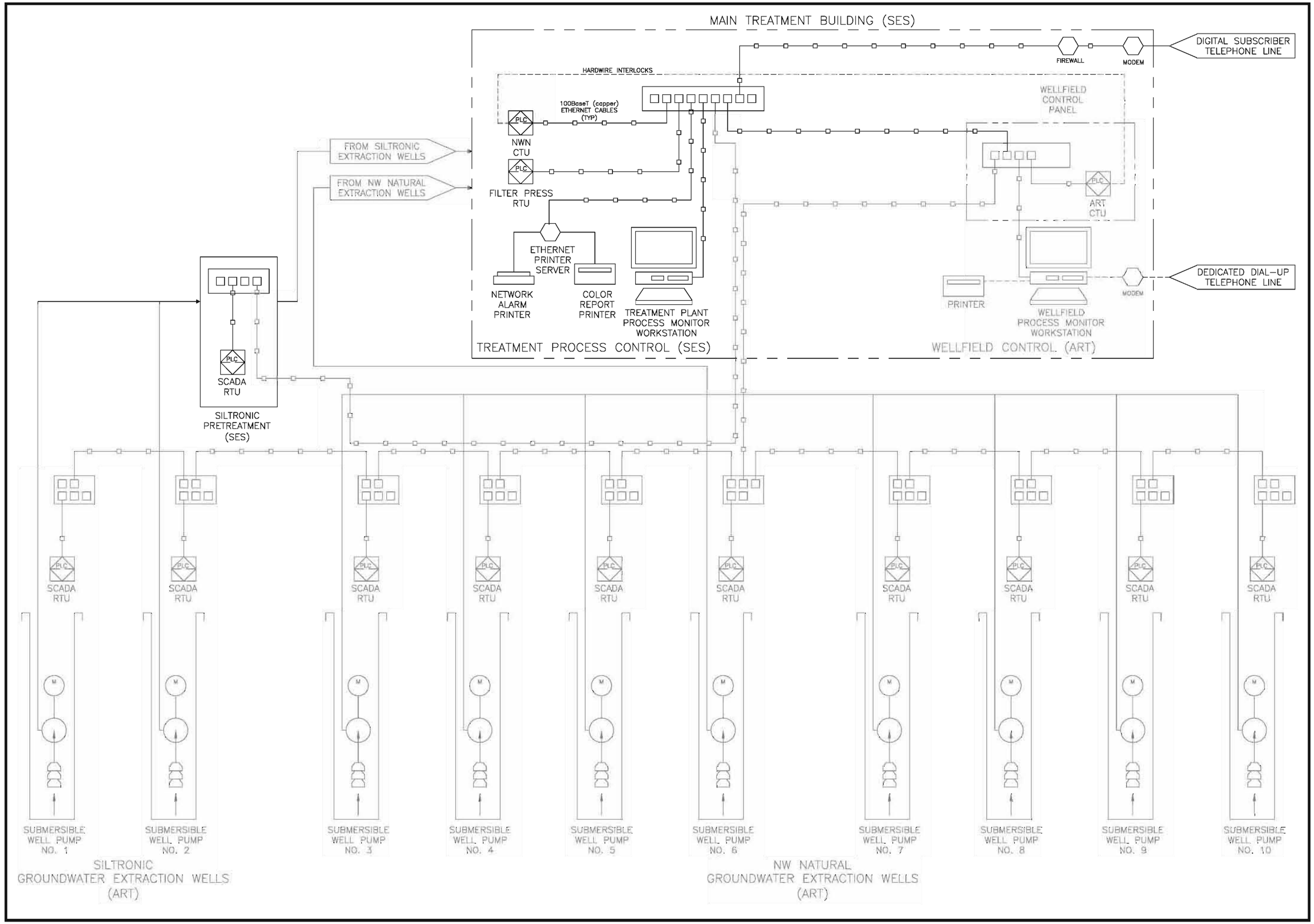
NW NATURAL GASCO SITE SOURCE CONTROL
INTERIM DESIGN REPORT
GROUNDWATER TREATMENT FACILITY
TREATMENT BUILDING LAYOUT

CADD NO. nwn gasco dwr (rev 7)	SCALE:	CONTRACT: -	JOB NO. SES-E975	DRN.BY TSJ
DSN.BY TPD/TSJ	CHK.BY TPD	APP.BY MDC		

M-2

FILE NO.

SHEET 1 OF 1



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NW NATURAL GASCO SITE SOURCE CONTROL

INTERIM DESIGN REPORT
GROUNDWATER TREATMENT FACILITY
SCADA NETWORK DIAGRAM

CADD NO. NWN GASCO DIK (REV 7)	SCALE:	CONTRACT: –	JOB NO. SES-E975	DRN.BY TSJ	DSN.BY TPD/TSJ	CHK.BY TPD	APP.BY MDC

M-3

FILE NO.

SHEET 1 OF 1

TYPICAL INSTRUMENTATION SYMBOL LETTER COMBINATIONS

FIRST LETTERS	INITIATING OR MEASURED VARIABLE	TRANSMITTERS			READOUT DEVICES		CONTROLLERS			SELF-ACTUATED CONTROL VALVE	SWITCH DEVICES			PILOT LIGHTS	ALARM DEVICES			SOLENOIDS, RELAYS, OR COMPUTING DEVICES	PRIMARY ELEMENT	TEST POINT	WELL OR PROBE	VIEWING DEVICE (GLASS)	SAFETY DEVICE	FINAL CONTROL ELEMENT
		RECORDING	INDICATING	BLIND	RECORDING	INDICATING	RECORDING	INDICATING	BLIND		HIGH	LOW	COMBINATION		HIGH	LOW	COMBINATION							
A	ANALYSIS	ART	AIT	AT	AR	AI	ARC	AIC	AC		ASH	ASL	ASHL		AAH	AAL	AAHL	AY	AE	AP	AW			AV
B	BURNER/COMBUSTION	BRT	BIT	BT	BR	BI	BRC	BIC	BC		BSH	BSL	BSHL		BAH	BAL	BAHL	BY	BE		BW	BG		BV
C	CONDUCTIVITY	CRT	CIT	CT	CR	CI	CRC	CIC	CC		CSH	CSL	CSHL	CL	CAH	CAL	CAHL	CY	CE					CV, CZ
D	DENSITY	DRT	DIT	DT	DR	DI	DRC	DIC	DC		DSH	DSL	DSHL	DL	DAH	DAL	DAHL	DY	DE					DV, DZ
E	VOLTAGE	ERT	EIT	ET	ER	EI	ERC	EIC	EC		ESH	ESL	ESHL	EL	EAH	EAL	EAHL	EY	EE					EZ
F	FLOW RATE	FRT	FIT	FT	FR	FI	FRC	FIC	FC	FCV	FSH	FSL	FSHL	FL	FAH	FAL	FAHL	FY	FE	FP		FG		FV
FQ	FLOW QUANTITY	FQRT	FQIT	FQT	FQR	FQI	FQRC	FQIC			FQSH	FQSL		FQL	FQAH	FQAL		FQY	FQE, FE					FQV
FF	FLOW RATIO	FFRT	FFIT	FFT	FFR	FFI	FFRC	FFIC	FFC		FFSH	FFSL		FFL	FFAH	FFAL		FFY						FFV
H	HAND							HIC	HC				HS											HV
I	CURRENT	IRT	IIT	IT	IR	II	IRC	IIC	IC		ISH	ISL	ISHL	IL	IAH	IAL	IAHL	IY	IE			LG		IZ
J	POWER	JRT	JIT	JT	JR	JI	JRC	JIC	JC		JSH	JSL	JSHL	JL	JAH	JAL	JAHL	JY	JE					JV
K	TIME	KRT	KIT	KT	KR	KI	KRC	KIC	KC	KCV	KSH	KSL	KSHL	KL	KAH	KAL	KAHL	KY	KE					KV
L	LEVEL	LRT	LIT	LT	LR	LI	LRC	LIC	LC	LCV	LSH	LSL	LSHL	LL	LAH	LAL	LAHL	LY	LE		LW			LV
M																								
N																								
O	OPTICAL																							
P	PRESSURE	PRT	PIT	PT	PR	PI	PRC	PIC	PC	PCV	PSH	PSL	PSHL	PL	PAH	PAL	PAHL	PY	PE	PP			PSV, PSE	PV
PD	PRESSURE DIFFERENTIAL	PDRT	PDIT	PDT	PDR	PDI	PDRC	PDIC	PDC	PDCV	PDSH	PDSL		PDL	PDAH	PDAL		PDY	PE	PP				PDV
Q	QUANTITY	QRT	QIT	QT	QR	QI	QRC	QIC	QC		QSH	QSL	QSHL	QL	QAH	QAL	QAHL	QY	QE					QZ
R	RADIATION	RRT	RIT	RT	RR	RI	RRC	RIC	RC		RSH	RSL	RSHL	RL	RAH	RAL	RAHL	RY	RE					RZ
S	SPEED/FREQUENCY	SRT	SIT	ST	SR	SI	SRC	SIC	SC	SCV	SSH	SSL	SSHL	SL	SAH	SAL	SAHL	SY	SE					SV, SZ
T	TEMPERATURE	TRT	TIT	TT	TR	TI	TRC	TIC	TC	TCV	TSH	TSL	TSHL	TL	TAH	TAL	TAHL	TY	TE	TP	TW		TSV, TSE	TV
TD	TEMP. DIFFERENTIAL	TDRT	TDIT	TDT	TDR	TDI	TDRC	TDIC	TDC	TDCV	TDSH	TDSL		TDL	TDAH	TDAL		TDY	TDE	TP	TW			TDV
U	MULTI-VARIABLE				UR	UI								UL			UA	UY						UV
V	VIBRATION	VRT	VIT	VT	VR	VI					VSH	VSL	VSHL	VL	VAH	VAL	VAHL	VY	VE					VZ
W	WEIGHT/FORCE	WRT	WIT	WT	WR	WI	WRC	WIC	WC	WCV	WSH	WSL	WSHL	WL	WAH	WAL	WAHL	WY	WE					WZ
X	UNCLASSIFIED	XRT	XIT	XT	UR	UI	XRC	XIC	XC	XCV	XSH	XSL	XSHL	XL	XAH	XAL	XAHL	XY	XE					XZ
Y	EVENT/STATE/PRESENCE	YRT	YIT	YT	YR	YI	YRC	YIC	YC	YCV	YSH	YSL	YSHL	YL	YAH	YAL	YAHL	YY	YE					YZ
Z	POSITION/DIMENSION	ZRT	ZIT	ZT	ZR	ZI	ZRC	ZIC	ZC	ZCV	ZSH	ZSL	ZSHL	ZL	ZAH	ZAL	ZAHL	ZY	ZE					ZV
ZD	GAUGING/DEVIATION	ZDRT	ZDIT	ZDT	ZDR	ZDI	ZDRC	ZDIC	ZDC	ZDCV	ZDSH	ZDSL		ZDL	ZDAH	ZDAL		ZDY	ZDE					ZDV

PANEL ABBREVIATIONS

ATS	AUTOMATIC TRANSFER SWITCH
CFP	CHEMICAL FEED PANEL
DCS	DISTRIBUTED CONTROL SYSTEM
GCP	GENERATOR CONTROL PANEL
MCC	MOTOR CONTROL CENTER
MCP	MIXER CONTROL PANEL
PC	PERSONAL COMPUTER
PCIP	PROCESS INSTRUMENTATION CONTROL PANEL
PCP	PROCESS CONTROL PANEL
PLC	PROGRAMMABLE LOGIC CONTROLLER
RTU	REMOTE TERMINAL UNIT
SPCP	SAMPLE PUMP CONTROL PANEL
TFP	TRUCK FILL PANEL
TPCS	TRANSFER PUMP CONTROL STATION
VFD	VARIABLE FREQUENCY DRIVE CONTROLLER

COMPUTERS

- INPUT/OUTPUT INTERFACE/CONDITIONING NOT NORMALLY ACCESSIBLE
- OPERATOR INTERFACE VIDEO DISPLAY NORMALLY ACCESSIBLE TO OPERATOR
- GENERAL UNDEFINED COMPLEX LOGIC OR SEQUENCE CONTROL
- PROGRAMMABLE LOGIC CONTROLLER OR DISTRIBUTED DIGITAL CONTROL NOT NORMALLY ACCESSIBLE TO OPERATOR
- PROGRAMMABLE LOGIC CONTROLLER OR DISTRIBUTED DIGITAL CONTROL WITH NORMALLY ACCESSIBLE OPERATOR INTERFACE
- INTERNAL COMPUTATION/CONDITIONING

PIPING AND INSTRUMENTATION SYMBOLS

PROCESS EQUIPMENT AND PIPING SYMBOLS

- GATE VALVE
- BALL VALVE
- PLUG VALVE
- GLOBE VALVE
- BUTTERFLY VALVE
- NEEDLE VALVE
- SWING CHECK VALVE
- BALL CHECK VALVE
- PINCH VALVE
- CONTROL VALVE
- PRESSURE SAFETY VALVE
- PRESSURE CONTROL VALVE
- CENTRIFUGAL PUMP
- ROTARY PUMP OR COMPRESSOR
- CHEMICAL METERING PUMP
- ELECTRIC MOTOR DRIVER
- FILTER
- ORIFICE PLATE

DISCRETE INSTRUMENTS

- FIELD MOUNTED DEVICE
- PANEL MOUNTED DEVICE
- REAR OF PANEL MOUNTED
- TWO MEASURED VARIABLES IN ONE DEVICE
- ILLUMINATED DEVICE
- 175 INSTRUMENT TAG NUMBER

LINE SYMBOLS

- INSTRUMENT SUPPLY OR CONNECTION TO PROCESS
- UNDEFINED SIGNAL
- ELECTRICAL SIGNAL
- PNEUMATIC SIGNAL
- HYDRAULIC SIGNAL
- ELECTROMAGNETIC OR SONIC SIGNAL
- SOFTWARE OR DATA LINK
- PROCESS AIR LINE
- EXISTING OR FUTURE EQUIPMENT
- SHIELDED TWISTED PAIR (STP) 100/10BaseT
  UNSHIELDED TWISTED PAIR (UTP) 100/10BaseT
  LOCAL AREA NETWORK (LAN) CABLE
- DUPLEX FIBER-OPTIC ETHERNET (10BaseF)
  LOCAL AREA NETWORK (LAN) CABLE
- CABLE TELEVISION (CTV) NETWORK CABLE

SHARED INSTRUMENTS

- SHARED BLIND CONTROLLER NOT NORMALLY ACCESSIBLE
- SHARED DISPLAY AND/OR CONTROL NORMALLY ACCESSIBLE TO OPERATOR

FUNCTION BLOCKS – FUNCTION DESIGNATIONS

- SUMMING
- AVERAGING
- DIFFERENCE
- PROPORTIONAL
- PROPORTIONAL 1:1
- PROPORTIONAL 1:2
- INTEGRAL
- DERIVATIVE
- MULTIPLYING
- DIVIDING
- ROOT EXTRACTION
- EXPONENTIAL
- HIGH SELECTING
- LOW SELECTING
- HIGH LIMITING
- LOW LIMITING
- REVERSE PROPORTIONAL
- VELOCITY LIMITER
- BIAS (M=X+B)
- BIAS (M=X−B)
- BIAS (M=X ±B)
- NONLINEAR OR UNSPECIFIED
- TIME FUNCTION

CONVERTER FUNCTIONS

SIGNAL CONVERTED TO: VOLTAGE, CURRENT, PNEUMATIC, ANALOG, BINARY, HYDRAULIC, FIBEROPTIC, RESISTANCE, DIGITAL

SIGNAL CONVERTED FROM:

	VOLTAGE	CURRENT	PNEUMATIC	ANALOG	BINARY	HYDRAULIC	FIBEROPTIC	RESISTANCE	DIGITAL
VOLTAGE		E/I	E/P	E/A	E/B	E/H	E/O	E/R	E/D
CURRENT	I/E		I/P	I/A	I/B	I/H	I/O	I/R	I/D
PNEUMATIC	P/E	P/I		P/A	P/B	P/H	P/O	P/R	P/D
ANALOG	A/E	A/I	A/P		A/B	A/H	A/O	A/R	A/D
BINARY	B/E	B/I	B/P	B/A		B/H	B/O	B/R	B/D
HYDRAULIC	H/E	H/I	H/P	H/A	H/B		H/O	H/R	H/D
FIBER-OPTIC, SONIC, ELECTRO-MAGNETIC	O/E	O/I	O/P	O/A	O/B	O/H		O/R	O/D
RESISTANCE (ELECTRICAL)	R/E	R/I	R/P	R/A	R/B	R/H	R/O		R/D
DIGITAL	D/E	D/I	D/P	D/A	D/B	D/H	D/O	D/R	

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10/13/2009

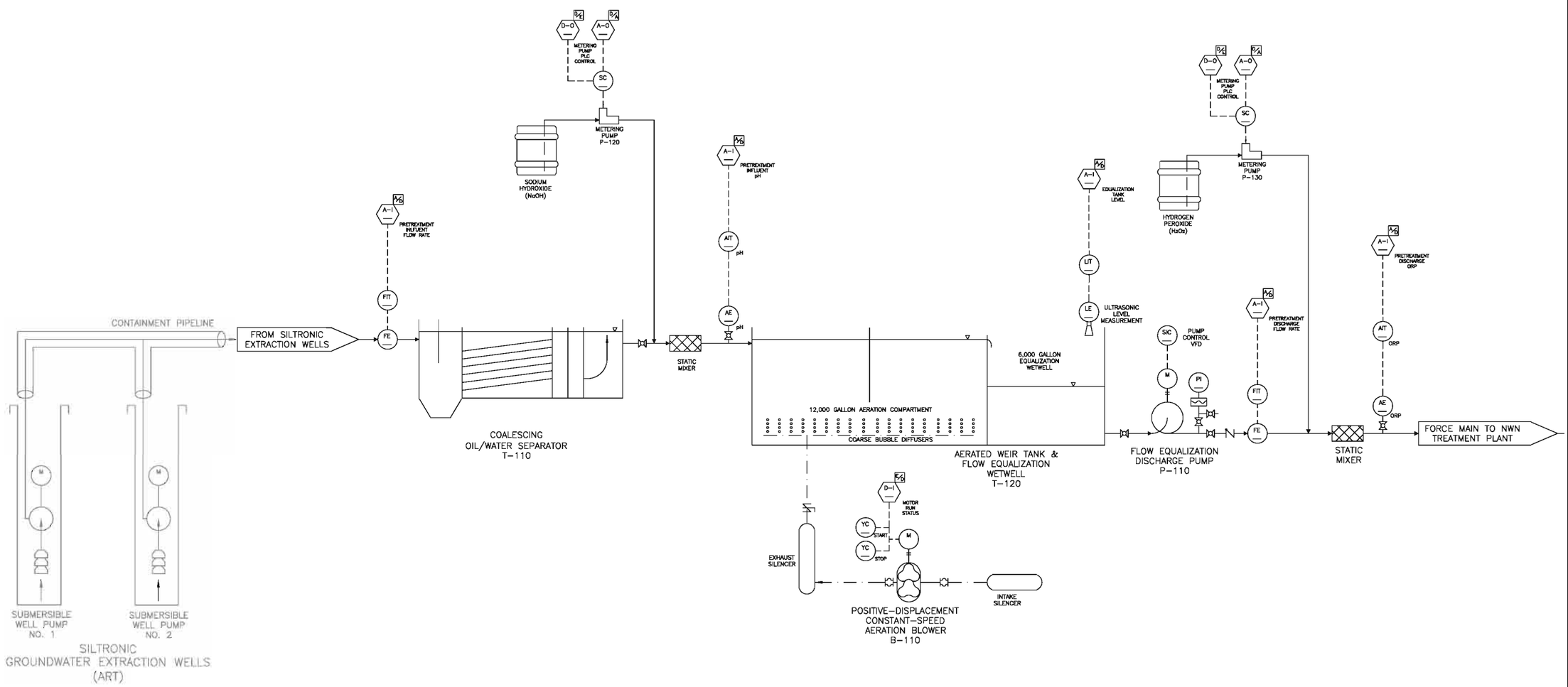
NW NATURAL GASCO SITE SOURCE CONTROL

INTERIM DESIGN REPORT
GROUNDWATER TREATMENT FACILITY
PIPING & INSTRUMENTATION DIAGRAM (P&ID) LEGEND

DRN.BY	DSN.BY	CHK.BY	APP.BY
TSJ	TPD/TSJ	TPD	MDC

JOB NO. SES-E975 | CONTRACT: – | SCALE: | CADD NO. NWN GASCO IDR (REV 7) | FILE NO.

M-4



P&ID #1
(SILTRONIC PRETREATMENT)

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NW NATURAL GASCO SITE SOURCE CONTROL

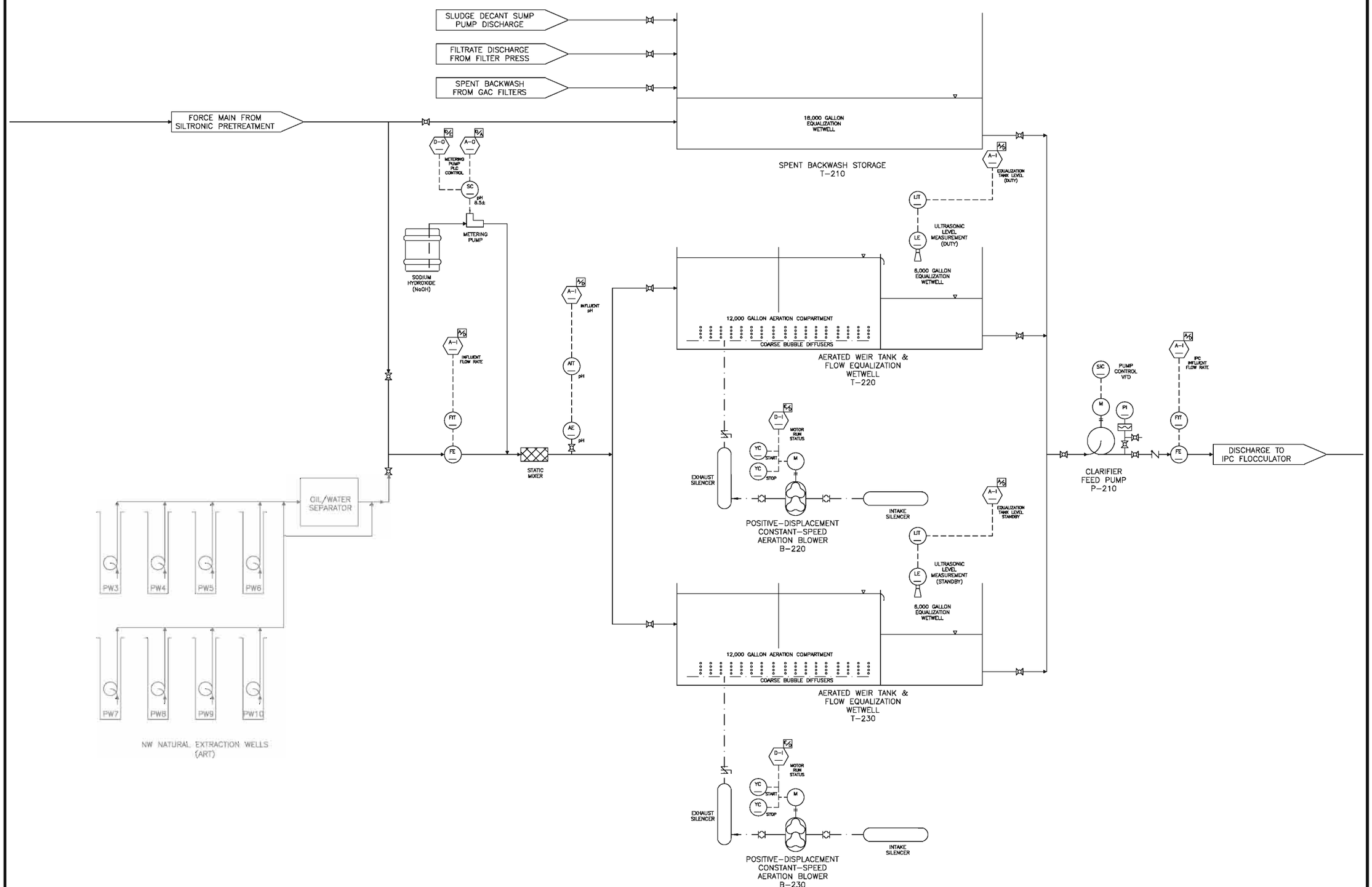
INTERIM DESIGN REPORT
GROUNDWATER TREATMENT FACILITY
PIPING & INSTRUMENTATION DIAGRAM (P&ID)

CADD NO.	SCALE:	CONTRACT:	JOB NO.	DRN.BY	DSN.BY	CHK.BY	APP.BY
NWN GASCO BPR (REV 7)		–	SES-E975	TSJ	TPD/TSJ	TPD	MDC

M-5

FILE NO.

SHEET 1 OF 4



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(NW NATURAL)

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NW NATURAL GASCO SITE SOURCE CONTROL

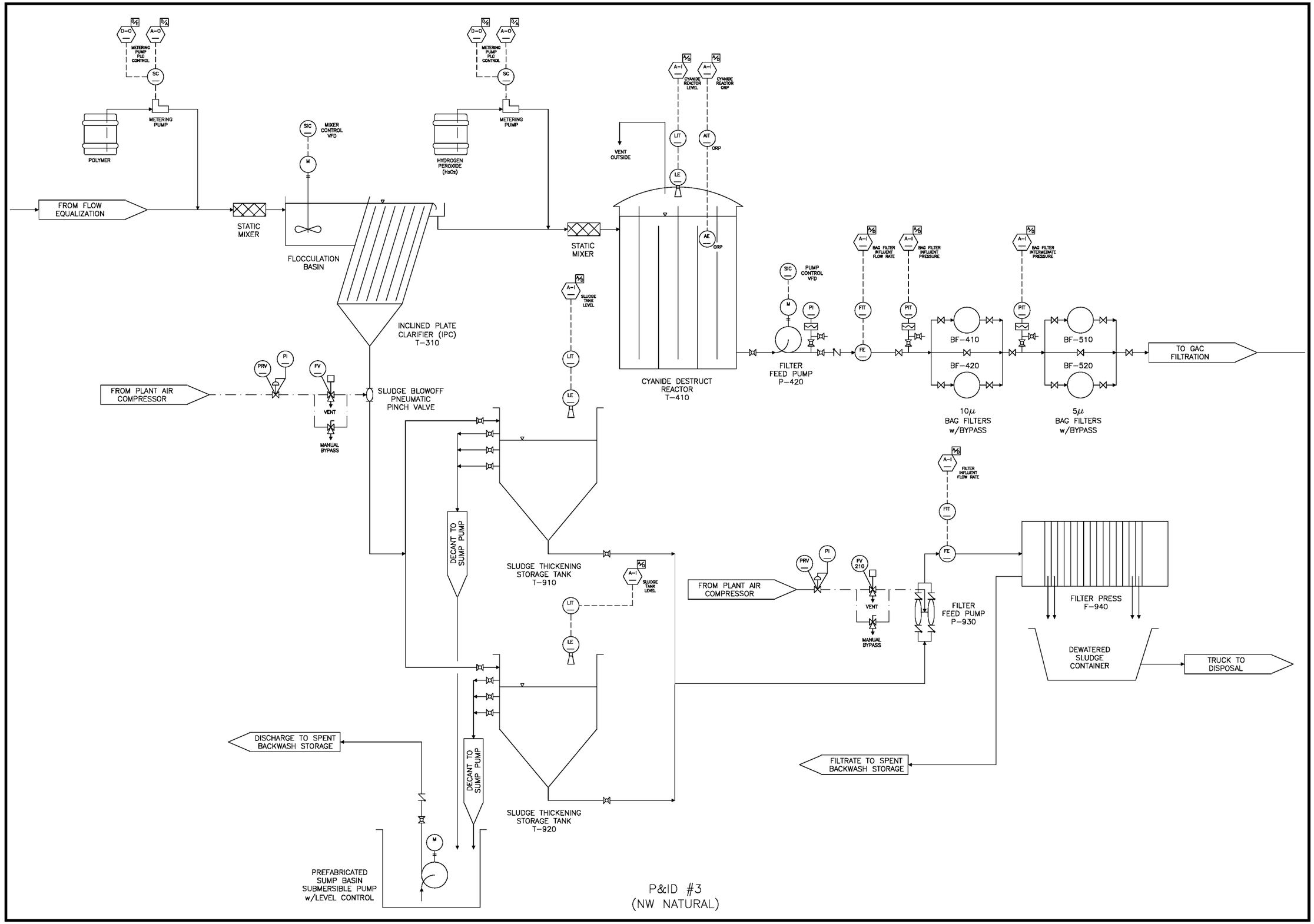
INTERIM DESIGN REPORT
GROUNDWATER TREATMENT FACILITY
PIPING & INSTRUMENTATION DIAGRAM (P&ID)

CADD NO.	SCALE:	CONTRACT:	JOB NO.	DRN.BY	DSN.BY	CHK.BY	APP.BY
NNN GASCO BR (REV. 7)		–	SES-E975	TSJ	TPD/TSJ	TPD	MDC

FILE NO.

M-6

SHEET 2 OF 4



P&ID #3
(NW NATURAL)

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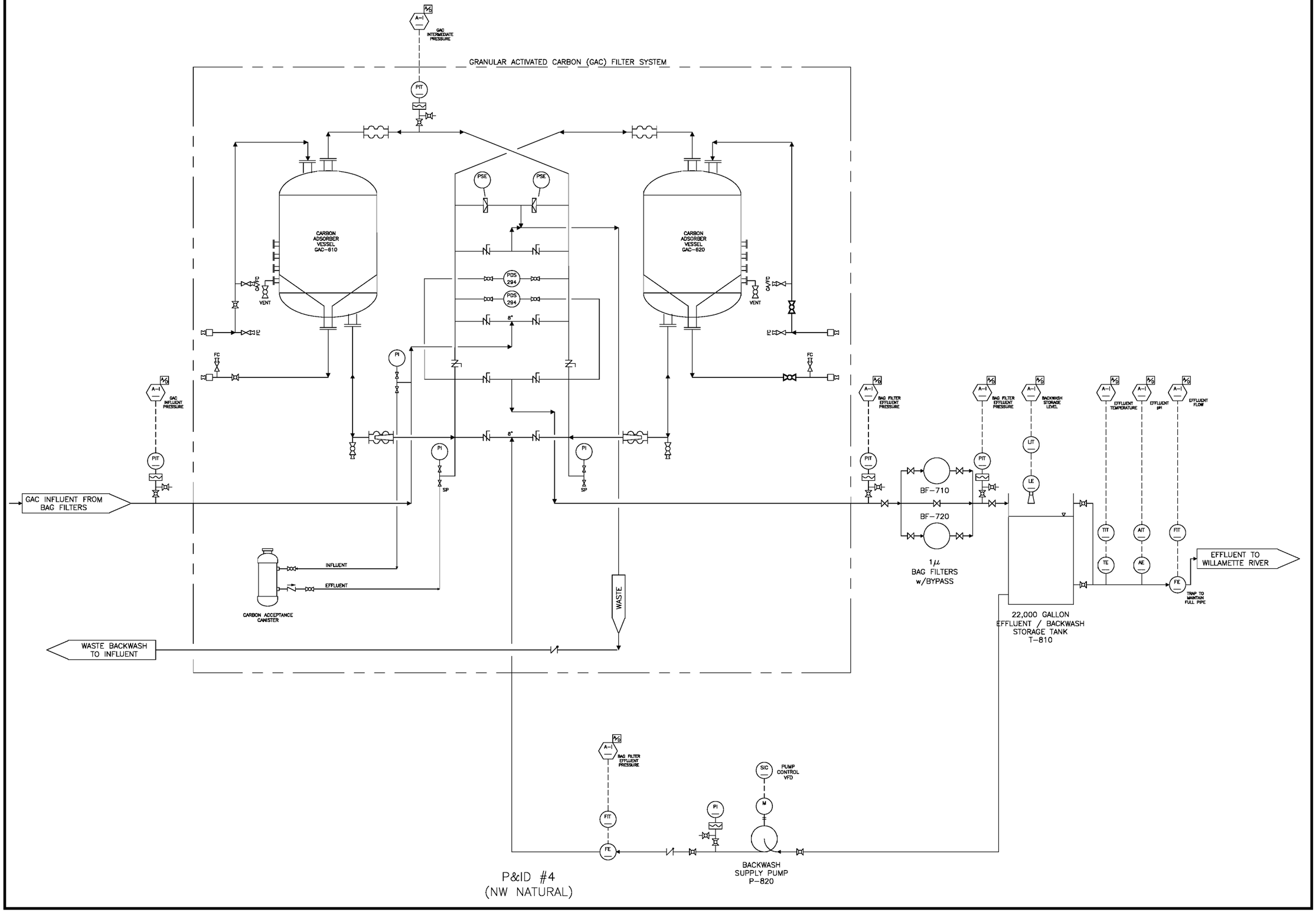
INTERIM DESIGN REPORT
GROUNDWATER TREATMENT FACILITY
PIPING & INSTRUMENTATION DIAGRAM (P&ID)

CADD NO.	SCALE:	CONTRACT:	JOB NO.	DRN.BY	DSN.BY	CHK.BY	APP.BY
NWN GASCO DIR (REV 7)		-	SES-E975	TSJ	TPD/TSJ	TPD	MDC

M-7

FILE NO.

SHEET 3 OF 4



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NW NATURAL GASCO SITE SOURCE CONTROL

INTERIM DESIGN REPORT
GROUNDWATER TREATMENT FACILITY
PIPING & INSTRUMENTATION DIAGRAM (P&ID)

CADD NO.	SCALE:	CONTRACT:	JOB NO.	DRN.BY	DSN.BY	CHK.BY	APP.BY
NWN GASCO BR (REV 7)		-	SES-E975	TSJ	TPD/TSJ	TPD	MDC

FILE NO.

M-8

SHEET 4 OF 4

ELECTRICAL SYMBOLS AND LEGEND

- DEMOLITION
- A — SURFACE OR PENDANT MOUNTED FLUORESCENT LIGHTING FIXTURE "A" DENOTES TYPE OF FIXTURE
- B — PENDANT MOUNTED COMPACT FLUORESCENT LIGHTING FIXTURE "B" DENOTES TYPE OF FIXTURE
- C — WALL-MOUNTED LIGHTING FIXTURE "C" DENOTES TYPE OF FIXTURE
- D — BATTERY OPERATED AUXILIARY LIGHTING UNIT "D" DENOTES TYPE OF FIXTURE
- F — BASE MOUNTED EXTERIOR AREA LIGHTING FIXTURE "F" DENOTES TYPE OF FIXTURE
- $o — SINGLE POLE SWITCH
- $3 — THREE-WAY SWITCH
- $M — SPDT RETURN TO CENTER MOMENTARY CONTACT SWITCH
- 2 — DUPLEX RECEPTACLE (GROUNDED TYPE), 125 VOLT "2" DENOTES LIGHTING PANEL CIRCUIT NUMBER
- SINGLE RECEPTACLE (GROUNDED TYPE), 125 VOLT
- A — SPECIAL PURPOSES RECEPTACLE, TYPE AND AMPERE RATING AS INDICATED ON PLAN
- MANUAL MOTOR STARTER
- MAGNETIC MOTOR STARTER
- COMBINATION MAGNETIC MOTOR STARTER AND DISCONNECT BREAKER
- SAFETY DISCONNECT SWITCH
- LC — MULTI-POLE LIGHTING CONTACTOR
- PANELBOARD
- MOTOR-FOR HORSEPOWER RATING SEE PANELBOARD SCHEDULE OR SINGLE LINE DIAGRAM
- D — DAMPER MOTOR
- H&V CONTROLS INTERLOCK
- TELEPHONE OUTLET, WALL MOUNTED
- J — JUNCTION BOX
- CONDUIT RUNS UNDERGROUND OR IN OR BELOW SLABS
- CONDUIT RUNS EXPOSED OR CONCEALED IN WALLS OR ABOVE CEILINGS
- CONDUIT TURNING UP OR TOWARD OBSERVER
- CONDUIT TURNING DOWN OR AWAY FROM OBSERVER
- PP2 — HOMERUN TO PANELBOARD – LETTERS AND NUMERALS DENOTE PANELBOARD, DIAGONAL LINES INDICATE NUMBER OF #12 AWG WIRES IN 3/4" RGS CONDUIT (SHORT DIAGONAL LINES INDICATE NUMBER OF GROUND WIRES)
- 5 — SQUIRREL CAGE INDUCTION MOTOR. NUMERAL DENOTES HORSEPOWER
- R — INDICATING LIGHTS: R=RED, B=BLUE, G=GREEN, A=AMBER
- WM — WM=WATTMETER
- SURGE PROTECTIVE EQUIPMENT

AFF	ABOVE FINISHED FLOOR
AFG	ABOVE FINISHED GRADE
W	DENOTES WATERTIGHT EQUIPMENT
WP	DENOTES WEATHERPROOF EQUIPMENT
SV	SOLENOID VALVE
GFCI	GROUND FAULT CIRCUIT INTERRUPTING
FACP	FIRE ALARM CONTROL PANEL
F	MANUAL FIRE ALARM STATION
F	FIRE ALARM HORN/LIGHT
H	HEAT DETECTOR, FIXED TEMPERATURE/ RATE OF RISE TYPE (DIV. 13)
SD	SMOKE DETECTOR (DIV. 13)
DS	DOOR SWITCH (DIV. 13)
KS	KEYSWITCH (DIV. 13)
HOA	HAND-OFF-AUTO
LS	LIMIT SWITCH
LT	LEVEL TRANSMITTER
PS	PRESSURE SWITCH
STP	SHIELDED TWISTED PAIR INSTRUMENT CABLE
T	THERMOSTAT
T/C	THERMOCOUPLE
MCC	MOTOR CONTROL CENTER
SF	SLOW-FAST SELECTOR SWITCH
FS	FLOW SWITCH
TC	TEMPERATURE CONTROLLER
RS	RUN-STOP SELECTOR SWITCH
SWBD	SWITCHBOARD
M	MOTOR STARTER OPERATING COIL
OL	MOTOR OVERLOAD
TD	TIME DELAY RELAY
CPT	CONTROL POWER TRANSFORMER
100/15	MOLDED CASE CIRCUIT BREAKER, THERMAL MAGNETIC TRIP, 3-POLE UNLESS OTHERWISE NOTED. UPPER NUMERAL INDICATES FRAME SIZE. LOWER NUMERAL INDICATES TRIP SETTING.
MCP	MOTOR CIRCUIT PROTECTOR
100	DENOTES AMPERE RATING
CT	CT = CURRENT TRANSFORMER
	POTENTIAL TRANSFORMER
	TRANSFORMER, SIZE AS NOTED
	NORMALLY OPEN CONTACT (DE-ENERGIZED POSITION)
	NORMALLY CLOSED CONTACT (DE-ENERGIZED POSITION)
AL	ALARM

MAGNETIC MOTOR STARTER

FVNR 1a 1b 2

- FVNR=FULL VOLTAGE, NON-REVERSING 2S2W=TWO SPEED, 2 WINDING
- AUXILIARY CONTACTS: 1a=ONE NORMALLY OPEN 1b=ONE NORMALLY CLOSED
- NUMERAL INDICATES NEMA SIZE

ELECTRICAL WORK GENERAL NOTES

1. ALL WORK SHALL CONFORM TO THE OREGON STATE BUILDING CODE (CURRENT EDITION) AND LATEST AMENDMENTS PACKAGES AND ALSO TO THE CODES, ORDINANCES, REGULATIONS, ETC. OF THE CITY OF PORTLAND, OREGON.

2. ALL ELECTRICAL WORK SHALL CONFORM TO NFPA-70, THE NATIONAL ELECTRICAL CODE (NEC), LATEST EDITION. GROUNDING SHALL CONFORM TO ARTICLE 250.

3. COORDINATE THE SPECIFIC PROCESS, MECHANICAL, HEATING, AND VENTILATING, ETC. EQUIPMENT SUBMITTED AND REVIEWED AND ADJUST THE ELECTRICAL AND CONTROL SYSTEM COMPONENTS ACCORDINGLY AT NO ADDITIONAL COST.

4. ALL ELECTRICAL EQUIPMENT (E.G., ENCLOSURES, BOXES, FITTINGS, RACEWAYS, ETC.) IN DESIGNATED WET, DAMP, CORROSIVE, HAZARDOUS OR EXPLOSIONPROOF AREAS AND/OR LOCATIONS SHALL BE UL LISTED WATERTIGHT CONSTRUCTION. ALL ELECTRICAL EQUIPMENT (E.G., ENCLOSURES, BOXES, FITTINGS, RACEWAYS, ETC.) IN DESIGNATED HAZARDOUS OR EXPLOSIONPROOF AREAS AND/OR LOCATIONS SHALL BE UL LISTED EXPLOSIONPROOF CONSTRUCTION.

5. LOCATION OF EQUIPMENT AND DEVICES ON THE ELECTRICAL DRAWINGS IS DIAGRAMMATIC ONLY. REFER TO SUBMITTALS AND OTHER DRAWINGS, ESPECIALLY THE MECHANICAL DRAWINGS, FOR EQUIPMENT LOCATIONS.

6. BURIED CONDUITS SHALL BE PVC COATED RIGID GALVANIZED STEEL (UNLESS OTHERWISE NOTED) INSTALLED IN TRENCHES WITH A MINIMUM 6" SAND BEDDING ALL AROUND. MINIMUM BURIED CONDUIT SIZE SHALL BE 1" DIAMETER. BURIED CONDUITS SHALL BE INSTALLED 24" DEEP (MINIMUM) WITH A 6" WIDE PLASTIC WARNING TAPE PLACED 12" ABOVE. THE TAPE SHALL BE RED AND PRINTED CONTINUOUSLY WITH THE WORDS "CAUTION – ELECTRIC LINES BURIED BELOW". WARNING TAPE SHALL HAVE EMBEDDED WIRE TO FACILITATE FINDING WITH ELECTRONIC LOCATOR INSTRUMENTS.

7. CONDUITS AND CONDUCTORS ARE NOT ALL SHOWN OR INDICATED. ALL POWER AND LIGHTING CONDUITS SHALL BE 3/4" MINIMUM (1" IF BURIED) WITH 5#12AWG+G. ALL CONTROL CONDUITS SHALL BE 3/4" MINIMUM (1" IF BURIED) WITH 8#14AWG. ALL SIGNAL CONDUITS SHALL BE 3/4" MINIMUM (1" IF BURIED) WITH 3#16 SHIELDED TWISTED PAIR (STP) CABLES, UNLESS OTHERWISE INDICATED. ALL CONDUITS (POWER, LIGHTING, CONTROL, AND SIGNAL) SHALL ALSO INCLUDE A #12AWG (OR LARGER) GREEN INSULATED GROUND WIRE.

8. ALL CONDUIT SHALL BE 3/4" MINIMUM (1" MINIMUM IF BURIED) RIGID GALVANIZED STEEL (RGS) WITH WRENCH-TIGHT THREADED FITTINGS UNLESS SPECIFICALLY NOTED OTHERWISE. BOXES SHALL BE 316 STAINLESS STEEL, CAST IRON, CAST STEEL, OR CAST ALUMINUM WITH THREADED WATERTIGHT HUBS. FITTINGS SHALL BE STAINLESS-STEEL, CAST-STEEL, CAST-IRON, OR CAST-ALUMINUM WITH THREADED WATERTIGHT HUBS.

9. ALL INTERIOR CONDUITS SHALL BE INSTALLED EXPOSED ON WALLS AND CEILINGS AND SHALL NOT BE EMBEDDED IN CONCRETE.

10. PROVIDE 3/4" (MINIMUM) BRANCH CIRCUITS FROM TERMINATION JUNCTION BOXES TO INDIVIDUAL DEVICES. FINAL CONNECTION TO ALL EQUIPMENT SHALL BE MINIMUM 1/2" PVC COATED FLEXIBLE METAL CONDUIT (LIQUIDTIGHT OR SEALTIGHT) WITH CORROSION RESISTANT WATERTIGHT FITTINGS.

11. PROVIDE CONDUIT RUNS FROM ALL OUTLETS, SWITCHES, FIXTURES, DEVICES, ETC. TO LIGHTING PANELS AS REQUIRED, WHETHER SHOWN OR NOT. PROVIDE 3/4" CONDUITS WITH 120Vac, 20A LIGHTING CIRCUITS TO ALL INSTRUMENTS AS REQUIRED. MINIMUM CONDUIT SIZE FOR OUTLETS AND LIGHTING CIRCUITS SHALL BE 3/4" RGS WITH 5#12AWG AND #12AWG GROUND.

12. SEPARATE CONDUIT RUNS ARE TYPICALLY INDICATED ON THE DRAWINGS. CONDUITS MAY BE COMBINED IN LARGER CONDUITS SUBJECT TO REVIEW BY THE ENGINEER. LIGHTING AND OUTLET CIRCUITS MAY BE COMBINED IN A SINGLE CONDUIT WITH SEPARATE NEUTRALS. MULTIPLE MOTOR BRANCH CIRCUITS MAY BE COMBINED. LIGHTING AND OUTLET CIRCUITS SHALL NOT BE COMBINED WITH MOTOR BRANCH CIRCUITS. MULTIPLE CURRENT CARRYING CONDUCTOR AMPACITY SHALL BE DERATED IN CONFORMANCE WITH NEC REQUIREMENTS.

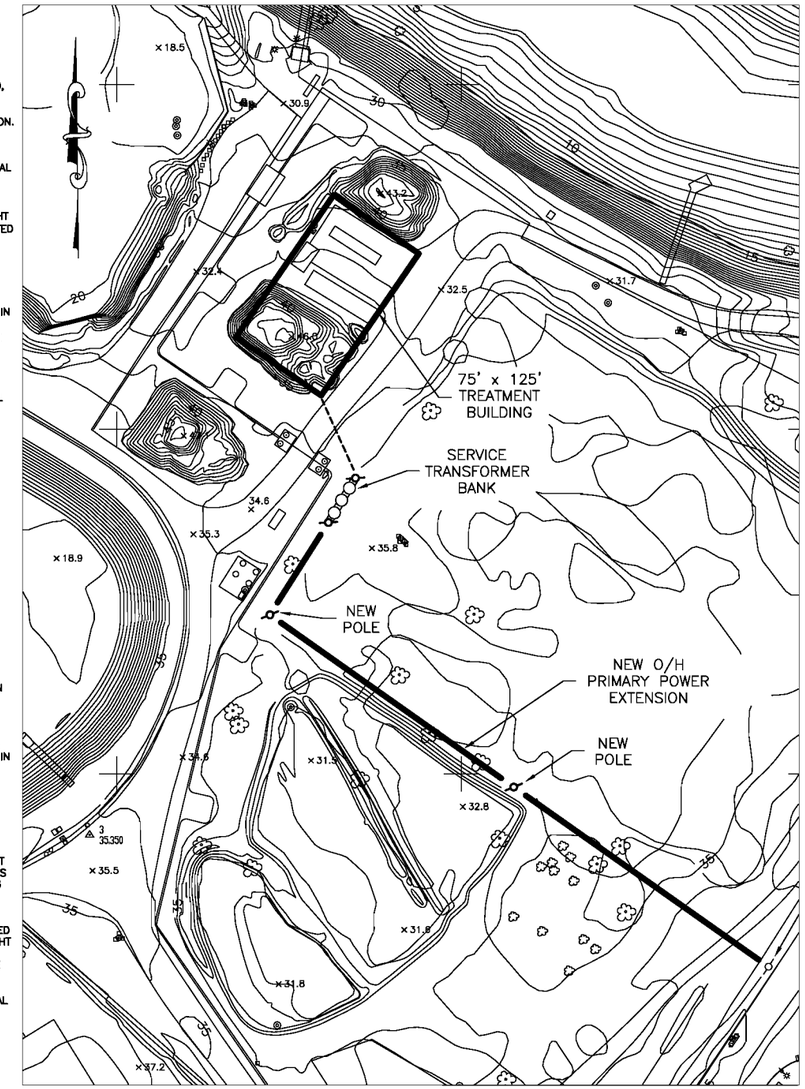
13. CONDUIT AND CONDUCTOR INSTALLATION SHALL MEET THE REQUIREMENTS OF SPECIFICATION DIVISIONS 13 & 16. MAINTAIN CONDUCTOR CLASS SEPARATION AND SEGREGATION AS SPECIFIED AND AS PER NEC SECTION 725. IN NO EVENT SHALL SIGNAL OR CONTROL CONDUCTORS BE COMBINED IN CONDUITS WITH POWER AND LIGHTING CONDUCTORS.

14. ALL ELECTRICAL AND CONTROL EQUIPMENT, EXCEPT FREESTANDING ENCLOSURES, SHALL BE MOUNTED ON STANCHIONS FABRICATED OF 316 STAINLESS STEEL UNISTRUT WITH 316 STAINLESS-STEEL FASTENERS AND 316 STAINLESS-STEEL ANCHOR BOLTS. GALVANIZED STEEL UNISTRUT MAY BE SUBSTITUTED IN DRY (NEMA 1) AREAS SUBJECT TO REVIEW BY THE ENGINEER.

15. FREESTANDING ENCLOSURES SHALL BE MOUNTED ON 4-INCH HIGH STEEL REINFORCED CONCRETE EQUIPMENT PADS AND FASTENED WITH 316 STAINLESS-STEEL ANCHOR BOLTS. EMERGENCY GENERATOR SET SUB-BASE TANKS SHALL BE MOUNTED ON 6-INCH HIGH STEEL REINFORCED CONCRETE EQUIPMENT PADS AND FASTENED WITH 316 STAINLESS-STEEL ANCHOR BOLTS. ONE-INCH CHAMFER ALL EXPOSED EDGES.

16. OUTLETS SHALL TYPICALLY BE LOCATED 36-42 INCHES ABOVE FINISHED FLOOR AND SHALL ALL INCLUDE WEATHERTIGHT LOCKING HINGED COVERS. SWITCHES SHALL TYPICALLY BE LOCATED 42-48 INCHES ABOVE FINISHED FLOORS AND SHALL ALL BE WEATHERPROOF PILOT LIGHT TYPE. ALL SWITCHES SHALL ALSO INCLUDE WEATHERTIGHT LOCKING HINGED COVERS. ALL DUPLEX CONVENIENCE RECEPTACLES SHALL BE CONNECTED TO GFCI CIRCUIT BREAKERS INSTALLED IN LIGHTING & APPLIANCE PANELBOARDS. ALL SIMPLEX APPLIANCE RECEPTACLES SHALL BE CONNECTED TO STANDARD (NON-GFCI) CIRCUIT BREAKERS.

17. TRANSFORMERS SHALL ALL BE ENERGY EFFICIENT TYPE. ALL TRANSFORMERS SHALL HAVE A MINIMUM NOMINAL EFFICIENCY OF 97% IN ACCORDANCE WITH NEMA STANDARD TP-1 "GUIDE FOR ENERGY EFFICIENCY FOR DISTRIBUTION TRANSFORMERS".



SITE PLAN
1" = 50'

LIGHTING FIXTURE SCHEDULE

FIXTURE			LAMP			FIXTURE DESCRIPTION	MANUFACTURER/MODEL
TYPE	MTG	ENC	TYPE	WATTS	VOLTS		
A	CEILING	NEMA 1	T-8 FLUORESCENT	4-32	120	FOUR-TUBE FLUORESCENT TROFFER	LITHONIA SERIES 20SP
B	CONDUIT STEM	NEMA 4X	FLUORESCENT	2-86	120	TWO TUBE FLUORESCENT (WATERTIGHT)	LITHONIA DMW 2 96TBHO AR 120 WLF
C	WALL	NEMA 4	COMPACT FLUORESCENT	2-13	120	OUTDOOR FLOODLIGHT (WATERTIGHT)	LITHONIA TCF 2/13DTT (PHOTO CELL)
D	WALL	NEMA 4	TUNGSTEN	2-7.2	120	EMERGENCY LIGHTING (WATERTIGHT)	DUAL LITE N4X2
E	WALL	NEMA 4	LED		120	EMERGENCY EXIT SIGN (WATERTIGHT)	DUAL LITE LN4XRWE
F	WALL	NEMA 4	COMPACT FLUORESCENT	13	120	OUTDOOR WALLPACK (WATERTIGHT)	LITHONIA TWS 13 TT 120 PE (PHOTO CELL)

Severson Environmental Services, Inc.
2749 LOCKPORT ROAD
NIAGARA FALLS, NY 14305

ADA
APONOWICH, DRISCOLL & ASSOCIATES, INC.
TS JONES CONSULTING

PRELIMINARY DRAFT DRAWINGS

NOT FOR CONSTRUCTION

10/13/2009

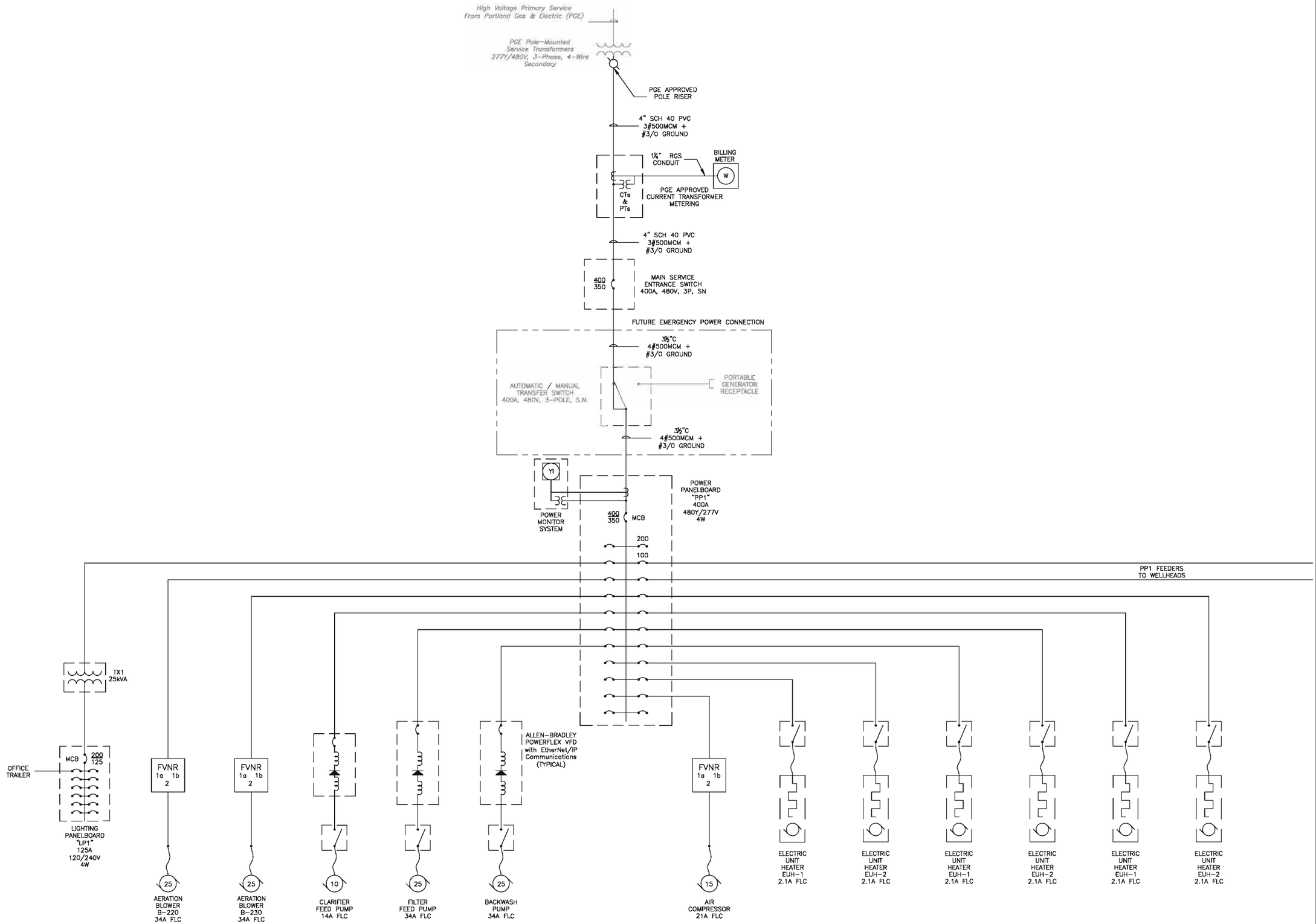
NW NATURAL GASCO SITE SOURCE CONTROL
INTERIM DESIGN REPORT
GROUNDWATER TREATMENT FACILITY
ELECTRICAL LEGEND, NOTES & SITE PLAN

CADD NO.	SCALE:	CONTRACT:	JOB NO.	DRN.BY	DSN.BY	CHK.BY	APP.BY
NW GASCO SIT (REV 7)		–	SES-E975	TSJ	TPD/TSJ	TPD	MDC

E-1

FILE NO.

SHEET 1 OF 3



Severson Environmental Services, Inc.
2749 LOCKPORT ROAD
NIAGARA FALLS, NY 14305

ADA
APONOWICH, DRISCOLL & ASSOCIATES, INC.

TS JONES CONSULTING

PRELIMINARY
DRAFT DRAWINGS

NOT FOR
CONSTRUCTION

10/13/2009

NW NATURAL GASCO SITE SOURCE CONTROL

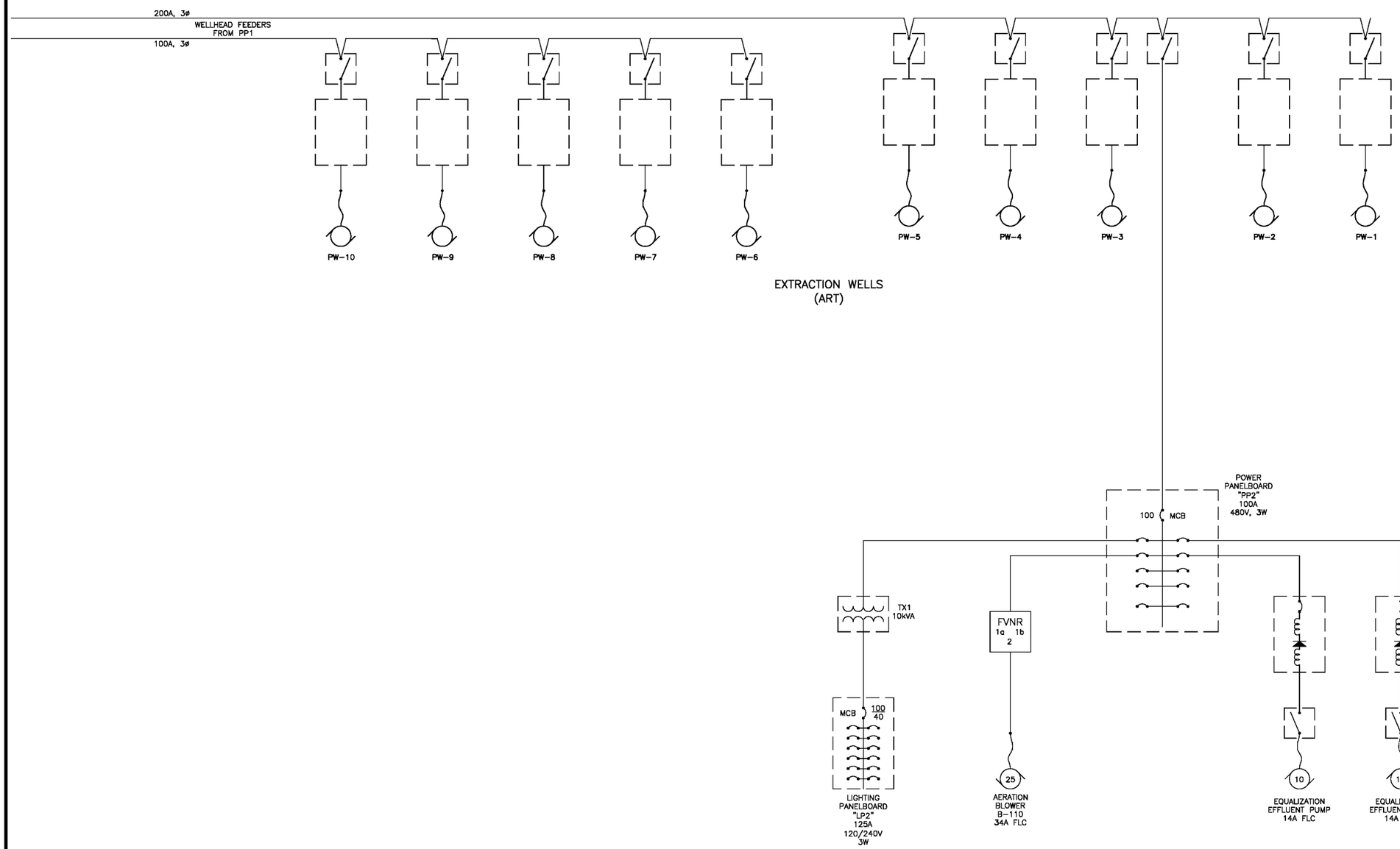
INTERIM DESIGN REPORT
GROUNDWATER TREATMENT FACILITY
SINGLE-LINE DIAGRAM #1

CADD NO.	SCALE:	CONTRACT:	JOB NO.	DRN.BY	DSN.BY	CHK.BY	APP.BY
NW_GASCO_IDW (REV 2)		-	SES-E975	TSJ	TPD/TSJ	TPD	MDC

E-2

FILE NO.

SHEET 2 OF 3



Sevenson Environmental Services, Inc.
2749 LOCKPORT ROAD
NIAGARA FALLS, NY 14305

ADA
APONOWICH, DRISCOLL & ASSOCIATES, INC.

TS JONES CONSULTING

PRELIMINARY
DRAFT DRAWINGS

NOT FOR
CONSTRUCTION

10/13/2009

NW NATURAL GASCO SITE SOURCE CONTROL

INTERIM DESIGN REPORT
GROUNDWATER TREATMENT FACILITY
SINGLE-LINE DIAGRAM #2

CADD NO.	SCALE:	CONTRACT:	JOB NO.	DRN.BY	DSN.BY	CHK.BY	APP.BY
NWN GASCO DIR (REV 7)		-	SES-E975	TSJ	TPD/TSJ	TPD	MDC

E-3

FILE NO.

SHEET 3 OF 3

Appendix C: NW Natural Inflow Routing Analysis

SUMMARY OF PROJECTED FLOWS--MW-1 & PW-1--**Max Inflow**

TIME	HOURLY FLOW, GPM	HOURLY FLOW, GALS	CUM FLOW, GALS	% OF TOTAL
Mid	0	0	0	0.0%
1	30	1800	1800	1.4%
2	67.5	4050	5850	4.5%
3	112.5	6750	12600	9.7%
4	120	7200	19800	15.3%
5	135	8100	27900	21.5%
6	150	9000	36900	28.5%
7	135	8100	45000	34.7%
8	120	7200	52200	40.3%
9	112.5	6750	58950	45.5%
10	67.5	4050	63000	48.6%
11	30	1800	64800	50.0%
Noon	0	0	64800	50.0%
1	30	1800	66600	51.4%
2	67.5	4050	70650	54.5%
3	112.5	6750	77400	59.7%
4	120	7200	84600	65.3%
5	135	8100	92700	71.5%
6	150	9000	101700	78.5%
7	135	8100	109800	84.7%
8	120	7200	117000	90.3%
9	112.5	6750	123750	95.5%
10	67.5	4050	127800	98.6%
11	30	1800	129600	100.0%

Avg Outflow (one set of wells) = 90 gpm

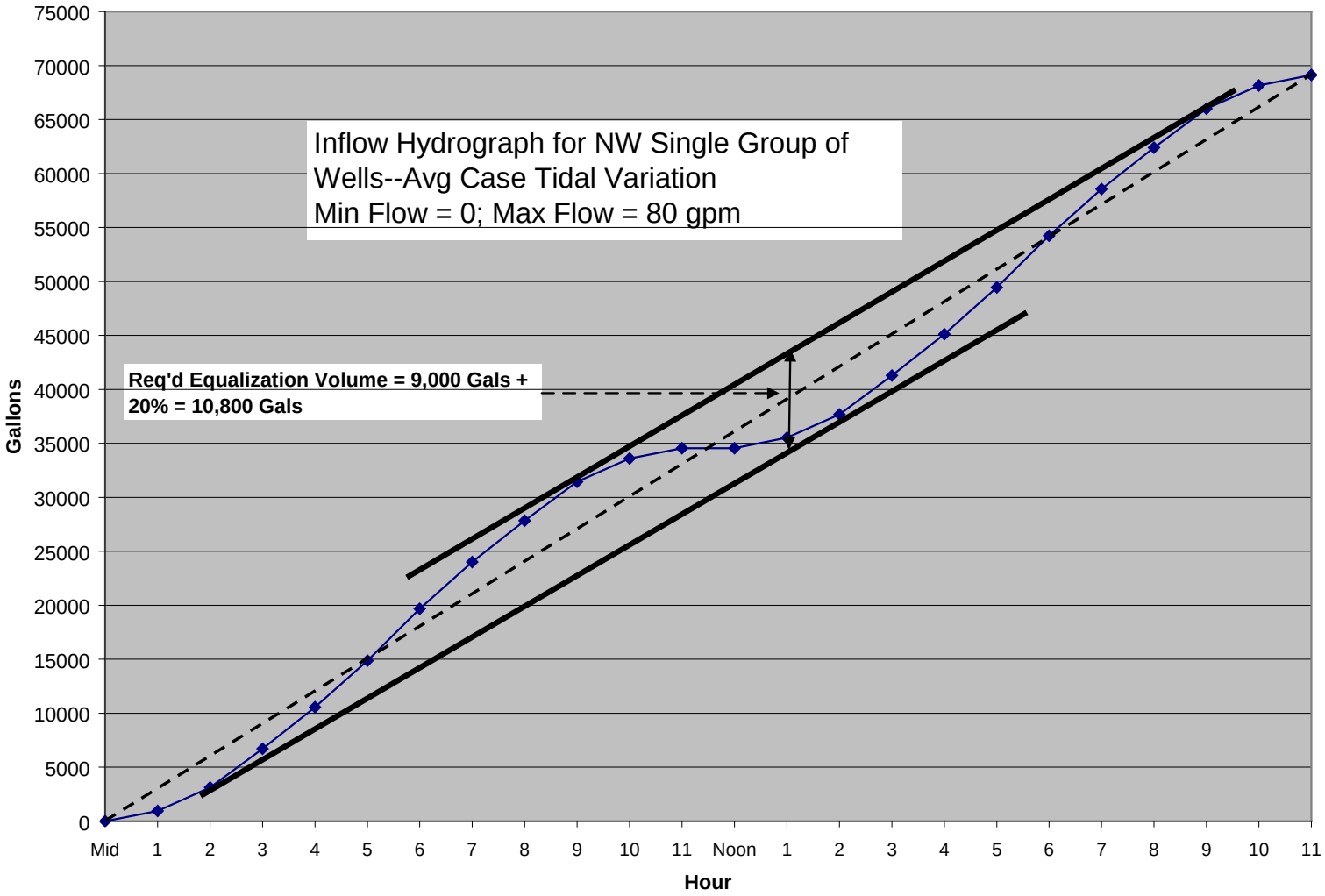
Avg Outflow (both sets of NW wells) = 180 gpm
+ Siltronic Wells @ Peak Inflow 42
+ LNG Basin Flow 30 gpm
Max Day Plant Flow 252 gpm

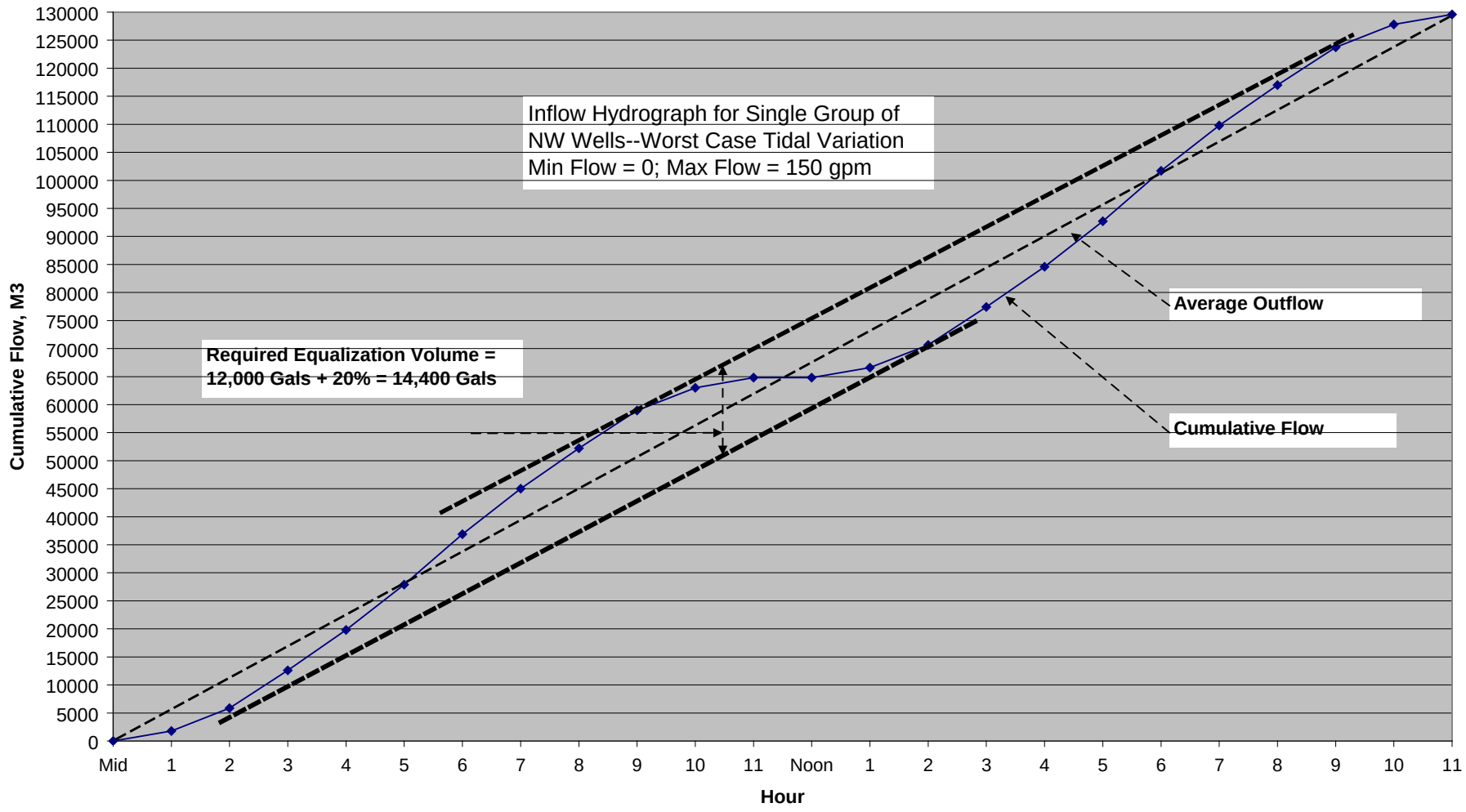
SUMMARY OF PROJECTED FLOWS--MW-1 & PW-1--**Average Inflow**

TIME	HOURLY FLOW, GPM	HOURLY FLOW, GALS	CUM FLOW, GALS	% OF TOTAL
Mid	0	0	0	0.0%
1	16	960	960	1.4%
2	36	2160	3120	4.5%
3	60	3600	6720	9.7%
4	64	3840	10560	15.3%
5	72	4320	14880	21.5%
6	80	4800	19680	28.5%
7	72	4320	24000	34.7%
8	64	3840	27840	40.3%
9	60	3600	31440	45.5%
10	36	2160	33600	48.6%
11	16	960	34560	50.0%
Noon	0	0	34560	50.0%
1	16	960	35520	51.4%
2	36	2160	37680	54.5%
3	60	3600	41280	59.7%
4	64	3840	45120	65.3%
5	72	4320	49440	71.5%
6	80	4800	54240	78.5%
7	72	4320	58560	84.7%
8	64	3840	62400	90.3%
9	60	3600	66000	95.5%
10	36	2160	68160	98.6%
11	16	960	69120	100.0%

Avg Outflow (one set of wells) = 48 gpm

Avg Outflow (both sets of NW wells) = 96 gpm
+ Siltronic Wells @ Peak Inflow 24 gpm
30 gpm
150 gpm


Inflow Hydrograph for NW Single Group of Wells--Avg Case Tidal Variation
Min Flow = 0; Max Flow = 80 gpm
Req'd Equalization Volume = 9,000 Gals + 20% = 10,800 Gals
Gallons
75000
70000
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
Mid
1
2
3
4
5
6
7
8
9
10
11
Noon
1
2
3
4
5
6
7
8
9
10
11
Hour


Inflow Hydrograph for Single Group of
NW Wells--Worst Case Tidal Variation
Min Flow = 0; Max Flow = 150 gpm
Required Equalization Volume =
12,000 Gals + 20% = 14,400 Gals
Average Outflow
Cumulative Flow
Cumulative Flow, M3
Hour
130000
125000
120000
115000
110000
105000
100000
95000
90000
85000
80000
75000
70000
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
Mid
1
2
3
4
5
6
7
8
9
10
11
Noon
1
2
3
4
5
6
7
8
9
10
11

Appendix C: Siltronic Inflow Routing Analysis

SUMMARY OF PROJECTED FLOWS--Siltronic--**Max Inflow**

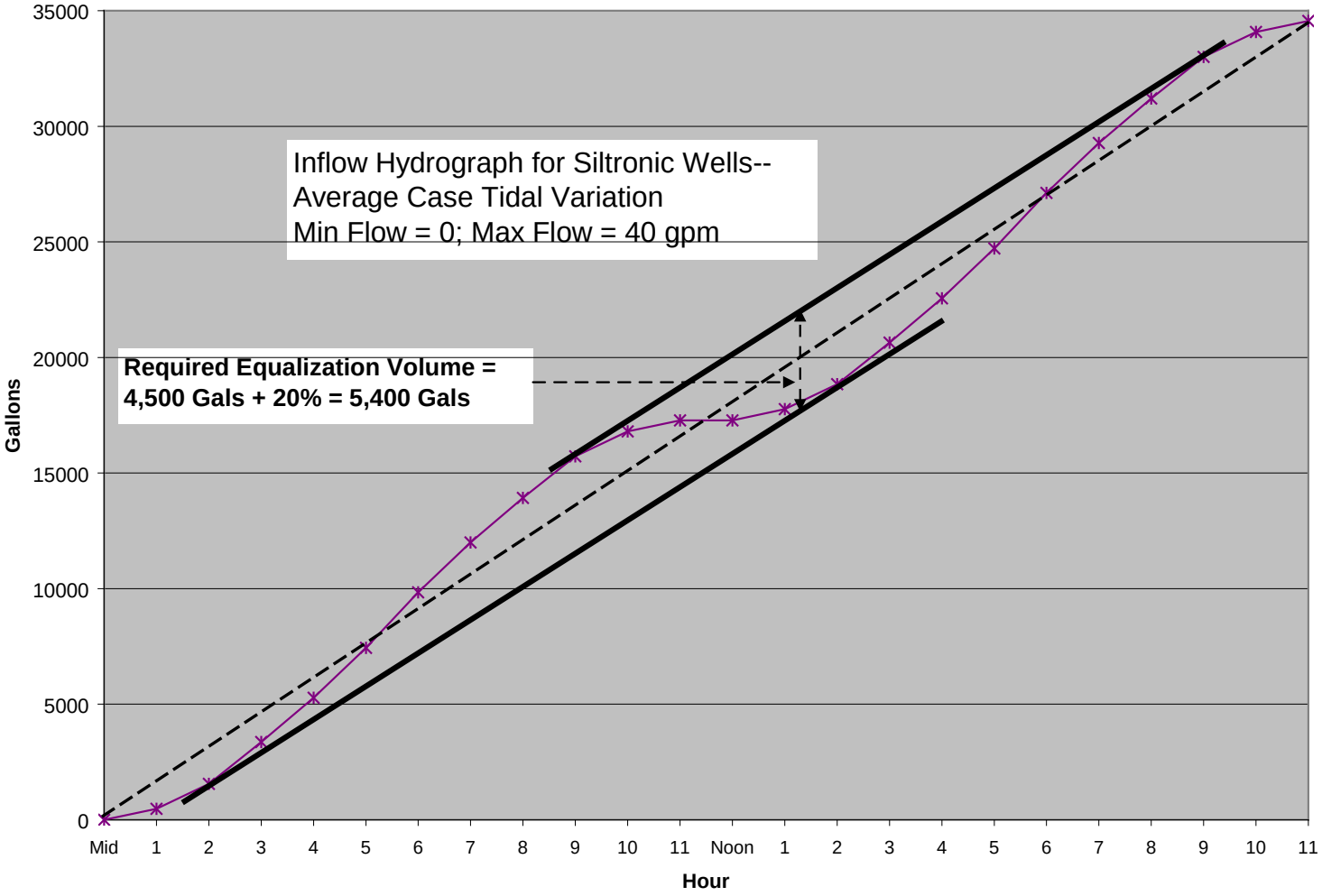
TIME	HOURLY FLOW, GPM	HOURLY FLOW, GALS	CUM FLOW, GALS	% OF TOTAL
Mid	0	0	0	0.0%
1	14	840	840	1.4%
2	31.5	1890	2730	4.5%
3	52.5	3150	5880	9.7%
4	56	3360	9240	15.3%
5	63	3780	13020	21.5%
6	70	4200	17220	28.5%
7	63	3780	21000	34.7%
8	56	3360	24360	40.3%
9	52.5	3150	27510	45.5%
10	31.5	1890	29400	48.6%
11	14	840	30240	50.0%
Noon	0	0	30240	50.0%
1	14	840	31080	51.4%
2	31.5	1890	32970	54.5%
3	52.5	3150	36120	59.7%
4	56	3360	39480	65.3%
5	63	3780	43260	71.5%
6	70	4200	47460	78.5%
7	63	3780	51240	84.7%
8	56	3360	54600	90.3%
9	52.5	3150	57750	95.5%
10	31.5	1890	59640	98.6%
11	14	840	60480	100.0%

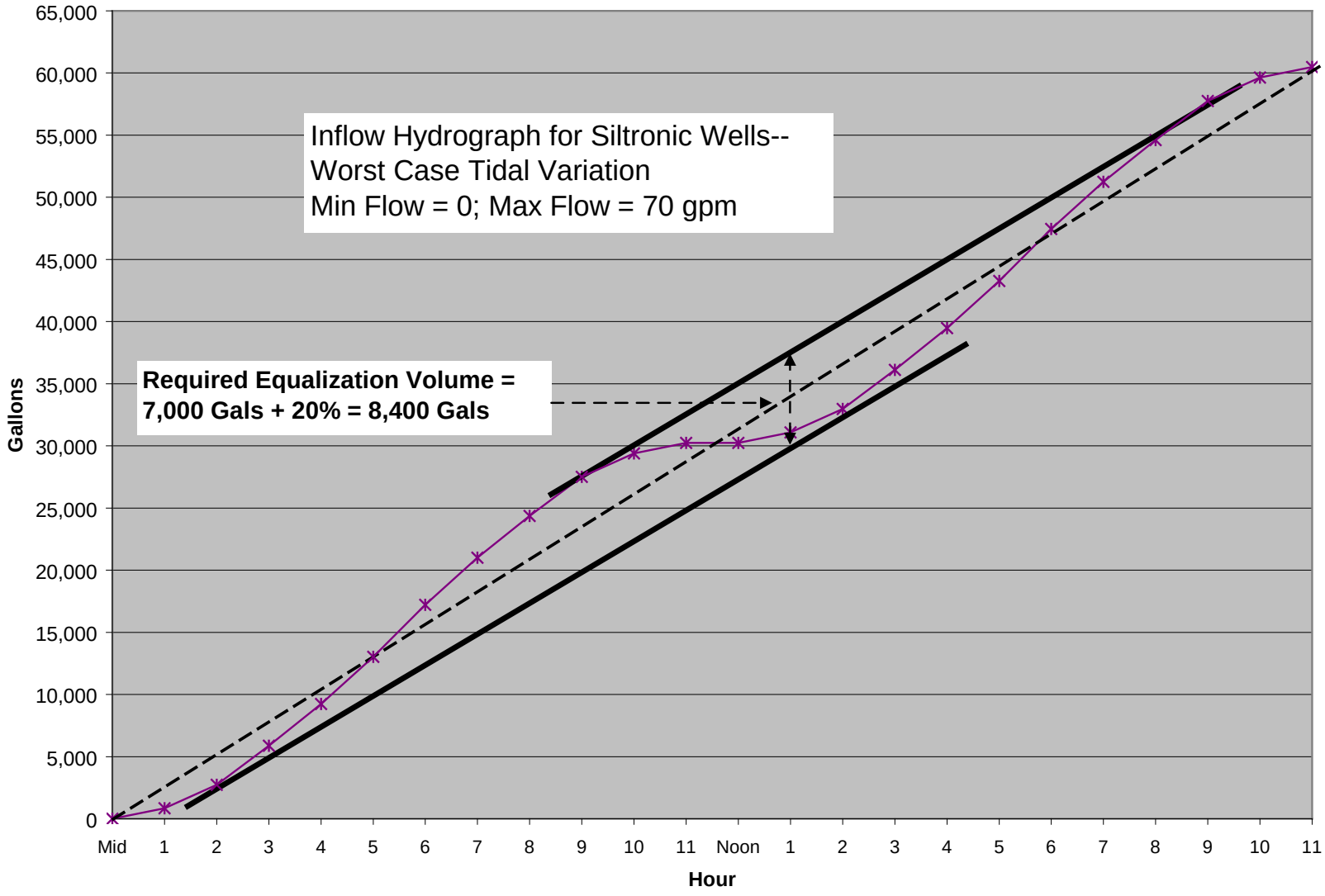
Avg Outflow (all Siltronic wells) @ Peak Inflow = 42 gpm

SUMMARY OF PROJECTED FLOWS--Siltronic--**Average Inflow**

TIME	HOURLY FLOW, GPM	HOURLY FLOW, GALS	CUM FLOW, GALS	% OF TOTAL
Mid	0	0	0	0.0%
1	8	480	480	1.4%
2	18	1080	1560	4.5%
3	30	1800	3360	9.7%
4	32	1920	5280	15.3%
5	36	2160	7440	21.5%
6	40	2400	9840	28.5%
7	36	2160	12000	34.7%
8	32	1920	13920	40.3%
9	30	1800	15720	45.5%
10	18	1080	16800	48.6%
11	8	480	17280	50.0%
Noon	0	0	17280	50.0%
1	8	480	17760	51.4%
2	18	1080	18840	54.5%
3	30	1800	20640	59.7%
4	32	1920	22560	65.3%
5	36	2160	24720	71.5%
6	40	2400	27120	78.5%
7	36	2160	29280	84.7%
8	32	1920	31200	90.3%
9	30	1800	33000	95.5%
10	18	1080	34080	98.6%
11	8	480	34560	100.0%

Avg Outflow (all Siltronic wells) @ Avg Inflow = 24 gpm


Inflow Hydrograph for Siltronic Wells--
Average Case Tidal Variation
Min Flow = 0; Max Flow = 40 gpm
Required Equalization Volume =
4,500 Gals + 20% = 5,400 Gals
Gallons
35000
30000
25000
20000
15000
10000
5000
0
Mid
1
2
3
4
5
6
7
8
9
10
11
Noon
1
2
3
4
5
6
7
8
9
10
11
Hour


Inflow Hydrograph for Siltronic Wells--
Worst Case Tidal Variation
Min Flow = 0; Max Flow = 70 gpm
Required Equalization Volume =
7,000 Gals + 20% = 8,400 Gals
Gallons
65,000
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Mid
1
2
3
4
5
6
7
8
9
10
11
Noon
1
2
3
4
5
6
7
8
9
10
11
Hour

APPENDIX D
GEOTECHNICAL BORING LOGS AND SOIL DATA TABLES

Legend

B-1 Geotechnical Boring Location and Number

0 150
Scale in Feet

Sep 10, 2008 12:01pm cdavidson K:\Jobs\000029-GASCO\00002902\00002902-214 GEO-XSEC MAP.dwg FIG 1

ANCHOR ENVIRONMENTAL, L.L.C.

Figure 1
Boring Location Map
Gasco, Portland, Oregon

Sample Description

Classification of soils in this report is based on visual field and laboratory observations which include density/consistency, moisture condition, grain size, and plasticity estimates and should not be construed to imply field nor laboratory testing unless presented herein. Visual-manual classification methods of ASTM D 2488 were used as an identification guide.

Soil descriptions consist of the following:
Density/consistency, moisture, color, minor constituents, MAJOR CONSTITUENT, additional remarks.

Density/Consistency

Soil density/consistency in borings is related primarily to the Standard Penetration Resistance. Soil density/consistency in test pits is estimated based on visual observation and is presented parenthetically on the test pit logs.

SAND or GRAVEL Density	Standard Penetration Resistance (N) in Blows/Foot	SILT or CLAY Consistency	Standard Penetration Resistance (N) in Blows/Foot	Approximate Shear Strength in TSF
Very loose	0 - 4	Very soft	0 - 2	<0.125
Loose	4 - 10	Soft	2 - 4	0.125 - 0.25
Medium dense	10 - 30	Medium stiff	4 - 8	0.25 - 0.5
Dense	30 - 50	Stiff	8 - 15	0.5 - 1.0
Very dense	>50	Very stiff	15 - 30	1.0 - 2.0
		Hard	>30	>2.0

Moisture

Dry	Little perceptible moisture
Damp	Some perceptible moisture, probably below optimum
Moist	Probably near optimum moisture content
Wet	Much perceptible moisture, probably above optimum

Minor Constituents

	Estimated Percentage
Not identified in description	0 - 5
Slightly (clayey, silty, etc.)	5 - 12
Clayey, silty, sandy, gravelly	12 - 30
Very (clayey, silty, etc.)	30 - 50

Legends

Sampling Test Symbols

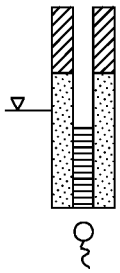
BORING SAMPLES

- ☒ Split Spoon
- ⧅ Shelby Tube
- ▥ Cuttings
- ◧ Core Run
- ✳ No Sample Recovery
- P Tube Pushed, Not Driven

TEST PIT SAMPLES

- ☒ Grab (Jar)
- ⧄ Bag
- ⧅ Shelby Tube

Groundwater Observations



Surface Seal

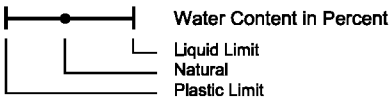
Groundwater Level on Date (ATD) At Time of Drilling

Observation Well Tip or Slotted Section

Groundwater Seepage (Test Pits)

Test Symbols

NS	No Sheen
SS	Slight Sheen
MS	Moderate Sheen
HS	Heavy Sheen
TCD	Triaxial Consolidated Drained
QU	Unconfined Compression
DS	Direct Shear
K	Permeability
PP	Pocket Penetrometer Approximate Compressive Strength in TSF
TV	Torvane Approximate Shear Strength in TSF
CBR	California Bearing Ratio
MD	Moisture Density Relationship
AL	Atterberg Limits



PID	Photoionization Detector Reading
CA	Chemical Analysis
DT	In Situ Density Test

Sep 10, 2008 12:13pm cdavidson K:\Jobs\000029-GASCO\00002902\00002902-227 FIG A-1.dwg FIG A-1

ANCHOR ENVIRONMENTAL, L.L.C.

Figure A-1
Key to Exploration Logs
Gasco, Portland, Oregon

Boring: B-1

N: 705,499
E: 7,623,921

Approximate Ground Surface in Feet: 30.0

Description	Depth in Feet	Samples	Lab Test
Loose to medium dense, dry to moist, dark brown to gray, silty SAND with gravel and chunks of brick, basalt, gravel, and lampblack. (SM)	0	S-1	- AL, GS, SPEC. GRAV.
		S-2	
		S-3	- Reactivity
	5	S-4	
		S-5	- AL, GS
		S-6	
	10	S-7	
	15	S-8	
	ATD		
	20	S-9	- AL, GS, SPEC. GRAV.
Loose, black, poorly graded SAND. (SP)			
- 24.4' Lampblack and rubbery tar-like material.	25	S-10	
Medium stiff, moist, dark gray, sandy SILT.	30	S-11	- Reactivity
Very loose to medium dense, moist to wet, dark gray to black, poorly graded SAND with intermittent thin (0.1 to 0.2 ft) silt layers and some chunks of riprap. (SP)	35	S-12	
	40	S-13	
	45	S-14	- AL, GS
	50	S-15	
	55	S-16	
Medium stiff, moist, dark gray, sandy SILT. (ML)	60	S-17	- AL, GS, SPEC. GRAV.
		ST 1-1	
Medium dense, moist, dark gray, silty SAND. (SM)	65		

▲ STANDARD PENETRATION RESISTANCE (blows per foot)

1 2 5 10 20 50 100

● Water Content (percent)

9/10/2008 cvd K:\Jobs\0002902\BORING LOGS\CorelDRAW logs\B-1.cdr

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive, and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling or at the time and date (SP)ecified. Ground water level may vary with time.

ANCHOR ENVIRONMENTAL, L.L.C.

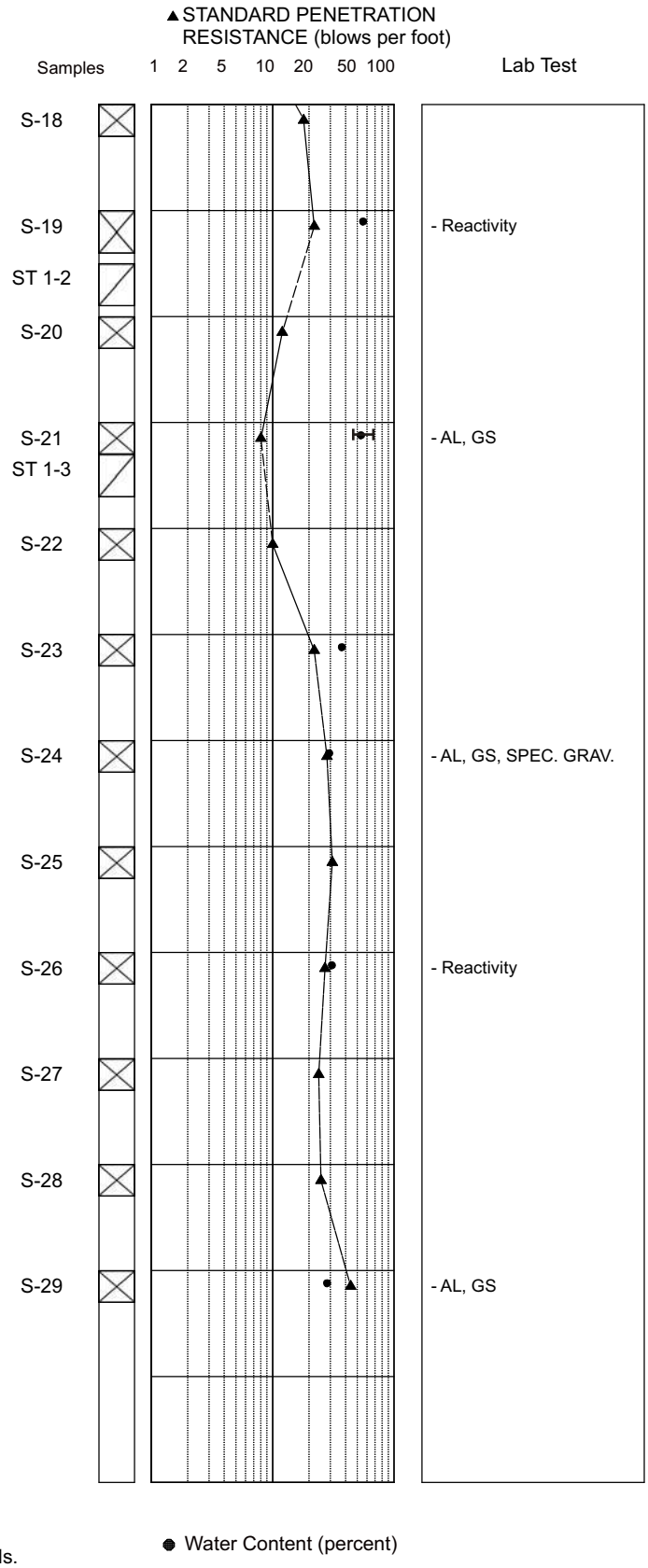
Figure A-2
Boring B-1
Gasco, Portland, Oregon

Boring: B-1

N: 705,499
E: 7,623,921

Approximate Ground Surface in Feet: 30.0

Description	Depth in Feet
Medium dense, moist, dark gray, silty SAND. (SM)	65
Very stiff, moist, dark gray SILT with sand. (MH)	70
Medium dense, moist, dark gray, silty SAND. (SM)	75
Soft to stiff, moist, dark gray, elastic SILT with sand. (MH)	80
Loose, wet, dark gray, silty SAND. (SM)	85
Stiff to very stiff, moist, dark gray SILT with inter(SP)ersed sand layers. (ML)	90
Medium dense to dense, wet, dark gray, poorly graded SAND with silt and chunks of wood. (SP)	95
	100
	105
	110
	115
	120
Bottom of Boring at 121.5 feet. Completed 2/29/08.	125
	130



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1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive, and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling or at the time and date (SP)ecified. Ground water level may vary with time.

ANCHOR ENVIRONMENTAL, L.L.C.

Figure A-2
Boring B-1
Gasco, Portland, Oregon

Boring: B-2

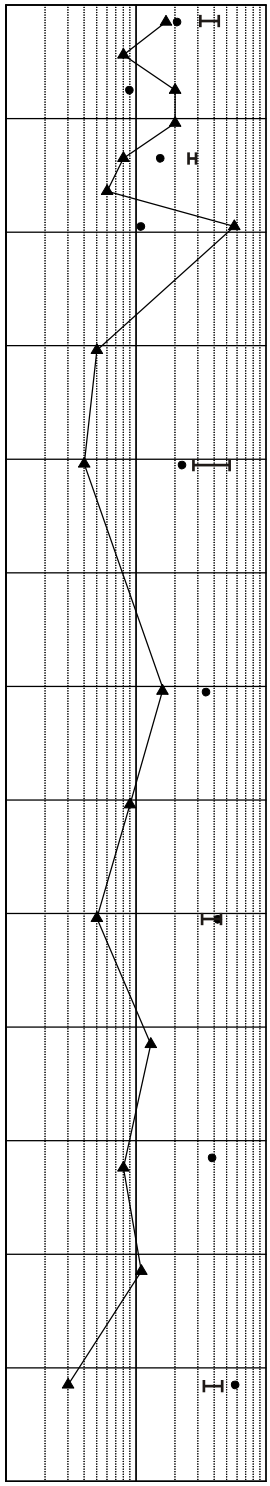
N: 705,402
E: 7,624,068

Approximate Ground Surface in Feet: 31.1

Description	Depth in Feet
Loose to very dense, dry to moist, dark brown to orange/red and gray with black staining, silty GRAVEL with sand and chunks of concrete. (GM)	0 – 30
- Lampblack	30
Loose, oily, dark gray with black staining, poorly graded SAND. (SP)	30 – 35
Medium stiff to stiff, moist, dark gray with black staining SILT wtih sand. (ML) - 1.5-foot thick poorly graded sand layer at 38 feet.	35 – 45
Loose to medium dense, wet, dark gray, poorly graded SAND with some silt. (SP) (1 - 2") thin intermittent sandy silt lenses.	45 – 60
Soft, moist, dark gray SILT with sand. ML	60 – 65
Medium dense, wet dark gray, poorly graded	65

ATD (15)

Samples	Lab Test
S-1	- AL, GS, SPEC. GRAV.
S-2	
S-3	- Reactivity
S-4	
S-5	- AL, GS
S-6	
S-7	
S-8	
S-9	- AL, GS, SPEC. GRAV.
S-10	
S-11	- Reactivity
S-12	
S-13	- AL, GS
S-14	
S-15	
S-16	
S-17	- AL, GS, SPEC. GRAV.



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1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive, and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling or at the time and date (SP)ecified. Ground water level may vary with time.

ANCHOR ENVIRONMENTAL, L.L.C.

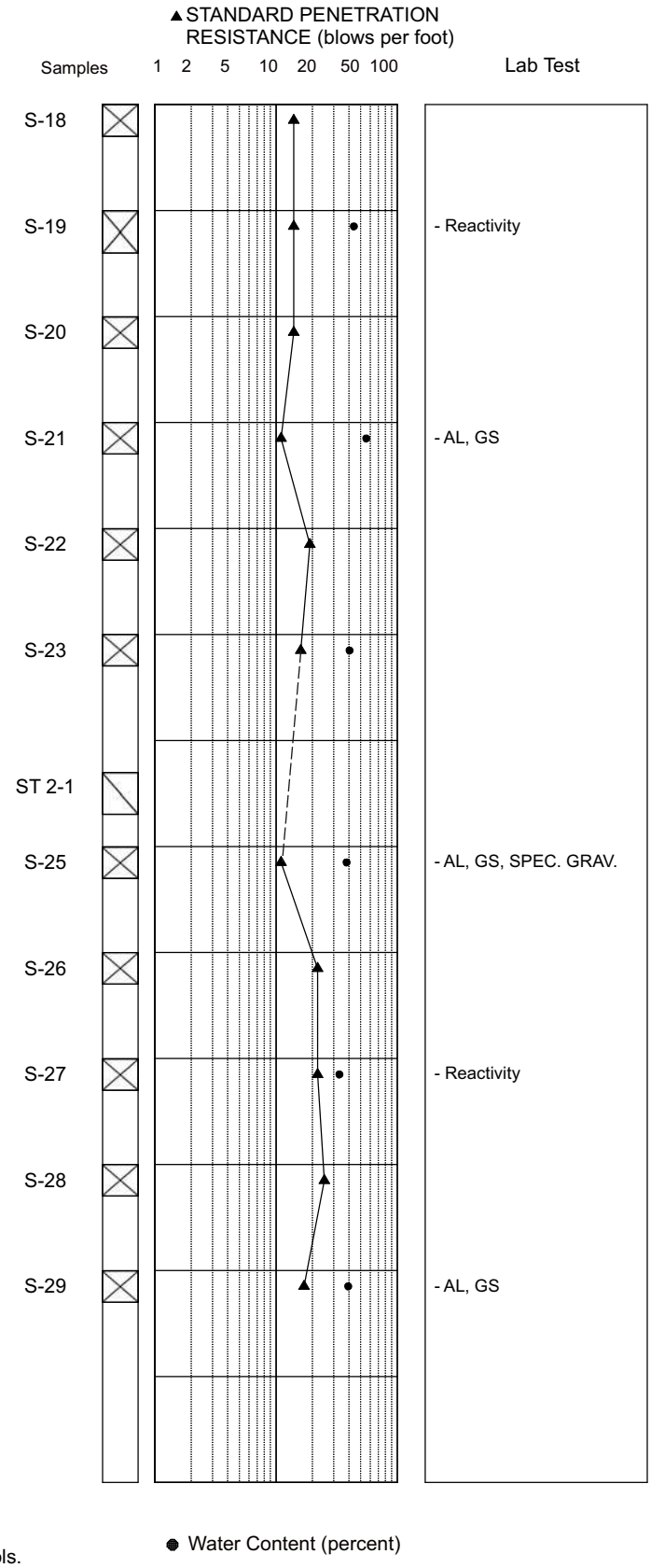
Figure A-3
Boring B-2
Gasco, Portland, Oregon

Boring: B-2

N: 705,402
E: 7,624,068

Approximate Ground Surface in Feet: 31.1

Description	Depth in Feet
Medium dense, wet dark gray, poorly graded SAND with some plant and organic matter. (SP)	65
Stiff, moist, dark gray SILT with sand. (ML)	70
Medium dense, wet, dark gray, poorly graded SAND with some thin silt layers. (SP)	75, 80, 85, 90, 95, 100, 105, 110, 115, 120, 125
Bottom of Boring at 121.5 feet. Completed 2/25/08.	130



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive, and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling or at the time and date (SP)ecified. Ground water level may vary with time.

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ANCHOR ENVIRONMENTAL, L.L.C.

Figure A-3
Boring B-2
Gasco, Portland, Oregon

Boring: B-3

N: 705,355
E: 7,624,255

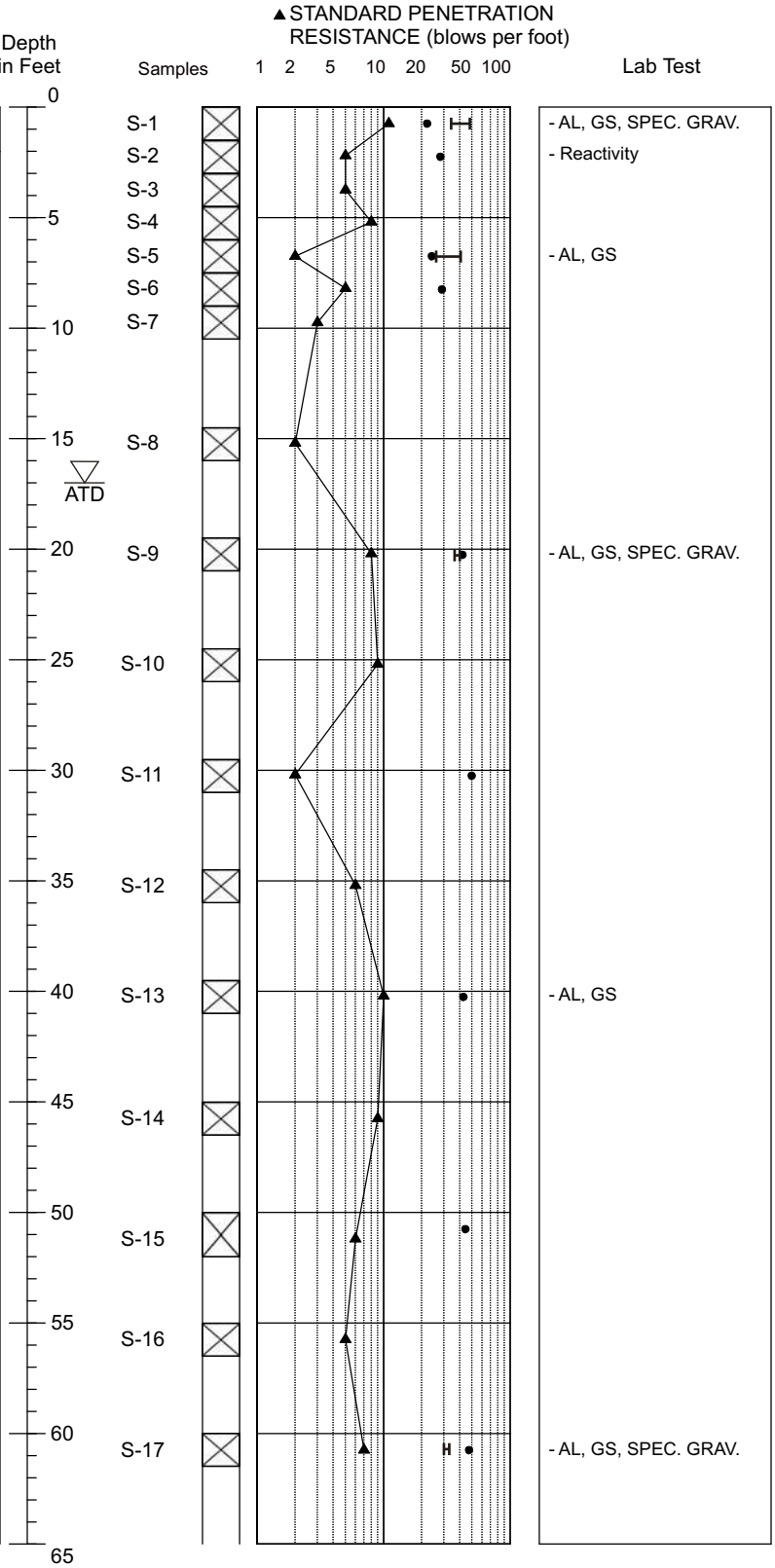
Approximate Ground Surface in Feet: 25.7

Medium dense, dry, dark brown, silty GRAVEL with sand. (GM)

Very soft to stiff, dry to wet, orange/red grading to tan, sandy SILT with some gravel. (ML)

- Inter(SP)ersed thin, poorly graded sand layers (1 - 2").

Loose to medium dense, wet, dark gray, silty SAND inter(SP)ersed with thin silt layers (1 - 2"). (SM)



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1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive, and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling or at the time and date SPECified. Ground water level may vary with time.

ANCHOR ENVIRONMENTAL, L.L.C.

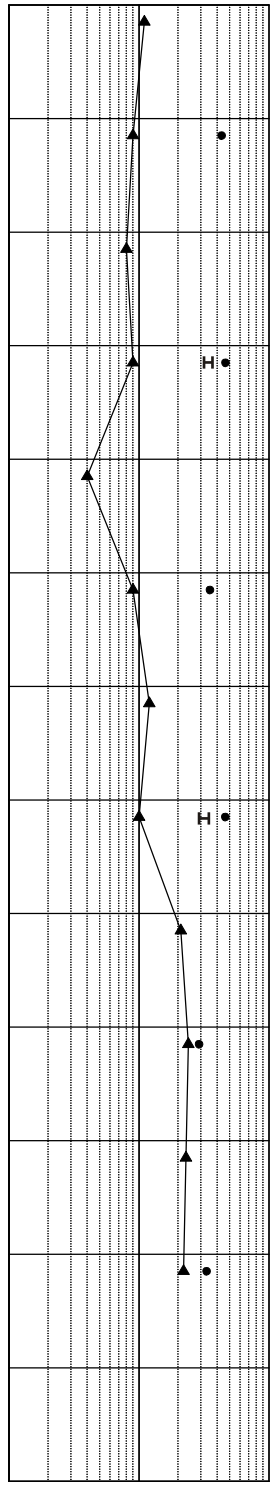
Figure A-4
Boring B-3
Gasco, Portland, Oregon

Boring: B-3

N: 705,355
E: 7,624,255

Approximate Ground Surface in Feet: 25.7

Description	Depth in Feet	Samples	Lab Test
Loose to medium dense, wet, dark gray, silty SAND inter(SP)ersed with thin silt layers (1 - 2"). (SM)	65	S-18	
	70	S-19	
Stiff to medium stiff, wet, dark gray SILT with sand. (ML). Intermittent thins sandy layers (1").	75	S-20	
	80	S-21	- AL, GS
-Micaceous	85	S-22	
Loose, wet, dark gray, poorly graded SAND with silt. (SP)	90	S-23	
- Alternating sand and silt layers (2 - 4").	95	S-24	
Stiff, wet, dark gray, sandy SILT. (ML)	100	S-25	- AL, GS, SPEC. GRAV.
-Loose sand, stiff silt.			
Medium dense, wet, dark gray, poorly graded SAND with silt. (SP-SM)	105	S-26	
	110	S-27	- Reactivity
	115	S-28	
	120	S-29	- AL, GS
Bottom of Boring at 121.5 feet. Completed 2/20/08.	125		
	130		



● Water Content (percent)

9/10/2008 cvd K:\Jobs\00002902\BORING LOGS\CorelDRAW logs\B-3.cdr

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive, and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling or at the time and date SPECified. Ground water level may vary with time.

ANCHOR ENVIRONMENTAL, L.L.C.

Figure A-4
Boring B-3
Gasco, Portland, Oregon

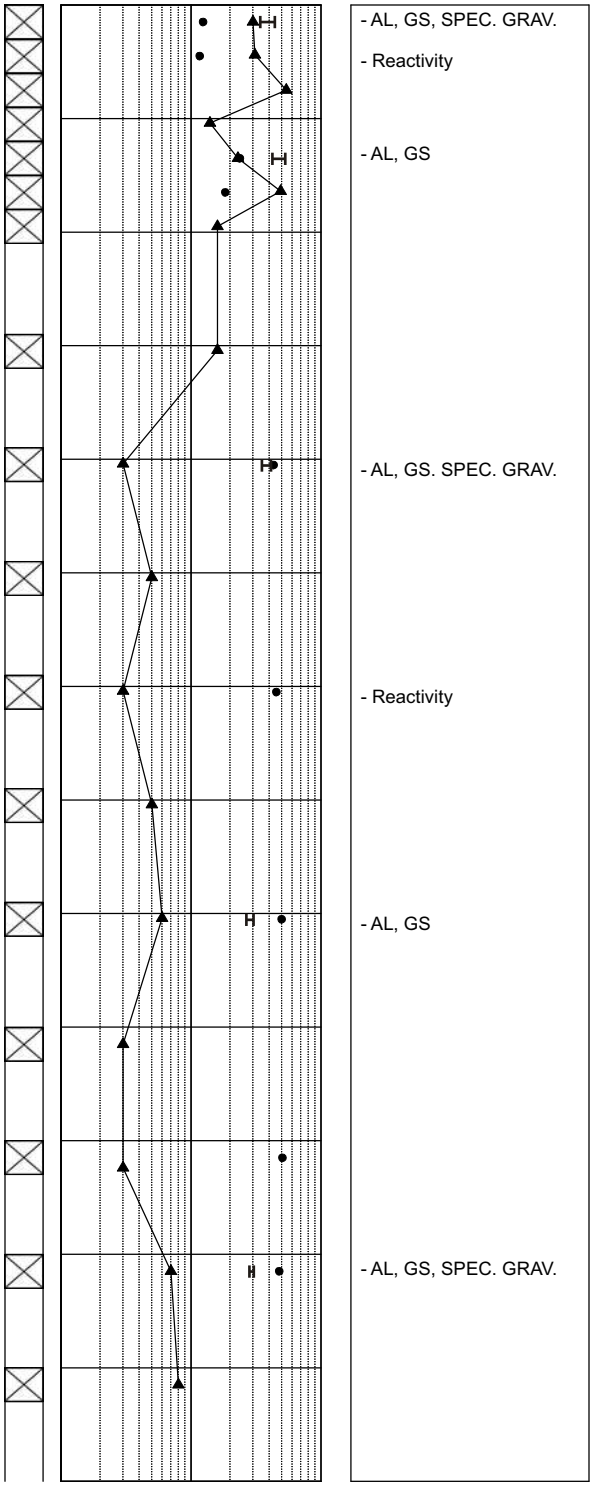
Boring: B-4/B-4B

N: 705,234
E: 7,624,418

Approximate Ground Surface in Feet: 23.7

Description	Depth in Feet
Medium dense to very dense, dry to damp, dark brown to gray, poorly graded GRAVEL with silt and sand. (GP-GM)	0 – 15
Soft to medium stiff, moist to wet, dark gray SILT with sand and intermittent sandy layers (1 - 2"). (ML)	15 – 40
Very loose to loose, wet, dark gray, silty SAND with gravel. S(M)	40 – 50
Soft, wet, dark gray SILT with sand. (ML)	50 – 55
Loose, wet, dark gray, silty SAND with interspersed silt lenses. (SM)	55 – 65

ATD



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive, and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling or at the time and date specified. Ground water level may vary with time.

9/10/2008 cvd K:\Jobs\0002902\BORING LOGS\CorelDRAW logs\B-4.cdr

ANCHOR ENVIRONMENTAL, L.L.C.

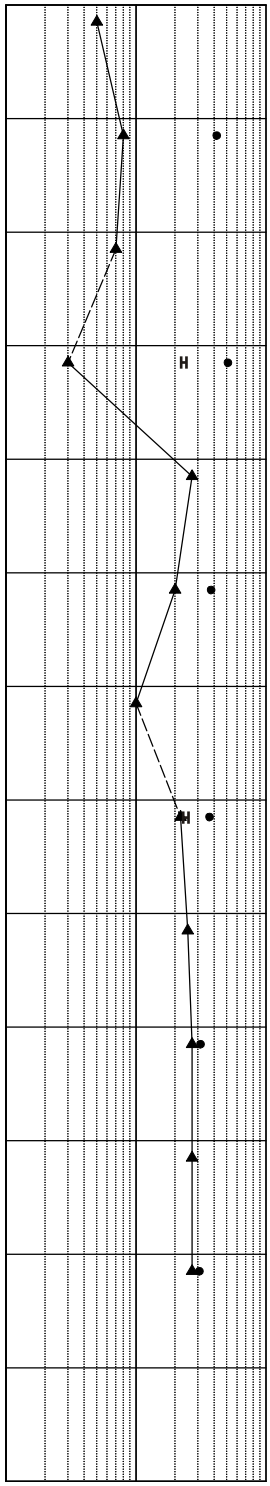
Figure A-5
Boring B-4/4B
Gasco, Portland, Oregon

Boring: B-4/B-4B

N: 705,234
E: 7,624,418

Approximate Ground Surface in Feet: 23.7

Description	Depth in Feet	Samples	Lab Test
Loose, wet, dark gray, silty SAND with interspersed silt lenses. (SM)	65	S-18	
	70	S-19	- Reactivity
Soft to medium stiff, wet, dark gray, sandy SILT with some sandy layers. (ML)	75	S-20, ST 4-1	
	80	S-21	- AL, GS
Medium dense, wet, dark gray, poorly graded SAND with silt. (SP-SM)	85	S-22	
- Thin silt layers (1 - 2").	90	S-23	
	95	S-24, ST 4-2	
- Trace wood debris.	100	S-25	- AL, GS, SPEC. GRAV.
	105	S-26	
	110	S-27	- Reactivity
	115	S-28	
	120	S-29	- AL, GS
Bottom of Boring at 121.5 feet. Completed 2/21/08.	125		
	130		



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1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive, and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling or at the time and date specified. Ground water level may vary with time.

ANCHOR ENVIRONMENTAL, L.L.C.

Figure A-5
Boring B-4/4B
Gasco, Portland, Oregon

Boring: B-5

N: 705,450
E: 7,623,997

Approximate Ground Surface in Feet: 31.3

Description	Depth in Feet	Samples	Lab Test
Loose to medium dense, moist, dark gray to dark brown, silty SAND with gravel and chunks of concrete and brick. (SM)	0	S-1	- AL,GS, SPEC. GRAV.
		S-2	
		S-3	- Reactivity
	5	S-4	
		S-5	- AL, GS
		S-6	
	10	S-7	
	15	S-8	
	ATD		
Dense, moist, dark brown silty SAND with gravel. (SM)	20	S-9	- AL, GS, SPEC. GRAV.
Stiff, moist, dark gray, gravelly SILT. (ML)	25	S-10	
Loose to medium dense, wet,(saturated with oil), dark gray, silty SAND. (SM) Thin layers of silt throughout.	30	S-11	- Reactivity
	35	S-12	
	40	S-13	- AL, GS
Bottom of Boring at 41.0 feet. Completed 2/26/08.	45		

▲ STANDARD PENETRATION RESISTANCE (blows per foot)

1 2 5 10 20 50 100

● Water Content (percent)

9/10/2008 cvd K:\Jobs\00002902\BORING LOGS\CorelDRAW logs\B-5.cdr

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive, and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling or at the time and date specified. Ground water level may vary with time.

ANCHOR ENVIRONMENTAL, L.L.C.

Figure A-6
Boring B-5
Gasco, Portland, Oregon

Boring: B-6

N: 705,354
E: 7,624,155

Approximate Ground Surface in Feet: 31.1

Depth in Feet	Samples	Description	Lab Test
0	S-1	Loose to very dense, dry, orangish red, silty SAND with gravel. (SM)	- AL, GS, SPEC. GRAV.
	S-2		
	S-3	- Yellow orange and brown mottling.	- Reactivity
5	S-4		
	S-5		
	S-6		- AL, GS
10	S-7	Medium stiff, dry to moist, orange-red to yellowish ornage, sandy SILT with gray, black, gray-tan and yellow mottling. (ML)	
15	S-8		
ATD			
20	S-9		- AL, GS, SPEC. GRAV.
		Loose to medium stiff, moist to wet, dark gray SILT with sand and orange-red mottling. (ML)	
25	S-10	- Lampblack layer.	
30	S-11		- Reactivity
		Loose, damp dark gray, silty SAND. (SM)	
35	S-12		
		Very loose, wet, dark gray, poorly graded SAND with interspersed silt layers. (SP)	
40	S-13		- AL, GS
		Bottom of Boring at 41.0 feet. Comleted 2/18/08.	
45			

▲ STANDARD PENETRATION RESISTANCE (blows per foot)

1 2 5 10 20 50 100

● Water Content (percent)

9/10/2008 cvd K:\Jobs\00002902\BORING LOGS\CorelDRAW logs\B-6.cdr

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive, and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling or at the time and date specified. Ground water level may vary with time.

ANCHOR ENVIRONMENTAL, L.L.C.

Figure A-7
Boring B-6
Gasco, Portland, Oregon

Boring: B-7

N: 705,297
E: 7,624,323

Approximate Ground Surface in Feet: 24.3

Depth in Feet	Samples	Description	Lab Test
0	S-1	Loose to very dense, moist, dark brown, silty GRAVEL with sand. (GM)	
	S-2	- Red, tan, and white mottling.	- AL, GS, SPEC. GRAV.
	S-3		- Reactivity
5	S-4		
	S-5		- AL, GS
	S-6		
10	S-7	Soft, moist, dark reddish brown, sandy, gravelly SILT. (ML)	
15	S-8	Loose damp, dark gray, silty SAND. (SM)	
		- Lampblack, wet, fissile.	
		ATD	
20	S-9	Soft, moist, dark gray, sandy SILT. (ML)	- AL, GS, SPEC. GRAV.
25	S-10		
		Loose, wet, dark gray, poorly graded, silty SAND. (SP)	
30	S-11	Soft, moist, dark gray, sandy SILT. (ML)	- Reactivity
		Loose, wet, dark gray, silty SAND. (SM)	
35	S-12		
40	S-13		- AL, GS
		Bottom of Boring at 41.0 feet. Completed 2/18/08.	
45			

▲ STANDARD PENETRATION RESISTANCE (blows per foot)

1 2 5 10 20 50 100

● Water Content (percent)

9/10/2008 cvd K:\Jobs\00002902\BORING LOGS\CorelDRAW logs\B-7.cdr

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive, and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling or at the time and date specified. Ground water level may vary with time.

ANCHOR ENVIRONMENTAL, L.L.C.

Figure A-8
Boring B-7
Gasco, Portland, Oregon

Table 1
Laboratory Results of Geotechnical Analyses

Sample ID	Date Sampled	Time	Top Sample Depth (ft)	Bottom Sample Depth (ft)	Average Sample Depth (ft)	Moisture Content [a] (%)	SPT N-value	Atterberg Limits [b]			Grain Size [c]									Atterberg Limits
								Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Gravel (%)	Sand (%)			Silt (%)	Clay (%)	Sand (%)	Gravel/ Sand (%)	Silt/Clay (%)	
												Coarse	Medium	Fine						
B7-S2	2/18/08	0940	1.5	3.0	2.3	7.13	48	26.1	21.6	4.5	52.9	9.3	14.6	10.8	8.9	3.6	34.6	87.5	12.5	ML
B7-S3	2/18/08	0950	3.0	4.5	3.8	11.39	18													
B7-S5	2/18/08	1005	6.0	7.5	6.8	15.29	19	31.7	24.0	7.7	40.8	8.7	15.1	15.6	14.6	5.2	39.4	80.2	19.8	ML
B7-S7	2/18/08	1020	9.0	10.5	9.8	18.09	4													
B7-S9	2/18/08	1040	19.5	21.0	20.3	41.01		37.3	30.2	7.1	0.0	0.2	4.5	42.5	46.8	6.0	47.2	47.2	52.8	ML
B7-S11	2/18/08	1100	29.5	31.0	30.3	45.00	4													
B7-S13	2/18/08	1115	39.5	41.0	40.3	29.27	8	NA	NA	NA	0.0	0.1	0.2	81.8	14.4	3.5	82.1	82.1	17.9	Non-PL
B6-S1	2/18/08	1415	0.0	1.5	0.8	21.94	42	43.1	36.1	7.0	12.9	11.0	28.1	23.2	20.2	4.6	62.3	75.3	24.8	ML
B6-S3	2/18/08	1430	3.0	4.5	3.8	24.01	64													
B6-S6	2/18/08	1445	7.5	9.0	8.3	23.89	10	51.8	29.4	22.4	32.0	10.6	16.5	12.3	20.8	7.9	39.4	71.4	28.6	MH
B6-S7	2/18/08	1450	9	10.5	9.8	28.98	6													
B6-S9	2/18/08	1500	19.5	21.0	20.3	31.36	5	41.5	28.5	13.0	10.3	5.9	8.9	11.1	45.2	18.6	25.9	36.2	63.8	ML
B6-S11	2/18/08	1515	29.5	31.0	30.3	44.80	3													
B6-S13	2/18/08	1540	39.5	41	40.3	42.74	3	NA	NA	NA	0.0	0.2	0.3	68.3	24.4	6.8	68.8	68.8	31.2	Non-PL
B3-S1	2/18/08	1655	0.0	1.5	0.8	22.05	11	49.2	35.5	13.7	36.3	10.0	12.2	9.6	22.6	9.3	31.7	68.1	31.9	ML
B3-S2	2/18/08	1700	1.5	3.0	2.3	28.09	5													
B3-S5	2/18/08	1715	6.0	7.5	6.8	24.03	2	40.5	26.4	14.1	12.9	8.1	8.9	10.1	41.4	18.7	27.1	40.0	60.0	ML
B3-S6	2/18/08	1720	7.5	9.0	8.3	28.91	5													
B3-S9	2/18/08	1740	19.5	21.0	20.3	42.01	8	40.0	37.5	2.5	2.0	1.6	11.1	33.6	47.6	4.0	46.3	48.4	51.6	ML
B2-S1	2/22/08	1140	0.0	1.5	0.8	20.66	17	42.7	31.6	11.2	31.1	5.2	10.7	12.5	27.4	13.1	28.4	59.5	40.5	ML
B2-S3	2/22/08	1200	3.0	4.5	3.8	8.89	20													
B2-S5	2/22/08	1215	6.0	7.5	6.8	15.35	8	29.7	26.7	3.0	35.9	4.6	10.9	18.4	22.9	7.3	33.9	69.8	30.2	ML
B2-S7	2/22/08	1235	9.0	10.5	9.8	10.91	56													
B2-S9	2/22/08	1310	19.5	21.0	20.3	22.58	4	52.0	38.0	14.1	58.4	3.9	7.3	7.5	17.7	5.2	18.7	77.1	22.9	MH
B2-S11	2/22/08	1335	29.5	31.0	30.3	34.59	16													
B2-S13	2/22/08	1400	39.5	41.0	40.3	42.60	5	44.4	32.3	12.1	0.0	0.0	0.2	25.8	61.1	12.9	26.0	26.0	74.0	ML
B2-S15	2/22/08	1505	50.0	51.5	50.8	38.48	8													
B2-S17	2/22/08	1540	60.0	61.5	60.8	57.80	3	46.0	34.0	12.0	0.0	0.0	0.2	11.7	70.9	17.2	11.9	11.9	88.1	ML
B2-S19	2/22/08	1620	70.0	71.5	70.8	43.89	14													
B2-S21	2/22/08	1710	80.0	81.5	80.8	55.42	11	NA	NA	NA	0.0	0.1	1.9	67.1	23.9	7.0	69.1	69.1	30.9	Non-PL
B2-S23	2/25/08	0840	90.0	91.5	90.8	40.33	16													
B2-S25	2/25/08	1230	100.0	101.5	100.8	38.15	11	NA	NA	NA	0.0	0.0	12.6	68.3	15.1	4.0	80.9	80.9	19.1	Non-PL
B2-S27	2/25/08	1325	110.0	111.5	110.8	33.34	22													
B2-S29	2/25/08	1440	120.0	121.5	120.8	39.39	15	NA	NA	NA	0.0	0.0	15.3	62.4	17.1	5.3	77.6	77.6	22.4	Non-PL
B5-S1	2/25/08	1705	0.0	1.5	0.8	16.33	26	34.3	25.4	8.9	23.4	6.2	11.5	17.2	30.2	11.6	34.9	58.3	41.8	ML
B5-S3	2/25/08	1715	3.0	4.5	3.8	15.10	17													
B5-S5	2/25/08	1730	6.0	7.5	6.8	14.20	16	31.2	26.2	4.9	32.2	5.8	13.4	20.8	21.5	6.4	39.9	72.1	27.9	ML
B5-S7	2/25/08	1745	9.0	10.5	9.8	11.92	25													
B3-S11	2/19/08	1035	29.5	31.0	30.3	49.61	2													
B3-S13	2/19/08	1100	39.5	41.0	40.3	42.68	10	NA	NA	NA	0.0	0.2	0.4	78.9	16.1	4.5	79.4	79.5	20.5	Non-PL
B3-S15	2/19/08	1230	50.0	51.5	50.8	44.39	6													

Table 1
Laboratory Results of Geotechnical Analyses

Sample ID	Date Sampled	Time	Top Sample Depth (ft)	Bottom Sample Depth (ft)	Average Sample Depth (ft)	Moisture Content [a] (%)	SPT N-value	Atterberg Limits [b]			Grain Size [c]									Atterberg Limits
								Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Gravel (%)	Sand (%)			Silt (%)	Clay (%)	Sand (%)	Gravel/ Sand (%)	Silt/Clay (%)	
												Coarse	Medium	Fine						
B3-S17	2/19/08	1425	60.0	61.5	60.8	47.37	7	32.5	30.4	2.1	0.0	0.0	0.2	55.5	35.0	9.3	55.7	55.7	44.3	ML
B3-S19	2/19/08	1450	70.0	71.5	70.8	43.18	9													
B3-S21	2/19/08	1540	80.0	81.5	80.8	46.25	9	36.0	31.7	4.4	0.0	0.0	0.3	22.7	62.6	14.5	22.9	22.9	77.1	ML
B3-S23	2/19/08	1630	90.0	91.5	90.8	35.13	9													
B3-S25	2/20/08	0855	100.0	101.5	100.8	46.13	10	35.4	29.5	6.0	0.0	0.0	4.4	34.5	48.1	13.0	38.9	38.9	61.2	ML
B3-S27	2/20/08	0945	110.0	111.5	110.8	28.99	24													
B3-S29	2/20/08	1040	120.0	121.5	120.8	33.12	22	NA	NA	NA	0.0	0.0	12.0	78.9	6.9	2.2	90.9	90.9	9.1	Non-PL
B4-S1	2/20/08	1605	0.0	1.5	0.8	12.38	30	44.9	35.1	9.8	46.2	17.6	16.3	5.3	10.7	3.9	39.2	85.4	14.6	ML
B4-S2	2/20/08	1615	1.5	3.0	2.3	11.68	31													
B4-S5	2/20/08	1635	6.0	7.5	6.8	23.80	23	53.4	42.8	10.6	69.4	7.7	10.3	5.5	5.2	1.9	23.5	92.9	7.1	MH
B4-S6	2/20/08	1645	7.5	9.0	8.3	18.35	49													
B4-S9	2/20/08	1710	19.5	21.0	20.3	43.24	3	40.9	35.9	5.0	0.4	0.0	0.1	29.5	56.7	13.4	29.6	29.9	70.1	ML
B4-S11	2/20/08	1730	29.5	31.0	30.3	45.40	3													
B4-S13	2/21/08	0830	39.5	41.0	40.3	49.81	6	30.7	27.4	3.4	18.2	0.2	0.5	39.1	34.1	7.8	39.8	58.1	41.9	ML
B4B-S15	2/21/08	1300	50.0	51.5	50.8	50.46	3													
B4B-S16	2/21/08	1310	55.0	56.5	55.8	47.79	7	30.4	28.7	1.7	0.0	0.0	0.3	54.4	37.0	8.3	54.8	54.8	45.3	ML
B4B-S19	2/21/08	1400	70.0	71.5	70.8	41.72	8													
B4b-S21	2/21/08	1445	80.0	81.5	80.8	51.01	3	36.7	31.7	5.0	0.0	0.0	0.3	47.3	40.0	12.5	47.5	47.5	52.5	ML
B4B-S23	2/21/08	1530	90.0	91.5	90.8	37.87	20													
B4B-S25	2/21/08	1630	100.0	101.5	100.8	36.74	22	25.4	23.6	1.7	0.5	0.0	4.4	59.8	27.8	7.5	64.2	64.7	35.3	ML
B4B-S27	2/21/08	1706	110.0	111.5	110.8	31.36	27													
B4B-S29	2/21/08	1800	120.0	121.5	120.8	30.78	27	NA	NA	NA	0.0	0.0	26.3	61.7	8.7	3.3	88.0	88.0	12.0	Non-PL
B5-S9	2/26/08	0830	19.0	20.5	19.8	23.91	50	33.6	27.6	6.0	33.3	7.8	13.8	18.2	16.0	10.9	39.8	73.1	26.9	ML
B5-S11	2/26/08	0900	29.0	30.5	29.8	38.14	18													
B5-S13	2/26/08	0940	39.0	40.5	39.8	37.95	7	NA	NA	NA	0.1	0.0	0.3	86.2	8.0	5.4	86.5	86.6	13.4	Non-PL
B1-S1	2/26/08	1215	0.0	1.5	0.8	20.54	9	38.1	28.3	9.8	26.4	4.3	10.5	15.8	28.3	14.8	30.5	56.9	43.1	ML
B1-S3	2/26/08	1315	3.0	4.5	3.8	19.64	10													
B1-S5	2/26/08	1330	6.0	7.5	6.8	20.97	10	28.7	25.1	3.6	36.1	7.3	10.0	19.4	17.0	10.2	36.7	72.8	27.2	ML
B1-S7	2/26/08	1350	9.0	10.5	9.8	26.75	12													
B1-S9	2/26/08	1425	19.0	20.5	19.8	20.39	11	24.8	23.7	1.1	35.8	5.4	15.6	26.1	10.5	6.7	47.0	82.8	17.2	ML
B1-S11	2/26/08	1500	29.0	30.5	29.8	41.29	7													
B1-S13	2/26/08	1540	39.0	40.5	39.8	30.76	6	NA	NA	NA	1.2	0.1	0.5	88.6	6.0	3.6	89.2	90.4	9.6	Non-PL
B1-S16	2/28/08	1620	55.0	56.5	55.8	38.64	8													
B1-S17	2/28/08	1700	60.0	61.5	60.8	40.34	7	31.9	27.2	4.8	0.0	0.6	1.1	38.9	46.6	12.8	40.6	40.6	59.4	ML
B1-S19	2/29/08	0955	70.0	72.0	71.0	55.58	22													
B1-S21	2/29/08	1120	80.0	81.5	80.8	53.49	11	67.7	48.9	18.9	0.0	0.0	0.2	5.6	70.3	23.9	5.8	5.8	94.2	MH
B1-S23	2/29/08	1300	90.0	91.5	90.8	37.23	22													
B1-S24	2/29/08	1350	95.0	96.5	95.8	29.19	28	NA	NA	NA	0.0	0.0	14.8	72.3	9.8	3.1	87.2	87.2	12.9	Non-PL
B1-S26	2/29/08	1515	105.0	106.5	105.8	30.73	27													
B1-S29	2/29/08	1650	120.0	121.5	120.8	28.12	44	NA	NA	NA	0.0	0.1	19.7	68.4	9.6	2.2	88.2	88.2	11.8	Non-PL
					totals	81.0	80.0	32.0	32.0	32.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	

Table 1
Laboratory Results of Geotechnical Analyses

Sample ID	Date Sampled	Time	Top Sample Depth (ft)	Bottom Sample Depth (ft)	Average Sample Depth (ft)	Moisture Content [a] (%)	SPT N-value	Atterberg Limits [b]			Grain Size [c]									
								Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Gravel (%)	Sand (%)			Silt (%)	Clay (%)	Sand (%)	Gravel/ Sand (%)	Silt/Clay (%)	Atterberg Limits
												Coarse	Medium	Fine						
					max	57.8	64.0	67.7	48.9	22.4	69.4	17.6	28.1	88.6	70.9	23.9	90.9	92.9	94.2	
					average	32.5	15.7	38.5	30.7	7.9	14.7	3.2	8.3	37.3	27.9	8.5	48.9	63.7	36.3	
					min	7.1	2.0	24.8	21.6	1.1	0.0	0.0	0.1	5.3	5.2	1.9	5.8	5.8	7.1	

Table 1
Laboratory Results of Geotechnical Analyses

Sample ID	Date Sampled	Time	USCS	Organic Content[d] (%)	Permeability[f]	Specific Gravity [e]	Bulk Density (Calc'd) (pcf)	Dry Density (Calc'd) (pcf)	pH	Total Solids %	Sulfate mg/kg	Soil Resistivity Res. (ohm-cm)	Soil Resistivity Temp - C	Redox Potential mV
B7-S2	2/18/08	0940	GM- silty gravel with sand	Dense		2.53								
B7-S3	2/18/08	0950		Medium Dense					7.39	83.10	22.60	4900	20.5	69.70
B7-S5	2/18/08	1005	GM - silty gravel with sand	Medium Dense										
B7-S7	2/18/08	1020		Very Loose										
B7-S9	2/18/08	1040	Sandy Silt	Very Soft		2.29								
B7-S11	2/18/08	1100		Soft					6.84	68.50	9.80	5200	20.5	186.40
B7-S13	2/18/08	1115	SC-SM silty, clayey sand	Loose										
B6-S1	2/18/08	1415	SM- silty sand	Dense		1.81								
B6-S3	2/18/08	1430		Very Dense					6.84	77.60	24.6	3900	20.5	200.20
B6-S6	2/18/08	1445	SM- silty sand with gravel	Loose										
B6-S7	2/18/08	1450		Loose										
B6-S9	2/18/08	1500	Sandy Silt	Medium Stiff		2.73								
B6-S11	2/18/08	1515		Soft					7.92	72.70	18.8	1700	20.5	239.80
B6-S13	2/18/08	1540	SC-SM silty, clayey sand	Very Loose										
B3-S1	2/18/08	1655	GM- silty gravel with sand	Medium Dense		2.6								
B3-S2	2/18/08	1700		Loose					7.95	78.20	16.7	3800	20.5	259.90
B3-S5	2/18/08	1715	Sandy Silt	Very Soft										
B3-S6	2/18/08	1720		Medium Stiff										
B3-S9	2/18/08	1740	Sandy Silt	Medium Stiff		1.58								
B2-S1	2/22/08	1140	GM - silty gravel with sand	Medium Dense		2.66								
B2-S3	2/22/08	1200		Medium Dense					11.63	88.40	86.5	3100	19.0	13.50
B2-S5	2/22/08	1215	GM - silty gravel with sand	Loose										
B2-S7	2/22/08	1235		Very Dense										
B2-S9	2/22/08	1310	GM - silty gravel with sand	Very Loose		2.82								
B2-S11	2/22/08	1335		Medium Dense					7.45	72.30	87.2	9300	20.0	64.20
B2-S13	2/22/08	1400	ML- silt with sand	Medium Stiff										
B2-S15	2/22/08	1505		Medium Stiff										
B2-S17	2/22/08	1540	ML- silt with sand	Soft		2.63								
B2-S19	2/22/08	1620		Stiff					6.84	65.90	461.0	3500	20.0	-52.00
B2-S21	2/22/08	1710	SC-SM silty, clayey sand	Medium Dense										
B2-S23	2/25/08	0840		Medium Dense										
B2-S25	2/25/08	1230	SC-SM silty, clayey sand	Medium Dense		2.72								
B2-S27	2/25/08	1325		Medium Dense					6.67	74.90	101.0	4900	20.5	-46.00
B2-S29	2/25/08	1440	SC-SM silty, clayey sand	Medium Dense										
B5-S1	2/25/08	1705	C-SM silty, clayey sand with grav	Medium Dense		2.69								
B5-S3	2/25/08	1715		Medium Dense					7.62	84.50	1100.0	4500	20.5	133.50
B5-S5	2/25/08	1730	C- SM silty, clayey sand with grav	Medium Dense										
B5-S7	2/25/08	1745		Medium Dense										
B3-S11	2/19/08	1035		Very Soft					6.82	69.40	5.5	3900	21.0	47.00
B3-S13	2/19/08	1100	SC-SM silty, clayey sand	Loose										
B3-S15	2/19/08	1230		Loose										

Table 1
Laboratory Results of Geotechnical Analyses

Sample ID	Date Sampled	Time	USCS	Organic Content[d] (%)	Permeability[f]	Specific Gravity [e]	Bulk Density (Calc'd) (pcf)	Dry Density (Calc'd) (pcf)	pH	Total Solids %	Sulfate mg/kg	Soil Resistivity Res. (ohm-cm)	Soil Resistivity Temp - C	Redox Potential mV
B3-S17	2/19/08	1425	SM- Silty Sand	Loose		2.7								
B3-S19	2/19/08	1450		Loose					7.33	68.80	43.10	2600	21.0	-92.40
B3-S21	2/19/08	1540	ML- silt with sand	Stiff										
B3-S23	2/19/08	1630		Stiff										
B3-S25	2/20/08	0855	ML- sandy silt	Stiff		2.73								
B3-S27	2/20/08	0945		Very Stiff					7.09	77.90	27.40	6200	20.5	60.80
B3-S29	2/20/08	1040	M-poorly graded sand with silt a	Medium Dense										
B4-S1	2/20/08	1605	GM- silty gravel with sand	Medium Dense		2.64								
B4-S2	2/20/08	1615		Dense					6.77	82.20	5.70	3800	20.0	211.10
B4-S5	2/20/08	1635	Poorly graded gravel with silt a	Medium Dense										
B4-S6	2/20/08	1645		Dense										
B4-S9	2/20/08	1710	ML- silt with sand	Soft		2.74								
B4-S11	2/20/08	1730		Soft					6.96	67.80	<1.4	4200	20.0	-19.80
B4-S13	2/21/08	0830	SM- silty sand with gravel	Loose										
B4B-S15	2/21/08	1300		Very Loose										
B4B-S16	2/21/08	1310	SM- silty sand	Loose		2.73								
B4B-S19	2/21/08	1400		Loose					6.95	65.90	30.50	3600	20.0	-76.30
B4b-S21	2/21/08	1445	ML- sandy silt	Soft										
B4B-S23	2/21/08	1530		Very Stiff										
B4B-S25	2/21/08	1630	SM- silty sand	Medium Dense		2.72								
B4B-S27	2/21/08	1706		Medium Dense					6.61	74.50	34.30	6600	19.0	6.20
B4B-S29	2/21/08	1800	M-poorly graded sand with silt a	Medium Dense										
B5-S9	2/26/08	0830	SM- silty sand with gravel	Dense		2.48								
B5-S11	2/26/08	0900		Medium Dense					7.22	71.90	57.70	1800	21.5	-61.20
B5-S13	2/26/08	0940	SC- SM silty, clayey sand	Loose										
B1-S1	2/26/08	1215	SM- silty sand with gravel	Loose		2.63								
B1-S3	2/26/08	1315		Loose					8.64	83.60	84.20	1600	21.0	203.50
B1-S5	2/26/08	1330	SM- silty sand with gravel	Loose										
B1-S7	2/26/08	1350		Medium Dense										
B1-S9	2/26/08	1425	SM- silty sand with gravel	Medium Dense		2.42								
B1-S11	2/26/08	1500		Loose					7.95	69.80	41.70	3300	21.0	136.40
B1-S13	2/26/08	1540	M-poorly graded sand with silt a	Loose										
B1-S16	2/28/08	1620		Loose										
B1-S17	2/28/08	1700	ML- sandy silt	Medium Stiff		2.71								
B1-S19	2/29/08	0955		Very Stiff					7.07	65.70	42.60	2600	20.0	147.70
B1-S21	2/29/08	1120	MH- elastic silt	Stiff										
B1-S23	2/29/08	1300		Very Stiff										
B1-S24	2/29/08	1350	SC-SM silty, clayey sand	Medium Dense		2.69								
B1-S26	2/29/08	1515		Medium Dense					6.95	76.70	36.60	8000	21.0	30.20
B1-S29	2/29/08	1650	M-poorly graded sand with silt a	Dense										
						22								

Table 1
Laboratory Results of Geotechnical Analyses

Sample ID	Date Sampled	Time	USCS	Organic Content[d] (%)	Permeability[f]	Specific Gravity [e]	Bulk Density (Calc'd) (pcf)	Dry Density (Calc'd) (pcf)	pH	Total Solids %	Sulfate mg/kg	Soil Resistivity		Redox Potential mV
												Res. (ohm-cm)	Temp - C	
						2.82								
						2.65								
						1.58								

Notes:
a: Moisture Content testing conducted according to ASTM D-2216
b: Atterberg Limits testing conducted according to ASTM D-4318
c: Grain Size testing conducted according to ASTM D-422
d: Organic Content testing conducted according to ASTM D-2974
e. Specific gravity testing conducted according to ASTM D-854
f. Permeability testing conducted according to ASTM D-5084-90

Project:	GASCO	00002902	geotech boring
Location:	Willamette River		
Technician:	M Wilson		
Date:	2/18/2008		

Table 2
Shelby Tube Testing Results
Gasco Site
Portland, Oregon

Soil Boring	Depth (ft)	Hydraulic Conductivity cm/s	Moisture Content (as received), percent	Sand, percent	silt, percent	clay, percent	Visual Description of sample
B-1	61.5-63.5	4.42E-07	54.7	14.73	61.05	24.22	Silt, Coarse woody matter, strong fuel odor
B-1	72.5-74.5	9.60E-08	63.3	5.99	66.29	27.72	Clayey Silt
B-1	81.5-83.5	1.67E-07	61.0	5.54	68.21	26.25	Clayey Silt
B-4B	76.5-78.5	3.19E-07	49.1	6.49	68.09	25.42	Clayey Silt with fine sand layers - strong fuel odor
B-4B	96.5-98.5	2.68E-07	49.7	3.77	73.43	22.80	Clayey silt with fine sand lenses
B-2	96.5-98.5	6.14E-05	35.6	88.90	11.10	NA	Fine sand

APPENDIX E
WELL CONSTRUCTION AND DEVELOPMENT PLAN
GROUNDWATER SOURCE CONTROL
INTERIM DESIGN REPORT
NW NATURAL GASCO SITE

Prepared for

NW Natural

Prepared by

Anchor QEA, LLC

November 2009

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1 INTRODUCTION

This Well Construction and Development Plan has been prepared as Appendix E to the Groundwater Source Control Interim Design Report for the NW Natural Gasco Site (Site) in Portland Oregon (Figure 1 of the Interim Design Report). Extraction wells, observation wells, and piezometers will be drilled and installed as part of the scope of the Capture Test Plan. Prior to installation of each well or piezometer, a borehole will be drilled using Sonic drilling techniques. The drilling contractor will obtain Oregon Start Cards for each well or piezometer. Each location will be checked for underground and above ground utilities prior to the start of drilling. For sites where the location of underground utilities is uncertain, a NW Natural representative will pre-approve those drilling locations. The well construction and development work will be done under the direction of an Oregon Registered Geologist. During drilling activities continuous cores will be obtained from the deepest boring at each location. The cores will then be photographed and a geologic log created in the field to assist in selection of the appropriate screened interval.

2 WELL DESIGN

2.1 Extraction Well Design

The extraction wells will be constructed of 8-inch diameter steel casing with 20 feet of Johnson stainless steel wire-wrapped screen with 0.035-inch slots and a 2-foot bottom sump. The stainless steel screens will be ordered in ten foot lengths to provide flexibility in design of the extraction well screen depth at each location. Some extraction wells may be installed with two ten foot screens instead of one 20 foot screen, depending upon the geology at that location. Upon completion of drilling activities, the well screen and casing will be placed in the borehole to the desired depth. A filter pack consisting of 10 to 20 Colorado silica sand will be installed in the annulus from the total depth of the borehole to approximately 2 feet above the top of the screened interval. A filter pack seal of at least 3 feet thickness consisting of 3/8-inch bentonite chips will then be installed in the annulus on top of the filter pack. A bentonite grout annular seal mixed to a weight of at least 9.5 pounds per gallon will be pumped in the remaining annulus via tremie pipe from the top of the bentonite seal until grout returns are observed at the surface, ensuring a complete grout column. If NAPL is present, an organoclay mix will be used instead of the bentonite grout seal and a NAPL funnel will installed at the base of the screen. A well monument and concrete surface seal will then be installed at the ground surface.

2.2 Observation Well Design

Groundwater level data at each extraction well will be necessary to evaluate drawdown and capture of groundwater at the Site; however, well loss effects inside of the pumping well will cause the water level inside the well casing to be lower than the groundwater level in the aquifer adjacent to the well. To obtain accurate groundwater levels, observation wells will be installed in the Alluvium water bearing zone (WBZ) adjacent to each extraction well. The alluvium observation wells will be screened at approximately the same elevation as the extraction wells. The observation wells will be constructed of 4-inch diameter PVC casing with Johnson stainless steel wire-wrapped screen with 0.035-inch slots, the same slot size planned for the extraction wells. The bottom sump length, filter sand pack material, filter pack seal material, and annular seal material for the observation wells will also be the same as the extraction wells. A Surficial fill WBZ observation well will also be installed adjacent to each pumping well. Construction of the surficial fill observation wells will follow the design of the monitoring wells described below.

2.3 Monitoring Well Design

Monitoring wells will be installed between extraction wells to monitor water level drawdown effects at various depths in the Alluvium WBZ due to pumping. The monitoring wells will be constructed of 2-inch diameter PVC casing with Johnson stainless steel wire-wrapped screen with 0.020-inch slots and a 1-foot bottom sump. Upon completion of drilling activities, the well screen and casing will be placed in the borehole to the desired depth. A filter pack consisting of 10 to 20 Colorado silica sand will be installed in the annulus from the total depth of the borehole to approximately 2 feet above the top of the screened interval. A filter pack seal of at least 3 feet thickness consisting of 3/8-inch bentonite chips will then be installed in the annulus on top of the filter pack. A bentonite grout annular seal mixed to a weight of at least 9.5 pounds per gallon will be pumped in the remaining annulus via tremie pipe from the top of the bentonite seal until grout returns are observed at the surface, ensuring a complete grout column. A well monument and concrete surface seal will then be installed at the ground surface.

2.4 Piezometer Design

Piezometers will be installed in the river sediments at locations along the existing FAMM dock and on the shoreline down-gradient of some the extraction wells. The purpose of the piezometers will be to measure ground water levels in the river sediments during testing of the shoreline extraction wells and during full scale operation of the system. The piezometers along the dock structure will be drilled using sonic techniques and installed from a barge. The piezometers at the base of the riprap slope will be drilled with a track mounted sonic drill rig. The piezometers will consist of 2-inch diameter PVC casing with 5-feet of 0.020-inch slotted screen with a pre-packed sand filter pack and a one-half foot sump. Granular bentonite or bentonite grout will then be added to the annulus to provide a filter pack seal from the top of screen to mudline. The piezometers to be installed adjacent to the FAMM dock will be attached to the dock structure for stability and access. The piezometers installed on the shoreline will be completed with locking above ground pipe casings, surrounded by protective casing monuments.

3 WELL DEVELOPMENT

Following installation, the wells and piezometers will be developed to clean the wells of drilling materials and remove fine materials from the annular sand pack, thereby developing the sand pack and increasing communication with the aquifer.

Monitoring wells and piezometers will be surged for at least 10 minutes with a device equipped with a surge-block in order to move water in and out of the well screen to loosen and flush out sediment from the well screen and from the filter sand pack. The well will then be pumped until at least 10 casing volumes of water have been removed, water quality parameters (pH, specific conductivity, and temperature) have stabilized to +/-10% of the previous reading, and sediment is removed from the well.

Extraction wells will undergo a more rigorous development process to obtain the best practical condition of the annular sand pack. The development of the extraction wells will be completed by the driller while the rig is still in location on the borehole. The drilling contractor will select the development method, but the well screens will be surged and pumped until the water is clear and colorless. In some instances, clear and colorless conditions will not be possible. If this is the case, development will continue until turbidity stabilizes at the best practical condition and field water quality parameters are stable. This may take up to 24 hours of development activities per extraction well.

4 EQUIPMENT DECONTAMINATION AND INVESTIGATION DERIVED WASTE PROTOCOLS

Between borehole locations all drilling and downhole sampling equipment will be decontaminated at a prepared location onsite. The drilling equipment will be decontaminated by steam-cleaning or a hot water pressure wash.

Residual soils, groundwater, and decontamination fluids (commonly referred to as investigation-derived waste [IDW]) will be handled as specified in this section. Generally, material generated during this scope of work will be contained, identified, and characterized. Holding containers will be labeled with their contents, the date of collection, and the origin of the material. The holding containers will be secured and stored in a designated IDW storage area on the site until it has been characterized.

After the work is complete and analytical results are received, residual soils and liquids will be evaluated for disposal method consistent with DEQ regulations.

4.1 Soil Cuttings

Soil cuttings originating from the soil borings will be contained in 55-gallon drums or lined drop boxes, which will be stored in the designated IDW storage area. Each storage container will be labeled to include the source of the soil.

4.2 Groundwater

Water generated during well development and sampling will be contained in 55-gallon drums or temporarily transferred to the onsite liquid holding container. The liquids will be treated using the onsite carbon filtration system and discharged to the POTW under the existing industrial wastewater discharge permit. The only exception to this would be if the water contains chlorinated solvents from the Siltronic site. In that case the groundwater may not be treated in the onsite carbon unit, but other treatment/disposal options will be evaluated for approval with DEQ. We will keep groundwater from the Siltronic site in separate containers from the groundwater sourced on the Gasco site.

4.3 Decontamination Water

Water generated by equipment decontamination will be properly contained during decontamination activities. Decontamination water will be transferred to the liquid storage containers and treated/disposed as described in the previous section for groundwater.

APPENDIX F
SAMPLING AND ANALYSIS PLAN
GROUNDWATER SOURCE CONTROL
INTERIM DESIGN REPORT
NW NATURAL GASCO SITE

Prepared for

NW Natural

Prepared by

Anchor QEA, LLC

November 2009

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1 INTRODUTION

This Sampling and Analysis Plan (SAP) has been prepared as Appendix F to the Groundwater Source Control Interim Design Report for the NW Natural Gasco Site (Site) in Portland Oregon. This SAP covers monitoring of groundwater elevation and chemistry in select monitoring wells to aid in evaluation of the proposed source control measures for Segments 1 and 2 at the Site.

2 HYDROLOGY MONITORING

2.1 Manual Water Level Monitoring

Following the procedures described herein, manual water level measurements will be made in selected monitoring wells, pumping wells, observation wells, and piezometers before and after the water level transducers are in place. The manual measurements will be used as reference points for the data generated by the transducer equipment. Measurements will be taken with an electronic water level indicator. Levels will be measured to the nearest 0.01 foot from a surveyed notch or mark at the top of the polyvinyl chloride (PVC) casing or other reference point. Measurements will be recorded immediately on a water level record sheet with the date, time (on a 24-hour clock), reference point, and initials of the person who made the measurements. The manual measurements will be used to calibrate the pressure transducers and monitor for "drift" of the readings. The water level indicator will be decontaminated in between wells as specified below.

2.2 Transducer Water Level Monitoring

Accurate, time coincident measurements will be used to evaluate the performance of the extraction well pumping system. Pressure transducers will be installed in selected wells and in the Willamette River to collect time coincident water level data for several depth intervals. Data will be downloaded weekly and checked for accuracy. Manual water level measurements will also be made when the weekly transducer checks are made. If the manual measurement is off by more than 0.1 foot from the transducer reading, the transducer will be corrected and a new test will be started.

2.2.1 Pressure Transducer Installation

Pressure transducers (15 PSI, In-Situ mini-TROLL professional or In-Situ level TROLL) will be installed at the selected locations. The pressure transducers will be installed using cables that extend from the surface to the instrument that is submerged in the well or river water. The cables allow in situ calibration of depth-to-water measurements from the surface. The full-length cables also allow for venting to the atmosphere, eliminating the need for barometric data correction.

The following procedure will be used to install the transducers:

1. Each instrument will be connected to a communication/vent cable of the appropriate length
2. The instrument and cable will be decontaminated before and after installation using the procedures described below
3. The instrument will be calibrated to zero in ambient air conditions
4. The instrument and cable will be slowly fed down into the well to a depth that will insure submersion throughout the monitoring period
5. The instrument cable will be securely attached to the well casing
6. The instrument and cable will cause the displacement of water in the well casing; therefore, the water level in the well will be allowed to equilibrate for 30 to 60 minutes before depth-to-water reference measurements are entered into the instrument
7. The installer will connect to the instrument cable with a portable personal computer
8. The installer will use an electric water level indicator to measure the depth-to-water from the monitoring point and enter the result into the instrument as a real-time reference value
9. The installer will program the instrument to collect one measurement of temperature and depth-to-water(pressure) every 15 minutes
10. The above-ground connector on the cable will be protected by a desiccant filter that is designed specifically for this application

3 WATER QUALITY MONITORING

Groundwater samples will be collected from select wells during the implementation of source control measures. Groundwater samples will be collected from extraction wells, monitoring wells, and piezometers along the shoreline of the Gasco site. The selected wells and frequency of sampling are described in Section 4.2 of the interim design report. The Interim Design Report also describes the target analytes, including volatile organic compounds (VOCs); polycyclic aromatic hydrocarbons (PAHs); and total and free cyanide.

3.1 Groundwater Sample Collection Procedures

Prior to groundwater sample collection, depth to water readings from the top of the well casing will be measured using a water level indicator. The water level indicator will be decontaminated between wells using the procedures outlined later in this section.

The wells will then be purged of at least three well casing volumes before groundwater is collected. Purging will be accomplished with one of the following methods: peristaltic pump with dedicated polyethylene tubing, Waterra inertial pump with dedicated Waterra tubing and check-valve, a disposable polyethylene bailer, or a submersible pump. After each well casing volume has been purged, water quality parameters (pH, specific conductance, temperature, and dissolved oxygen) will be recorded using a calibrated water quality meter. The well will be considered adequately purged when the water quality parameters have stabilized to within +/-10% of the previous measurement.

After the water quality parameters have stabilized, the sample will be collected directly from the dedicated tubing or disposable bailer into the sample container. The samples will then be stored on ice for shipment to an analytical laboratory.

4 EQUIPMENT CLEANING AND DECONTAMINATION PROCEDURES

Decontamination procedures are specified below. The objective for decontamination is to reduce the chance of cross-contaminating samples. All waters generated by cleaning and decontamination will be contained and disposed of. The water from sampling the Gasco wells will be treated in the onsite treatment system. The water from sampling wells on the Siltronic site will be evaluated to select the appropriate treatment/disposal option.

4.1 Groundwater Monitoring Equipment

Groundwater sampling equipment includes items used during groundwater sampling and water level monitoring. All equipment that contacts groundwater will be decontaminated before its first use and between sampling locations. Decontamination will proceed as follows:

- Distilled-water rinse
- Non-phosphatic detergent (e.g., Liquinox) and water wash
- Distilled-water rinse
- Final distilled-water rinse

5 QUALITY ASSURANCE PLAN

5.1 Data Quality Objectives and Criteria

The overall DQO for this project is to ensure that the data collected are of known and acceptable quality so that the project objectives described in this document can be achieved. The quality of the laboratory data is assessed by precision, accuracy, representativeness, comparability, and completeness (the "PARCC" parameters). Definitions of these parameters and the applicable Quality Control (QC) procedures are given below. Applicable quantitative goals for these data quality parameters are listed or referenced in Table F-1.

5.1.1 Precision

Precision is the ability of an analytical method or instrument to reproduce its own measurement. It is a measure of the variability, or random error, in sampling, sample handling, and in laboratory analysis. The American Society of Testing and Materials (ASTM) recognizes two levels of precision: repeatability—the random error associated with measurements made by a single test operator on identical aliquots of test material in a given laboratory, with the same apparatus, under constant operating conditions; and reproducibility—the random error associated with measurements made by different test operators, in different laboratories, using the same method but different equipment to analyze identical samples of test material (ASTM 2002).

In the laboratory, "within-batch" precision is measured using replicate sample or QC analyses and is expressed as the relative percent difference (RPD) between the measurements. The "batch-to-batch" precision is determined from the variance observed in the analysis of standard solutions or laboratory control samples from multiple analytical batches.

Field precision will be evaluated by the collection of blind field duplicates for chemistry samples at a frequency of one in 10 samples. Field chemistry duplicate precision will be screened against a RPD of 50 percent for groundwater samples. However, no data will be qualified based solely on field duplicate precision.

Precision measurements can be affected by the nearness of a chemical concentration to the method detection limit (MDL), where the percent error (expressed as RPD) increases. The equation used to express precision is as follows:

$$RPD = \frac{(C_1 - C_2) \times 100\%}{(C_1 + C_2)/2}$$

Where:

RPD = relative percent difference

C_1 = larger of the two observed values

C_2 = smaller of the two observed values

5.1.2 Accuracy

Accuracy is a measure of the closeness of an individual measurement (or an average of multiple measurements) to the true or expected value. Accuracy is determined by calculating the mean value of results from ongoing analyses of laboratory-fortified blanks, standard reference materials, and standard solutions. In addition, laboratory-fortified (i.e., matrix-spiked) samples are also measured; this indicates the accuracy or bias in the actual sample matrix. Accuracy is expressed as percent recovery (%R) of the measured value, relative to the true or expected value. If a measurement process produces results for which the mean is not the true or expected value, the process is said to be biased. Bias is the systematic error either inherent in a method of analysis (e.g., extraction efficiencies) or caused by an artifact of the measurement system (e.g., contamination). Analytical laboratories utilize several QC measures to eliminate analytical bias, including systematic analysis of method blanks, laboratory control samples, and independent calibration verification standards. Because bias can be positive or negative, and because several types of bias can occur simultaneously, only the net, or total, bias can be evaluated in a measurement.

Laboratory accuracy will be evaluated against quantitative matrix spike and surrogate spike recovery performance criteria provided by the laboratory. Accuracy can be expressed as a percentage of the true or reference value, or as a %R in those analyses where reference materials are not available and spiked samples are analyzed. The equation used to express accuracy is as follows:

$$\%R = 100\% \times (S-U)/Csa$$

Where:

%R = percent recovery

S = measured concentration in the spiked aliquot

U = measured concentration in the unspiked aliquot

C_{sa} = actual concentration of spike added

Field accuracy will be controlled by adherence to sample collection procedures outlined in the SAP.

5.1.3 Bias

Bias is the systematic or persistent distortion of a measurement process that causes errors in one direction. Bias assessments for environmental measurements are made using personnel, equipment, and spiking materials or reference materials as independent as possible from those used in the calibration of the measurement system. When possible, bias assessments should be based on analysis of spiked samples rather than reference materials so that the effect of the matrix on recovery is incorporated into the assessment. A documented spiking protocol and consistency in following that protocol are important to obtaining meaningful data quality estimates.

5.1.4 Representativeness

Representativeness expresses the degree to which data accurately and precisely represent an environmental condition. For the Gasco site, the list of analytes has been identified to provide a comprehensive assessment of the known and potential contaminants at the site.

5.1.5 Comparability

Comparability expresses the confidence with which one data set can be evaluated in relation to another data set. For this program, comparability of data will be established through the use of standard analytical methodologies and reporting formats, as well as the use of common traceable calibration and reference materials.

5.1.6 Completeness

Completeness is a measure of the amount of data that is determined to be valid in proportion to the amount of data collected. Completeness will be calculated as follows:

$$C = \frac{\text{(Number of acceptable data points)} \times 100}{\text{(Total number of data points)}}$$

The DQO for completeness for all components of this project is 90 percent. Data that have been qualified as estimated because the QC criteria were not met will be considered valid for the purpose of assessing completeness. Data that have been qualified as rejected will not be considered valid for the purpose of assessing completeness.

5.1.7 Sensitivity

Analytical sensitivities must be consistent with or lower than the regulated criteria values as listed in Table 1 in order to demonstrate compliance with this QAPP. When they are achievable, target detection limits specified will be at least a factor of 2 less than the analyte's corresponding regulated criteria value.

The MDL is defined as the minimum concentration at which a given target analyte can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero. Laboratory practical quantitation limits (PQLs) or reporting limits (RLs) are defined as the lowest level that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions. Laboratory MDLs and RLs will be used to evaluate the method sensitivity and/or applicability prior to the acceptance of a method for this program.

The sample-specific MDL and RL will be reported by the laboratory and will take into account any factors relating to the sample analysis that might decrease or increase the reporting limit (e.g., dilution factor, percent moisture, sample volume, and sparge volume). In the event that the MDL and RL are elevated for a sample due to matrix interferences and subsequent dilution or reduction in the sample aliquot, the data will be evaluated by Anchor QEA and the laboratory to determine if an alternative course of action is required or possible. If this situation cannot be resolved readily (i.e., detection limits less than criteria are achieved), DEQ will be contacted to discuss an acceptable resolution. The sample-specific RL will be the value provided in the project database and subsequent EQuIS deliverable.

5.1.8 Special Training Requirements/Certifications

The 29 CFR 1910.120 Occupational Safety and Health Administration (OSHA) regulations require training to provide employees with the knowledge and skills enabling them to perform their jobs safely and with minimum risk to their personal health. All sampling personnel will have completed the 40-hour Hazardous Waste Operations and Emergency Response (HAZWOPER) training course and 8-hour refresher courses, as necessary, to meet the OSHA regulations.

5.2 Documentation and Records

This project will require central project files to be maintained at Anchor QEA. Project records will be stored and maintained in a secure manner. Each project team member is responsible for filing all necessary project information or providing it to the person responsible for the filing system. Individual team members may maintain files for individual tasks, but must provide such files to the central project files upon completion of each task. A project-specific index of file contents is to be kept with the project files. Hard copy documents will be kept on file at Anchor QEA or at a document storage facility throughout the duration of the project, and all electronic data will be maintained in the database at Anchor QEA.

5.2.1 Field Records

All documents generated during the field effort are controlled documents that become part of the project file.

5.2.1.1 Field Forms

Field team members will keep a daily record of significant events, observations, and measurements on field forms. Copies of typical field forms are in Appendix F-1. All field activities will be recorded on forms specific to the collection activity and will be maintained by the FC. Field forms will be the main source of field documentation for all field activities. The on-site field representative will record on the field log form information pertinent to the investigation program. The sampling documentation will contain information on each sample collected, and will include at a minimum the following information:

- Project name
- Field personnel on site

- Facility visitors
- Weather conditions
- Field observations and any deviations from the SAP
- Maps and/or drawings
- Date and time sample collected
- Sampling method and description of activities
- Identification or serial numbers of instruments or equipment used
- Deviations from the QAPP and SAP
- Conferences associated with field sampling activities

The field forms will be on water-resistant, durable paper for adverse field conditions. Notes will be taken in indelible, waterproof blue or black ink. Errors will be corrected by crossing out with a single line, dating, and initialing. Each form will be marked with the project name, number, and date. The field forms will be scanned into Anchor QEA's project file directory as convenient during the sampling event or upon completion of each sampling event.

Sample collection tables will be prepared prior to each sampling program. The checklist will include proposed coordinates of each location, the sampling scheme, and whether any QC samples are to be collected.

5.2.2 Analytical and Chemistry Records

Analytical data records will be retained by the laboratory and in the Anchor QEA central project files. For all analyses, the data reporting requirements will include those items necessary to complete data validation, including copies of all raw data. The analytical laboratory will be required, where applicable, to report the following:

- **Project Narrative.** This summary, in the form of a cover letter, will discuss problems, if any, encountered during any aspect of analysis. This summary should discuss, but not be limited to, QC, sample shipment, sample storage, and analytical difficulties. Any problems encountered, actual or perceived, and their resolutions will be documented in as much detail as appropriate.

- **COC Records.** Legible copies of the COC forms will be provided as part of the data package. This documentation will include the time of receipt and condition of each sample received by the laboratory. Additional internal tracking of sample custody by the laboratory will also be documented on a sample receipt form. The form must include all sample shipping container temperatures measured at the time of sample receipt.
- **Sample Results.** The data package will summarize the results for each sample analyzed. The summary will include the following information when applicable:
  - Field sample identification code and the corresponding laboratory identification code
  - Sample matrix
  - Date of sample extraction
  - Date and time of analysis
  - Weight and/or volume used for analysis
  - Final dilution volumes or concentration factor for the sample
  - Identification of the instrument used for analysis
  - MDLs
  - Method reporting limits accounting for sample-specific factors (e.g., dilution, total solids)
  - Analytical results with reporting units identified
  - Data qualifiers and their definitions
  - A computer disk with the data in a format specified in advance by Anchor QEA
- **QA/QC Summaries.** This section will contain the results of the laboratory QA/QC procedures. Each QA/QC sample analysis will be documented with the same information required for the sample results (see above). No recovery or blank corrections will be made by the laboratory. The required summaries are listed below; additional information may be requested.
- **Calibration Data Summary.** This summary will report the concentrations of the initial calibration and daily calibration standards, and the date and time of analysis. The response factor, percent relative standard deviation, percent difference, and retention

time for each analyte will be listed, as appropriate. Results for standards to indicate instrument sensitivity will be documented.

- **Internal Standard Area Summary.** The stability of internal standard areas will be reported.
- **Method Blank Analysis.** The method blank analyses associated with each sample and the concentration of all compounds of interest identified in these blanks will be reported.
- **Surrogate Spike Recovery.** This will include all surrogate spike recovery data for organic compounds. The name and concentration of all compounds added, percent recoveries, and range of recoveries will be listed.
- **Matrix Spike Recovery.** This will report all matrix spike recovery data for organic and metal compounds. The name and concentration of all compounds added, percent recoveries, and range of recoveries will be listed. The RPD for all duplicate analyses will be included.
- **Matrix Duplicate.** This will include the percent recovery and associated RPD for all matrix duplicate analyses.
- **Laboratory Control Sample.** All laboratory control sample recovery data for organic and metal compounds will be reported. The name and concentration of all compounds added, percent recoveries, and range of recoveries will be listed. The RPD for all duplicate analyses will be included.
- **Relative Retention Time.** This will include a report of the relative retention time of each analyte detected in the samples for both primary and conformational analyses.
- **Original Data.** Legible copies of the original data generated by the laboratory will include:
  - Sample extraction, preparation, identification of extraction method used, and cleanup logs
  - Instrument specifications and analysis logs for all instruments used on days of calibration and analysis
  - Calculation worksheets for inorganic analyses
  - Reconstructed ion chromatograms for all samples, standards, blanks, calibrations, spikes, replicates, and reference materials

- Original printouts of full scan chromatograms and quantitation reports for all gas chromatography (GC) and/or GC/matrix spike (MS) samples, standards, blanks, calibrations, spikes, replicates, and reference materials
- Enhanced spectra of detected compounds with associated best-match spectra for each sample

All instrument data shall be fully restorable at the laboratory from electronic backup. Laboratories will be required to maintain all records relevant to project analyses for a minimum of 7 years. Data validation reports will be maintained in the central project files with the analytical data reports.

5.2.3 Data Reduction

Data reduction is the process by which original data (analytical measurements) are converted or reduced to a specified format or unit to facilitate analysis of the data. Data reduction requires that all aspects of sample preparation that could affect the test result, such as sample volume analyzed or dilutions required, be taken into account in the final result. It is the laboratory analyst's responsibility to reduce the data, which are subjected to further review by the Laboratory Manager, the Project Manager, the QA/QC Manager, and independent reviewers. Data reduction may be performed manually or electronically. If performed electronically, all software used must be demonstrated to be true and free from unacceptable error.

- Copies of complete laboratory data packages, as appendices or attachments.
- Copies of applicable sections of the field log, as appendices or attachments.
- Copies of validation reports and/or findings.

5.3 Overview of Data Generation and Acquisition

The rationale for the sampling design and design assumptions for locating and selecting environmental samples is detailed in the Work Plan. The methods and procedures for collection of field samples are also provided in the Work Plan.

5.3.1 Analytical Methods

This section summarizes the target chemical analyses for the sediment samples. All sample analyses will be conducted in accordance with DEQ-approved methods. Prior to analysis, all

samples will be maintained according to the appropriate holding times and temperatures for each analysis as defined in Table F-2. Table F-1 presents the proposed analytes, the analytical methods to be used, and the targeted detection limits for the sediment chemical testing. The analytical laboratory will prepare a detailed report in accordance with this QAPP, to be included as an appendix in the Data Report.

Prior to the analysis of the samples, the laboratory will calculate method detection limits for each analyte of interest, where applicable. Method detection limits will be below the values specified in Table F-1, if technically feasible. To achieve the required detection limits, some modifications to the methods may be necessary. These modifications from the specified analytical methods will be provided by the laboratory at the time of establishing the laboratory contract, and must be approved by DEQ prior to implementation.

Chemical testing will be conducted at CAS. CAS is accredited under the National Environmental Laboratories Accreditation Program (NELAP). In completing chemical analyses for this project, the contract laboratory is expected to meet the following minimum requirements:

- Adhere to the methods outlined in this QAPP, including methods referenced for each analytical procedure (Table F-1)
- Deliver facsimile, hard copy, and electronic data as specified
- Meet reporting requirements for deliverables
- Meet turnaround times for deliverables
- Implement QA/QC procedures including data quality objectives, laboratory QC requirements, and performance evaluation testing requirements
- Notify the project QA/QC Manager of any QA/QC problems when they are identified to allow for quick resolution
- Allow laboratory and data audits to be performed, if deemed necessary

5.3.2 Quality Assurance and Quality Control

Field and laboratory activities must be conducted in such a manner that the results meet specified quality objectives and are fully defensible. Guidance for QA/QC is derived from the

protocols developed for the EPA SW-846 (1986), the EPA Contract Laboratory Program (EPA 1999; EPA 2004; EPA 2005), and the cited methods.

5.3.2.1 Field Quality Control

Anchor QEA personnel will identify and label samples in a consistent manner to ensure that field samples are traceable and that labels provide all information necessary for the laboratory to conduct required analyses properly. Samples will be placed in appropriate containers and preserved for shipment to the laboratory.

5.3.2.1.1 Sample Containers

Sample containers and preservatives will be provided by the laboratory. The laboratory will maintain documentation certifying the cleanliness of bottles and the purity of preservatives provided. Specific container requirements will be subject to the sample design as described in this QAPP.

5.3.2.1.2 Sample Identification and Labels

Each sample will have an adhesive plastic or waterproof paper label affixed to the container and will be labeled at the time of collection. The following information will be recorded on the container label at the time of collection:

- Project name
- Sample identification
- Date and time of sample collection
- Preservative type (if applicable)
- Analysis to be performed

Samples will be uniquely identified with a sample identification that at a minimum specifies sample matrix, sample number, sample location, and type of sample. Specific sample ID schemes are provided in the SAP.

5.3.2.1.3 Sample Custody and Shipping Requirements

Samples are considered to be in one's custody if they are: 1) in the custodian's possession or view; 2) in a secured location (under lock) with restricted access; or 3) in a container that is secured with an official seal(s) such that the sample cannot be reached without breaking the seal(s).

COC procedures will be followed for all samples throughout the collection, handling, and analysis process. The principal document used to track possession and transfer of samples is the COC form. Each sample will be represented on a COC form the day it is collected. All data entries will be made using indelible ink pen. Corrections will be made by drawing a single line through the error, writing in the correct information, then dating and initialing the change. Blank lines/spaces on the COC form will be lined-out, dated, and initialed by the individual maintaining custody.

A COC form will accompany each cooler of samples to the analytical laboratories. Each person who has custody of the samples will sign the COC form and ensure that the samples are not left unattended unless properly secured. Copies of all COC forms will be retained in the project files.

All samples will be shipped to the analytical laboratory no later than the day after collection. Samples collected on Friday may be held until the following Monday for shipment provided that this does not jeopardize any hold time requirements. Specific sample shipping procedures are as follows:

- Each cooler or container containing the samples for analysis will be hand-delivered by courier or shipped via overnight delivery to the appropriate analytical laboratory. In the event that Saturday delivery is required, the FC will contact the analytical laboratory before 3 p.m. on Friday to ensure that the laboratory is aware of the number of coolers shipped and the airbill tracking numbers for those coolers. Following each shipment, the FC will call the laboratory and verify the shipment from the day before has been received and is in good condition.
- Coolant ice will be placed in the shipping containers.
- Individual sample containers will be packed to prevent breakage, and transported in a sealed ice chest or other suitable container.

- Glass jars will be separated in the shipping container by shock absorbent material (e.g., bubble wrap) to prevent breakage.
- The shipping containers will be clearly labeled with sufficient information (name of project, time and date container was sealed, person sealing the container, and consultant's office name and address) to enable positive identification.
- A sealed envelope containing COC forms will be enclosed in a plastic bag and taped to the inside lid of the cooler.
- A minimum of two signed and dated COC seals will be placed on adjacent sides of each cooler prior to shipping.
- Each cooler will be wrapped securely with strapping tape and will be clearly labeled with the laboratory's shipping address and the consultant's return address.
- Upon transfer of sample possession to the analytical laboratory, the persons transferring custody of the sample container will sign the COC form. Upon receipt of samples at the laboratory, the shipping container seal will be broken and the receiver will record the condition of the samples on a sample receipt form. COC forms will be used internally in the lab to track sample handling and final disposition.

5.3.2.1.4 Field Quality Assurance Sampling

Field QA procedures will consist of following procedures for acceptable practices for collecting and handling of samples. Adherence to these procedures will be complemented by periodic and routine equipment inspection.

Field QA samples will be collected along with the environmental samples. Field QA samples are useful in identifying possible problems resulting from sample collection or sample processing in the field. The collection of field QA samples includes one field blank and one duplicate sample. The field blank will be analyzed for the identical chemical list as the groundwater samples. In addition, a trip blank will be included in each shipping container that includes samples for volatiles analysis. The trip blank samples will be analyzed for VOCs.

Field QA samples will also include the collection of additional sample volume, to ensure that the laboratory has sufficient sample volume to run the program-required analytical QA/QC (MS/matrix spike duplicate [MSD]) samples for analysis as specified in Table F-4. Additional

sample volume to meet this requirement will be collected at a frequency of one per sampling event or one in 20 samples processed, whichever is more frequent. The samples designated for MS/MSD analyses should be clearly marked on the COC.

All field QA samples will be documented on the field forms and verified by the QA/QC Manager or designee.

5.3.2.2 Laboratory Quality Control

Laboratory QC procedures, where applicable, include initial and continuing instrument calibrations, standard reference materials, laboratory control samples, matrix replicates, matrix spikes, surrogate spikes (for organic analyses), and method blanks. Table F-4 lists the frequency of analysis for laboratory QA/QC samples, and Table F-3 summarizes the DQOs of sample testing for precision, accuracy, and completeness.

Results of the QC samples from each sample group will be reviewed by the analyst immediately after a sample group has been analyzed. The QC sample results will then be evaluated to determine if control limits have been exceeded. If control limits are exceeded in the sample group, the QA/QC Manager will be contacted immediately, and corrective action (e.g., method modifications followed by reprocessing the affected samples) will be initiated prior to processing a subsequent group of samples.

5.3.2.2.1 Laboratory Instrument Calibration and Frequency

An initial calibration will be performed on each laboratory instrument to be used at the start of the project, after each major interruption to the analytical instrument, and when any ongoing calibration does not meet method control criteria. A calibration verification will be analyzed following each initial calibration and will meet method criteria prior to analysis of samples. Continuing calibration verifications (CCV) will be performed daily prior to any sample analysis to track instrument performance. The frequency of CCVs varies with method. For GC/MS methods, one will be analyzed every 12 hours. For GC, metals, and inorganic methods, one will be analyzed for every 10 field samples, or daily, whichever is more frequent. If the ongoing continuing calibration is out of control, the analysis must come to a halt until the source of the control failure is eliminated or reduced to meet control specifications. All project samples analyzed while instrument calibration was out of control will be reanalyzed.

Instrument blanks or continuing calibration blanks provide information on the stability of the baseline established. Continuing calibration blanks will be analyzed immediately prior to continuing calibration verification at the instrument for each type of applicable analysis.

5.3.2.2.2 Laboratory Duplicates/Replicates

Analytical duplicates provide information on the precision of the analysis and are useful in assessing potential sample heterogeneity and matrix effects. Analytical duplicates and replicates are subsamples of the original sample that are prepared and analyzed as a separate sample.

5.3.2.2.3 MS and MSDs

Analysis of MS samples provides information on the extraction efficiency of the method on the sample matrix. By performing duplicate MS analyses, information on the precision of the method is also provided for organic analyses.

5.3.2.2.4 Method Blanks

Method blanks are analyzed to assess possible laboratory contamination at all stages of sample preparation and analysis. The method blank for all analyses must be less than the method reporting limit of any single target analyte/compound. If a laboratory method blank exceeds this criterion for any analyte/compound, and the concentration of the analyte/compound in any of the samples is less than five times the concentration found in the blank (10 times for common contaminants), analyses must stop and the source of contamination must be eliminated or reduced.

5.3.2.2.5 Laboratory Control Samples

Laboratory control samples are analyzed to assess possible laboratory bias at all stages of sample preparation and analysis. The laboratory control sample is a matrix-dependent spiked sample prepared at the time of sample extraction along with the preparation of sample and MSs. The laboratory control sample will provide information on the precision of the analytical process, and when analyzed in duplicate, will provide accuracy information as well.

5.3.2.2.6 Laboratory Deliverables

Data packages will be checked for completeness immediately upon receipt from the laboratory to ensure that data and QA/QC information requested are present. Data quality will be assessed by considering the following:

- Holding times
- All compounds of interest reported
- Reporting limits
- Surrogate spike results
- MS/MSD results
- Blank spikes
- Laboratory control samples/laboratory control sample duplicates
- Standard reference material results
- Method blanks
- Detection limits

5.3.3 Instrument/Equipment Testing, Inspection, and Maintenance Requirements

This section describes procedures for testing, inspection, and maintenance of field and laboratory equipment.

5.3.3.1 Field Instruments/Equipment

In accordance with the QA program, Anchor QEA shall maintain an inventory of field instruments and equipment. The frequency and types of maintenance will be based on the manufacturer's recommendations and/or previous experience with the equipment.

The frequency of maintenance is dependent on the type and stability of the equipment, the methods used, the intended use of the equipment, and the recommendations of the manufacturer. Detailed information regarding the calibration and frequency of equipment calibration is provided in specific manufacturer's instruction manuals.

All maintenance records will be verified prior to each sampling event. The FC will be responsible for verifying that required maintenance has been performed prior to using the equipment in the field.

5.3.3.2 Laboratory Instruments/Equipment

In accordance with the QA program, the laboratory shall maintain an inventory of instruments and equipment and the frequency of maintenance will be based on the manufacturer's recommendations and/or previous experience with the equipment.

The laboratory preventative maintenance program, as detailed in their QA Plan, is organized to maintain proper instrument and equipment performance, and to prevent instrument and equipment failure during use. The program considers instrumentation, equipment, and parts that are subject to wear, deterioration, or other changes in operational characteristics, the availability of spare parts, and the frequency at which maintenance is required. Any equipment that has been overloaded, mishandled, gives suspect results, or has been determined to be defective will be taken out of service, tagged with the discrepancy noted, and stored in a designated area until the equipment has been repaired. After repair, the equipment will be tested to ensure that it is in proper operational condition. The client will be promptly notified in writing if defective equipment casts doubt on the validity of analytical data. The client will also be notified immediately regarding any delays due to instrument malfunctions that could impact holding times.

Laboratories will be responsible for the preparation, documentation, and implementation of the preventative maintenance program. All maintenance records will be checked according to the schedule on an annual basis and recorded by the responsible individual. The Laboratory QA/QC Manager, or designee, shall be responsible for verifying compliance.

5.3.4 Instrument Calibration

Proper calibration of equipment and instrumentation is an integral part of the process that provides quality data. Instrumentation and equipment used to generate data must be calibrated at a frequency that ensures sufficient and consistent accuracy and reproducibility.

5.3.4.1 Field Instrument/Equipment Calibration

Field equipment will be calibrated prior to each sampling event according to manufacturer's recommendations using manufacturer's standards. The equipment, calibration, and maintenance information will be documented. The frequency of calibration is dependent on the type and stability of the equipment, the methods used, the intended use of the equipment, and the recommendations of the manufacturer. Detailed information regarding the calibration and frequency of equipment calibration is provided in specific manufacturer's instruction manuals.

Equipment that fails calibration or becomes inoperable during use will be removed from service and tagged (time and date of action) to prevent inadvertent use. Such equipment will be satisfactorily recalibrated or repaired and tagged (date and time of return to service) prior to use.

5.3.4.2 Laboratory Instrument/Equipment Calibration

As part of their QC program, laboratories perform two types of calibrations. A periodic calibration is performed at prescribed intervals (i.e., balances, drying ovens, refrigerators, and thermometers), and operational calibrations are performed daily, at a specified frequency, or prior to analysis (i.e., initial calibrations) according to method requirements. Calibration procedures and frequency are discussed in the laboratory QA Plan. Calibrations are discussed in the laboratory standard operating procedures (SOPs) for analyses.

The Laboratory QA/QC Manager will be responsible for ensuring that the laboratory instrumentation is calibrated in accordance with specifications. Implementation of the calibration program shall be the responsibility of the respective laboratory Group Supervisors. Recognized procedures (EPA, ASTM, or manufacturer's instructions) shall be used when available.

Physical standards (i.e., weights or certified thermometers) shall be traceable to nationally recognized standards such as the National Institute of Standards and Technology (NIST). Chemical reference standards shall be NIST Standard Reference Materials (SRMs) or vendor certified materials traceable to these standards.

The calibration requirements for each method and respective corrective actions shall be accessible, either in the laboratory SOPs or the laboratory's QA Plan for each instrument or analytical method in use. All calibrations shall be preserved on electronic media.

5.3.5 Inspection/Acceptance Requirements for Supplies and Consumables

Inspection and acceptance of field supplies, including laboratory-prepared sampling bottles, will be performed by the FC. All primary chemical standards and standard solutions used in this project either in the field or laboratory will be traceable to documented, reliable, commercial sources. Standards will be validated to determine their accuracy by comparison with an independent standard. Any impurities found in the standard will be documented.

TABLES

Table F-1
Sampling Parameters and Analytical Methods for Groundwater

Parameter	Analytical Method	Unit	Reporting Limit
Volatile Organic Compounds			
1,1,1,2-Tetrachloroethane	8260B	µg/L	0.5
1,1,1-Trichloroethane (TCA)	8260B	µg/L	0.5
1,1,2,2-Tetrachloroethane	8260B	µg/L	0.5
1,1,2-Trichloroethane	8260B	µg/L	0.5
1,1-Dichloroethane	8260B	µg/L	0.5
1,1-Dichloroethene	8260B	µg/L	0.5
1,2,3-Trichloropropane	8260B	µg/L	0.5
1,2,4-Trichlorobenzene	8260B	µg/L	2
1,2-Dibromoethane (EDB)	8260B	µg/L	2
1,2-Dichlorobenzene	8260B	µg/L	0.5
1,2-Dichloroethane (EDC)	8260B	µg/L	0.5
1,2-Dichloropropane	8260B	µg/L	0.5
1,3-Dichlorobenzene	8260B	µg/L	0.5
1,4-Dichlorobenzene	8260B	µg/L	0.5
2-Butanone (MEK)	8260B	µg/L	20
2-Chloroethyl Vinyl Ether	8260B	µg/L	5
2-Hexanone	8260B	µg/L	20
4-Methyl-2-pentanone (MIBK)	8260B	µg/L	20
Acetone	8260B	µg/L	20
Acrolein	8260B	µg/L	20
Acrylonitrile	8260B	µg/L	5
Benzene	8260B	µg/L	0.5
Bromochloromethane	8260B	µg/L	0.5
Bromodichloromethane	8260B	µg/L	0.5
Bromoform	8260B	µg/L	0.5
Bromomethane	8260B	µg/L	0.5
Carbon Disulfide	8260B	µg/L	0.5
Carbon Tetrachloride	8260B	µg/L	0.5
Chlorobenzene	8260B	µg/L	0.5
Chloroethane	8260B	µg/L	0.5
Chloroform	8260B	µg/L	0.5
Chloromethane	8260B	µg/L	0.5
cis-1,2-Dichloroethene	8260B	µg/L	0.5
cis-1,3-Dichloropropene	8260B	µg/L	0.5
Dibromochloromethane	8260B	µg/L	0.5
Dibromomethane	8260B	µg/L	0.5
Dichlorodifluoromethane	8260B	µg/L	0.5
Ethylbenzene	8260B	µg/L	0.5
Hexachlorobutadiene	8260B	µg/L	2
Iodomethane	8260B	µg/L	5
Isopropylbenzene	8260B	µg/L	2
m,p-Xylenes	8260B	µg/L	0.5
Methyl tert-Butyl Ether	8260B	µg/L	0.5
Methylene Chloride	8260B	µg/L	2

Table F-1
Sampling Parameters and Analytical Methods for Groundwater

Parameter	Analytical Method	Unit	Reporting Limit
Naphthalene	8260B	µg/L	2
o-Xylene	8260B	µg/L	0.5
Styrene	8260B	µg/L	0.5
Tetrachloroethene (PCE)	8260B	µg/L	0.5
Toluene	8260B	µg/L	0.5
trans-1,2-Dichloroethene	8260B	µg/L	0.5
trans-1,3-Dichloropropene	8260B	µg/L	0.5
trans-1,4-Dichloro-2-butene	8260B	µg/L	10
Trichloroethene (TCE)	8260B	µg/L	0.5
Trichlorofluoromethane	8260B	µg/L	0.5
Vinyl Acetate	8260B	µg/L	5
Vinyl Chloride	8260B	µg/L	0.5
PAHs/SVOCs (µg/L)			
Acenaphthene	8270C-SIM	µg/L	0.02
Acenapthylene	8270C-SIM	µg/L	0.02
Anthracene	8270C-SIM	µg/L	0.02
Benzo(a)anthracene	8270C-SIM	µg/L	0.02
Benzo(a)pyrene	8270C-SIM	µg/L	0.02
Benzo(b)fluoranthene	8270C-SIM	µg/L	0.02
Benzo(k)fluoranthene	8270C-SIM	µg/L	0.02
Chrysene	8270C-SIM	µg/L	0.02
Dibenzo(a,h)anthracene	8270C-SIM	µg/L	0.02
Fluoranthene	8270C-SIM	µg/L	0.02
Fluorene	8270C-SIM	µg/L	0.02
Indeno(1,2,3-cd)pyrene	8270C-SIM	µg/L	0.02
1-Methylnaphthalene	8270C-SIM	µg/L	0.02
2-Methylnaphthalene	8270C-SIM	µg/L	0.02
Naphthalene	8270C-SIM	µg/L	0.02
Phenanthrene	8270C-SIM	µg/L	0.02
Pyrene	8270C-SIM	µg/L	0.02
Benzo(g,h,i)perylene	8270C-SIM	µg/L	0.02
Dibenzofuran	8270C-SIM	µg/L	0.02
Carbazole	8270C-SIM	µg/L	0.02
Inorganics			
Total Cyanide	335.4	mg/L	0.01
AmenableCyanide	335.1	mg/L	0.01
Free Cyanide	ASTM D4282	mg/L	0.01

Notes:
µg/L= micrograms per Liter
mg/L= milligrams per Liter
PAH= Polycylic Aromatic Hydrocarbons
SVOC= Semi-Volatile Organic Compounds

Table F-2
Container Requirements, Holding Times, and Preservation Methods for Groundwater

Parameter	Method	Sample Size	Container Size and Type	Holding Time	Sample Preservation Technique
PAHs	EPA 8270D SIM	2 x 1 L	1-L Amber glass	7 days to extraction, 40 days to analysis	Cool/4° C
VOCs	EPA 8260B	3 x 40 mL	40 mL glass VOA vials, Teflon-lined septum cap	14 days	Zero head space/ pH < 2 with HCl
					Cool/4° C
Total and Amenable Cyanide	335.4 & 335.1	500 mL	500-mL HDPE	14 days	NaOH, pH>12, Cool, 4°
Free Cyanide	D4282	500 mL	500-mL HDPE	48 hours	NaOH, pH>12, Cool, 4°

Notes:
HCl = hydrochloric acid
L = liter
mL = milliliter
VOA = volatile organic analysis
VOCs = volatile organic compounds
SVOCs = semivolatile organic compounds
SIM = Selected Ion Monitoring
HDPE = high density polyethylene

Table F-3
Data Quality Objectives for Groundwater

Parameter	Precision (duplicates)	Accuracy (Spike Recoveries)	Completeness
Volatile organic compounds	+/- 30% RPD	70-130% R	90%
PAHs/ SVOC	+/- 30% RPD	50-140% R	90%
Cyanide (total, amenable, free)	+/- 25% RPD	75-125% R	90%

Notes:
RPD = Relative percent difference
R = Recovery

Table F-4
Laboratory Quality Control Sample Analysis Frequency for Groundwater

Analysis Type	Initial Calibration	Ongoing Calibration	Replicates	Matrix Spikes	LCS	Matrix Spike Duplicates	Method Blanks	Surrogate Spikes
Cyanide	Daily or each batch	1 per 10 samples	1 per 20 samples	1 per 20 samples	1 per 20 samples	NA	1 per 20 samples	NA
SVOCs/PAHs	As needed [a]	Every 12 hours	NA	1 per 20 samples	1 per 20 samples	1 per 20 samples	1 per 20 samples	Every sample
Volatile organics	As needed [a]	Every 12 hours	NA	1 per 20 samples	1 per 20 samples	1 per 20 samples	1 per 20 samples	Every sample

Notes:

a = Initial calibrations are considered valid until the ongoing continuing calibration no longer meets method specifications. At that point, a new initial calibration is performed.

APPENDIX F-1
FIELD FORMS

Daily Log

ANCHOR QEA

Anchor QEA, LLC
6650 SW Redwood Lane, Suite 333
Portland, OR 97224
Phone 503.670.1108 Fax 503.670.1128

PROJECT NAME: **DATE:**

SITE ADDRESS: **PERSONNEL:**

WEATHER:	**WIND FROM:**	N	NE	E	SE	S	SW	W	NW	LIGHT	MEDIUM	HEAVY
		SUNNY		CLOUDY		RAIN		?		**TEMPERATURE:**	° F	° C

(Circle appropriate units)

TIME	COMMENTS

Signature: ______________________________

ANCHOR QEA

LOG OF EXPLORATORY BORING

CLIENT/PROJECT NAME_____ BORING #_____

PROJECT NUMBER_____ DATE BEGAN_____

GEOLOGIST/ENGINEER_____ DATE COMPLETED_____

DRILLING CONTRACTOR_____ TOTAL DEPTH_____

DRILLING METHOD_____ SHEET_____OF_____

HOLE DIAMETER_____

OTHER*	WELL OR PIEZOMETER DETAILS	SAMPLING DATA						DEPTH IN FEET	SOIL GROUP SYMBOL (USCS)	Field location of boring LITHOLOGIC DESCRIPTION
		SAMPLING METHOD	SAMPLE NUMBER	FID / PID (ppm)	RECOVERY (feet)	BLOWS / 6 INCHES	DEPTH SAMPLED			
								1		
								2		
								3		
								4		
								5		
								6		
								7		
								8		
								9		
								0		
								1		
								2		
								3		
								4		
								5		
								6		
								7		
								8		
								9		
								0		

Remarks:

WELL DETAILS

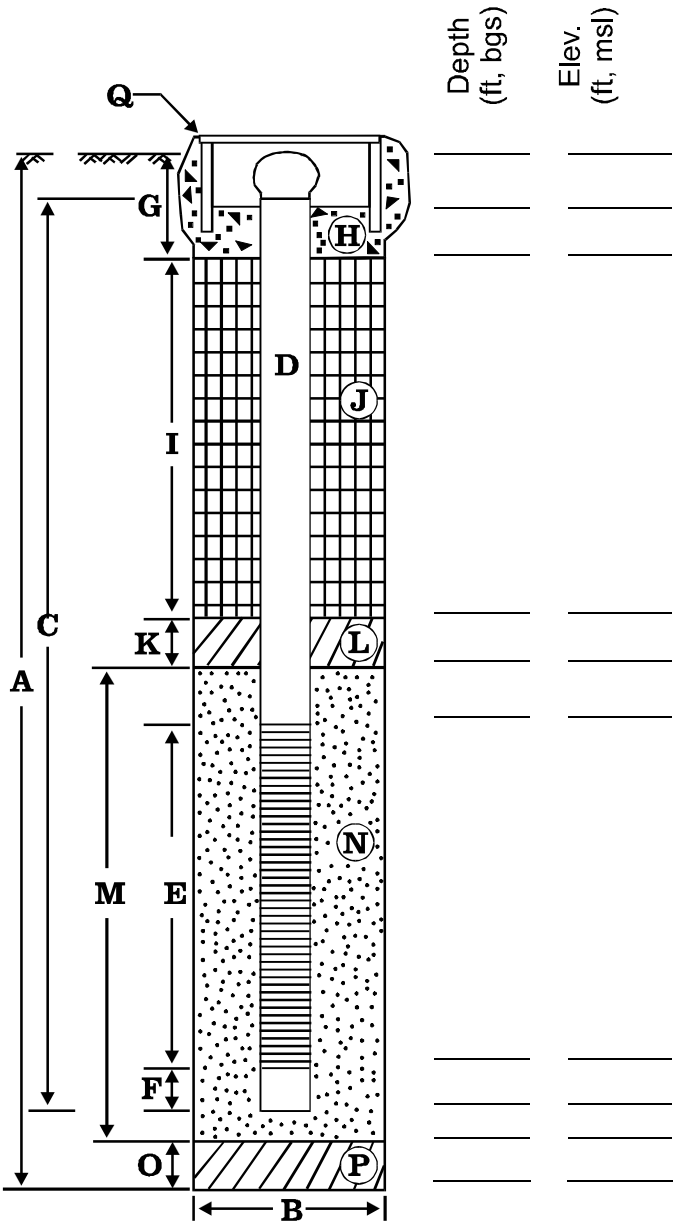
Project Number: _____ Boring/Well No.: _____

Client Name: _____ Top of Casing Elev.: _____

Project Name: _____ Ground Surface Elev.: _____

Location: _____ Installation Date: _____

Driller: _____ Permit/Start Card No.: _____



EXPLORATORY BORING

A. Total depth: _____ **ft.**

B. Diameter _____ **in.**

Drilling method: _____

WELL CONSTRUCTION

C. Well casing length: _____ **ft.**

Well casing material: _____

D. Well casing diameter: _____ **in.**

E. Well screen length: _____ **ft.**

Well screen type: _____

Well screen slot size: _____ **in.**

F. Well sump/end cap length: _____ **ft.**

G. Surface seal thickness: _____ **ft.**

H. Surface seal material: _____

I. Annular seal thickness: _____ **ft.**

J. Annular seal material: _____

K. Filter pack seal thickness: _____ **ft.**

L. Filter pack seal material: _____

M. Sand pack thickness: _____ **ft.**

N. Sand pack material: _____

O. Bottom material thickness: _____ **ft.**

P. Bottom material: _____

Q. Vault box type: _____

Well centralizer depths: _____ **ft.**

NOTES:

Installed by: _____

Reviewed by: _____

Date: _____

WELL DEVELOPMENT FORM

ANCHOR QEA

Project No.	Date:	Well:
Site Location:	Initial DTB:	Final DTB:
Name:	Initial DTW:	Final DTW:
Development Method:	Casing Volume:	
Total Water Removed:	Casing Diameter:	
Water Contained ?	Meter #:	
Estimate of specific capacity or recharge to well:		

Time	Cum. Vol Removed	Sand/Silt (ml/1000ml)	Temp.	EC	pH	DTW (TOC)	Appearance/Comments

FIELD SAMPLING DATA SHEET

ANCHOR QEA

6650 SW Redwood Lane, Suite 333
Portland, OR 97224
Office: (503) 670-1108 Fax: (503) 670-1128

PROJECT NAME: **WELL ID:**

SITE ADDRESS: **BLIND ID:**

DUP ID: **NA**

WIND FROM:	N	NE	E	SE	S	SW	W	NW	LIGHT	MEDIUM	HEAVY

WEATHER:	SUNNY	CLOUDY	RAIN	?	**TEMPERATURE:**	° F . ° C

[Circle appropriate units]

HYDROLOGY/LEVEL MEASUREMENTS (Nearest 0.01 ft)

Date	Time	DT-Bottom	DT-Product	DT-Water	DTP-DTW [Product Thickness]	DTB-DTW [Water Column]		Volume (gal) [Water Column x Gal/ft]
/ /	:	.	.	.	.	.	X 1	.
/ /	:	.	.	.	.		X 3	.

Gal/ft = (dia./2)^2 x 0.163	1" = 0.041	2" = 0.163	3" = 0.367	4" = 0.653	6" = 1.469	10" = 4.080	12" = 5.875

§ METHODS: (A) Submersible Pump (B) Peristaltic Pump (C) Disposable Bailer (D) PVC/Teflon Bailer (E) Dedicated Bailer (F) Dedicated Pump (G) Other =

GROUNDWATER SAMPLING DATA (if product is detected, do NOT sample) Sample Depth: [√ if used]

Bottle Type	Date	Time	Method §	Amount & Volume mL		Preservative [circle]	Ice	Filter	pH	√
VOA Glass	/ /	:		3	40 ml	HCl	YES	NO		
Amber Glass	/ /	:			250, 500, 1L	(None) (HCl) (H_2SO_4)	YES	NO		
White Poly	/ /	:			250, 500, 1L	None	YES	NO	NA	
Yellow Poly	/ /	:			250, 500, 1L	H_2SO_4	YES	NO		
Green Poly	/ /	:			250, 500, 1L	NaOH	YES	NO		
Red Total Poly	/ /	:			250, 500, 1L	HNO_3	YES	NO		
Red Diss. Poly	/ /	:			250, 500, 1L	HNO_3	YES	YES		
	/ /	:			250, 500, 1L		YES			
Total Bottles (include duplicate count):										

Analysis Allowed per Bottle Type

BOTTLE TYPE	TYPICAL ANALYSIS ALLOWED PER BOTTLE TYPE (Circle applicable or write non-standard analysis below)
VOA - Glass	(8021) (8260B) (BTEX) (NWTPH-Gx)
AMBER - Glass	(PAH) (TPH-HCID) (NWTPH-Dx) (TPH-418.1) (Oil &Grease) (8081A)
WHITE - Poly	(pH) (Conductivity) (TDS) (TSS) (BOD) (Turbidity) (Alkalinity) (HCO_3/CO_3) (Cl) (SO_4) (NO_3) (NO_2) (F)
YELLOW - Poly	(COD) (TOC) (Total PO_4) (Total Keldahl Nitrogen) (NH_3) (NO_3/NO_2)
GREEN - Poly	(Cyanide)
RED TOTAL - Poly	(As) (Sb) (Ba) (Be) (Ca) (Cd) (Co) (Cr) (Cu) (Fe) (Pb) (Mg) (Mn) (Ni) (Ag) (Se) (Tl) (V) (Zn) (Hg) (K) (Na)
RED DISSOLVED - Poly	(As) (Sb) (Ba) (Be) (Ca) (Cd) (Co) (Cr) (Cu) (Fe) (Pb) (Mg) (Mn) (Ni) (Ag) (Se) (Tl) (V) (Zn) (Hg) (K) (Na) (Hardness) (Silica)

WATER QUALITY DATA Purge Start Time: : Pump/Bailer Inlet Depth:

Meas.	Method §	Purged (gal)	pH	E Cond (µS)	°F Temp °C	Other	Diss O_2 (mg/l)	Water Quality
4		.	.		.		.	
3		.	.		.		.	
2		.	.		.		.	
1		.	.		.		.	
0		**0.00**	.		.		.	

[Casing] [Select A-G] [Cumulative Totals] [Circle units] [Clarity, Color]

SAMPLER: _____ _____

(PRINTED NAME) (SIGNATURE)

APPENDIX G

HEALTH AND SAFETY PLAN

NW NATURAL "GASCO" SITE FIELD ACTIVITIES FOR INTERIM DESIGN

Prepared for

NW Natural

Prepared by

Anchor QEA, LLC
6650 SW Redwood Lane, Suite 333
Portland, Oregon 97224

November 2009

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LIST OF ACRONYMS

Anchor QEA	Anchor QEA, LLC
AST	Aboveground Storage Tank
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
DNAPL	Dense Non-Aqueous Phase Liquid
EPA	United States Environmental Protection Agency
FC	Field Coordinator
FSP	Field Sampling Plan
HASP	Health and Safety Plan
HAZWOPER	Hazardous Waste Operations and Emergency Response
HSM	Health and Safety Manager
HSO	Health and Safety Officer
ID	Inner Diameter
Order	Administrative Order on Consent
OSHA	Occupational Safety and Health Administration
OVM	Organic Vapor Monitor
PAH	Polycyclic Aromatic Hydrocarbon
PEC	Project Emergency Coordinator
PFD	Personal Flotation Device
PM	Project Manager
PPE	Personal Protective Equipment
ppmv	Parts Per Million by Volume
RAA	Removal Action Area
RAWP	Removal Action Work Plan
TPH	Total Petroleum Hydrocarbons
VOC	Volatile Organic Compound

1 INTRODUCTION

NW Natural is conducting an investigation to evaluate the extent of groundwater capture and to measure groundwater gradients induced by the pumping of extraction wells installed along the Gasco shoreline. Field activities covered under this HASP include subsurface drilling and well installation conducted from a drill rig operated from both a barge and onshore, well development, and well pump test activities.

2 SITE DESCRIPTION AND PROJECT SCOPE

The "Gasco site" is a former oil gasification plant located at 7900 NW St. Helens Road, Portland, Oregon, 97210 and is bounded on the northeast by the Willamette River at River Mile 6 and on the southwest by State Highway 30 (St. Helens Road). The site is within the initial study area of the Portland Harbor Superfund site. It is adjacent to Wacker Siltronics Corporation and the U.S. Army Corps of Engineers U.S. Moorings facilities. The site is currently used as a storage facility for liquefied natural gas.

Prior to 1941, wastewater effluent and tar-stills from the gasification process and by-product refining at the site were discharged to a stream channel leading from the production area to the Willamette River, or to low-lying areas of the "Gasco site." Previous investigations identified the approximate limits of the tar residue on the river sediments adjacent to the site, "tar body," and characterized sediment conditions along the rest of the shoreline of the site. The scope of the current investigation is to drill and install extraction wells, observation wells, and offshore piezometers and to evaluate the extent of groundwater capture created by performing pumping tests with varying rates in the extraction wells.

3 HAZARD EVALUATION AND CONTROL MEASURES

This section covers potential chemical and physical hazards that may be associated with the proposed field activities and presents control measures to address these potential hazards. A recent risk assessment study identified the presence of metals, volatile organic compounds (VOCs), total petroleum hydrocarbons (TPH), and polycyclic aromatic hydrocarbons (PAHs) in sediments and groundwater in the vicinity of the Removal Action Area (RAA; Anchor, 2001).

Section 4.3 presents the activity hazard analysis which lists the potential hazards associated with each site activity and the recommended site control to be used to minimize each potential hazard. Confined space entry will not be necessary for this project; therefore, hazards associated with this activity are not discussed in this HASP.

3.1 Exposure Routes

Potential routes of exposure to the chemicals include inhalation, dermal contact, and ingestion of dust, mist, gas, vapor, or liquid. Exposure will be minimized by using safe work practices and by wearing the appropriate personal protective equipment (PPE). Further discussion of PPE requirements is presented in Section 6.0.

3.1.1 Inhalation

Inhalation of particulates, dust, mist, gas, or vapor during coring and sampling activities is possible. Whenever possible the coring equipment will be oriented so that personnel are upwind of the coring location. An organic vapor monitor (OVM) will be used to monitor ambient air and the breathing zone within the work area for organic compounds. Air monitoring may also be conducted for the presence of hydrogen cyanide within worker's breathing zones when opening monitoring well heads and other intrusive activities. Section 7.2 describes OVM action levels and response procedures.

3.1.2 Dermal Contact

Dermal contact with potentially contaminated soil, sediment, or groundwater during shoreline and vessel-based coring operations is possible. Direct contact will be minimized through the use of appropriate PPE and decontamination procedures.

3.1.3 Ingestion

Ingestion of contaminants is a less likely route of exposure than inhalation or dermal contact for many of the contaminants of concern. Direct ingestion of contaminants can occur by inhaling airborne dust, mist, or vapors or swallowing contaminants trapped in the upper respiratory tract. Indirect ingestion can occur by introducing the contaminants into the mouth by way of food, tobacco, fingers, or other carriers. Although ingestion of contaminants can occur, proper decontamination/contamination reduction procedures should eliminate the probability of this route of exposure.

3.2 Chemical Hazards

Contaminants of concern in the RAA to be sampled include VOCs such as benzene, toluene, ethylbenzene and xylenes (BTEX); PAHs, TPH, and low levels of cyanide compounds. Low levels of metals may also be associated with sediment samples, and as a precaution, are assumed to be present for the purposes of this HASP. In addition, there is some potential for exposure to hydrogen sulfide gas from native soil and hexane, which in rare cases may be used as a decontamination liquid.

The following sections provide information on the identified compounds of concern (COC).

3.2.1 Metals

The primary exposure routes for metals during coring activities are inhalation or ingestion of dust particles. Metals may also be indirectly ingested, as described in Section 3.1.3. A secondary route of exposure to metals is dermal contact. The target organs primarily affected by prolonged exposure to metals are the respiratory tract, gastrointestinal tract, central nervous system, kidneys, and liver.

Prolonged exposure to metals through any of the potential routes of exposure is not expected. Skin will be washed immediately when exposed to soil, sediment, dust, or water potentially impacted by metals.

3.2.2 Total Petroleum Hydrocarbons

Petroleum hydrocarbons likely at the site include tar and oil related materials in sediments and soils, which contain benzene and aromatic hydrocarbons. Gasoline, diesel, fuel, and waste oil, and heavier hydrocarbons such as grease may also be present associated with sampling

equipment. Volatile components of gasoline include benzene, toluene, ethylbenzene, and xylenes (BTEX). The primary exposure routes for petroleum hydrocarbons during coring activities are inhalation, dermal contact, and ingestion of contaminated soil, sediment, dust, or water. Lighter petroleum hydrocarbons such as gasoline and benzene readily volatilize and are primarily an inhalation concern, whereas the primary route of exposure to heavier petroleum hydrocarbons such as aromatic hydrocarbons, oil, and grease is dermal contact. The target organs primarily affected by prolonged exposure to petroleum hydrocarbons are the respiratory system, central nervous system, kidneys, liver, and skin. Prolonged dermal contact with petroleum hydrocarbons can cause irritation or dermatitis. The BTEX compounds are known or suspected human carcinogens. An OVM equipped with a photo-ionization detector will be used to monitor ambient air and the breathing zone for VOCs such as benzene and naphthalene (an aromatic hydrocarbon). Respiratory protection will be employed if elevated levels of organic compounds are measured by the OVM, if odors are present, or other conditions warrant its use. Inhalation of hydrocarbon vapors should be avoided. Work upwind of contaminated areas whenever possible. Particulates from soil pose potential heavy metal and semivolatile inhalation hazards. Implement dust control measures whenever visible dust is generated by work activities. Avoid all skin contact with contaminated soil and groundwater by wearing nitrile or neoprene gloves.

Diesel or Fuel Oil No. 2, is a brown, slightly viscous liquid from the middle distillate in petroleum distillation. Diesel has a flash point of 110 to 120o F, a density <1, and an auto ignition temperature of 494o F. The lower explosive limit (LEL) is approximately 1% with an upper explosive limit (UEL) of about 6%. Diesel can cause irritation of the skin, and inhalation of high concentrations of vapors causes headaches and stupor. There is no established Permissible Exposure Limit (PEL) for diesel, fuel oil #2, or kerosene. The closest thing to a PEL for these types of products is probably Petroleum distillates (naphtha) which a PEL-time-weighted average (TWA) of 500 ppm / 2000 mg/m3.

Heavy oil range petroleum hydrocarbons usually fall within the category of fuel oil #5, and #6 which are also referred to as Bunker C. These are highly viscous, dark liquids with a flash point between 130 and 1500 degrees F. It has a density <1 and an auto ignition temperature of approximately 7500 F. The toxic effects of these oil range petroleum hydrocarbons may be similar to that of diesel except to a lesser degree since it doesn't volatilize as readily. These toxic effects include irritation of the skin, and inhalation of high concentrations of vapors and cause headaches and stupor. There is no established PEL for these oil range petroleum hydrocarbons.

The OSHA PEL for petroleum distillates (naphtha) is 500 ppm, with a 1100 ppm (10% LEL) immediate danger to life or health (IDLH) level.

Gasoline is a mixture of mostly low molecular weight alkanes and aromatics, such as toluene, xylene, and benzene. It is highly volatile, and its toxic properties resemble solvents more than oils. Its major health effects are related to its volatile constituents. Various additives may also be toxic, including phenols, amines, and phosphates. The benzene additive is known to cause leukemia. Ingestion causes inebriation, vomiting, vertigo, fever, drowsiness, confusion, and cyanosis. Aspiration can cause bronchitis or pneumonia. Inhalation of high concentrations can cause an intense burning in the throat and lungs, and possible bronchopneumonia. Skin contact should be avoided as gasoline is a defatting agent. There is no established OSHA PEL for gasoline, however, the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) is 300 ppm, with a Short Term Exposure Limit (STEL) of 500 ppm.

Petroleum hydrocarbons such as gasoline are also flammable and can be a physical hazard when present in high concentrations. Physical hazards associated with flammable compounds are addressed in Section 3.3.8. Combustion of petroleum hydrocarbons can produce carbon dioxide, carbon monoxide, aldehydes, fumes, smoke (particulate matter), and other products of incomplete combustion. Intentional and inadvertent combustion of petroleum hydrocarbons is not expected during sampling activities; however, personnel will be removed from the area should a fire occur.

3.2.3 Polycyclic Aromatic Hydrocarbons

PAHs are petroleum hydrocarbons which are relatively nonvolatile due to their large molecular structure and high molecular weight. Consequently, the primary route of exposure to PAHs is through dermal contact. PAHs may also be indirectly ingested as described in Section 3.1.3. Inhalation of PAHs is unlikely due to their nonvolatile nature. Dermal or eye contact with PAHs can cause irritation or burning.

PAHs are found throughout the environment. The primary source of many PAHs in air is the incomplete combustion of wood and fossil fuels. PAHs are products of common sources as motor vehicle exhaust, wood burning stoves and furnaces, cigarette smoke, industrial smoke and soot, and charcoal-broiled foods. PAHs found in the wood preservative creosote include chrysene, naphthalene, phenanthrene, fluoranthene, pyrene, acenaphthene,

methylnaphthalenes, and anthracene. Most human exposure is to a mixture of PAHs, as opposed to a single PAH compound.

Smaller PAHs with two rings, such as naphthalene, have a higher vapor pressure and are more water soluble than those with five rings, such as benzo[a]pyrene (B[a]P). While there will be some volatilization of the smaller PAHs, those with larger structures are unlikely to volatilize appreciably. Dissolved PAHs will breakdown in light rapidly. PAHs are very persistent in sediment and aquatic systems; for example, the half-life for B[a]P in hydrocarbon-contaminated sediments is about 2.4 years, but may be 10-400 times longer in uncontaminated sediments. In soil, biodegradation is the major fate, but it is a slow process.

There are essentially no experimental or clinical data that provide evidence for a direct association between human exposure (ingestion, inhalation, or skin contact) to individual PAHs and adverse health effects. Therefore, in order to try to predict adverse responses in humans following exposure to PAHs, toxicologists must rely on reported effects in humans (primarily cancer) after exposure to complex mixtures of PAHs and on information derived from studies in which high doses of PAHs were administered to animals. However, even when animal studies are reviewed, it is evident that there are very little data on the potential non-carcinogenic and carcinogenic effects of many PAHs.

The carcinogenic PAH benzo[a]pyrene (B[a]P) has been the most-studied PAH in animals, and the toxicity of it and other PAHs in humans is often inferred from its toxicity. B[a]P absorption following inhalation and ingestion is nearly complete. Studies suggest dermal absorption may be also appreciable. With a few exceptions where dermal absorption is slower, data indicate that absorption of other PAHs is quantitatively similar to that of B[a]P. Distribution is quantitatively dependent on the route of exposure and on the associated medium. Orally administered B[a]P, benz[a]anthracene, chrysene, and dibenz[a,h]anthracene primarily distribute to blood, liver, lung, and kidney.

The non-carcinogenic PAH naphthalene has produced nausea, vomiting, abdominal pain, diarrhea, and even death when ingested in large doses following suicide attempts and accidental ingestion of naphthalene-containing mothballs by children.

Exposure to naphthalene can result in cataracts and hemolytic anemia. Results of studies employing dermal exposure are difficult to interpret but may indicate appreciable toxicity via this route.

There are no studies available on either the reproductive or developmental effects (that is, the production of birth defects) of either B[a]P or any other PAH in humans.

B[a]P has been extensively evaluated for genotoxic effects, and the results have been overwhelmingly positive. These studies show B[a]P and PAH mixtures are capable of producing heritable genetic damage and cancer. Other cPAHs have similarly been shown to produce genotoxic effects. Noncarcinogenic PAHs such as naphthalene do not demonstrate genotoxicity.

Results of epidemiological studies show increased lung cancer in workers exposed to air emissions containing PAHs and other carcinogenic compounds. Dermal exposure to shale oils and coal tar (which contain PAHs in addition to other carcinogens) has been associated with an increased incidence of skin tumors in workers. Workers exposed by skin contact to creosote (composed primarily of PAHs) have also developed skin tumors. When applied to the skin, all fifteen PAHs listed below induced skin tumors in mice.

The National Toxicology Program of the U.S. Department of Health and Human Services has determined that the following fifteen PAHs may reasonably be anticipated to cause cancer in humans:

Benzo[a]anthracene	Benzo[b]fluoranthene	Benzo[j]fluoranthene
Benzo[k]fluoranthene	Benzo[a]pyrene	Dibenz[a,h]acridine
Dibenz[a,j]acridine	Dibenz[a,h]anthracene	7H-Dibenzo[c,g]carbazole
Dibenzo[a,e]pyrene	Dibenzo[a,h]pyrene	Dibenzo[a,i]pyrene
Dibenzo[a,l]pyrene	Indeno[1,2,3-cd]pyrene	5-Methylchrysene

The OSHA Permissible Exposure Limit (PEL) and ACGIH Threshold Limit Value (TLV) for occupational exposure to coal tar pitch volatiles is 0.2 mg/m3. Since we are concerned about potential exposure to carcinogenic varieties of PAHs, no lower limit of protection, the intake of these substances by personnel should be maintained as low as possible.

3.2.4 Hydrogen Sulfide

Hydrogen sulfide is a naturally occurring gas often associated with organic clay and peat. Hydrogen sulfide gas is potentially toxic through inhalation, ingestion, and contact with the skin and eyes. Inhalation can result in respiratory irritation, rhinitis, and edema of the lungs. Inhalation of hydrogen sulfide gas can result in headache, dizziness, and agitation. Acute exposure at high concentrations may result in coma and death as a result of respiratory failure. Hydrogen sulfide gas has a distinct rotten egg odor, and will be noted if encountered in the field.

The odor of hydrogen sulfide can be detected at approximately 0.03 ppm and become offensive at 3 ppm, and causes irritation at 10 ppm. An especially dangerous situation is brief exposure to concentrations of 50 ppm, which can cause a person to lose the sense of smell. This has been described in accident reports as "I first smelled hydrogen sulfide, then it went away." This is called olfactory fatigue. The toxic effect of hydrogen sulfide paralyzes the respiratory control center, which leads to suffocation and then death.

Hydrogen sulfide has a wide flammable range (LEL 4.0%, UEL 44.0 %). This property, coupled with its heavier-than-air density, makes it a hazard in trenches and low-lying areas.

Hydrogen sulfide is regulated by OSHA on a 20 ppm ceiling concentration and an Immediately Dangerous to Life or Health (IDLH) concentration of 100 ppm. A ceiling concentration means that this level can not be exceeded during any part of the work period. NIOSH has also established a ceiling concentration of 10 ppm. The ACGIH has established a TLV of 10 ppm and a STEL of 15 ppm.

Employees are directed to shut down ignition sources and leave the area if hydrogen sulfide is detected above 10 ppm. Generally, natural cross-ventilation will reduce hydrogen sulfide to acceptable levels. Re-entry and continuation of work may be done only under controlled conditions involving monitoring equipment and in supplied air respirators if levels exceed, or are likely to exceed, 10 ppm.

3.2.5 Cyanide

Cyanide (CN, CAS 57-12-5; related compounds: Sodium cyanide, Potassium cyanide, Hydrogen cyanide) There is little bioaccumulation of cyanide, because organisms either metabolize cyanide quickly or die from its effects. Cyanide is fairly mobile in soil. In water, it dissipates primarily by evaporation and biodegradation. Sodium and potassium cyanides are used primarily in the extraction of ores, in electroplating, in metal treatment, in printing, in fumigation, in photography, and various other manufacturing processes.

Cyanide is considered to be of high toxicity. Routes of harmful exposure to cyanide include inhalation, ingestion, and skin contact. Fatal doses can be absorbed through the skin, if there are cuts. Symptoms of exposure include eye and skin irritation, weakness, headaches, confusion, dizziness, numbness, rapid pulse, nausea, vomiting, slow gasping respiration, convulsions, loss of consciousness, suffocation, and death. Cyanide may be teratogenic, but does not appear to be mutagenic or carcinogenic. The OSHA PEL-TWA for cyanide is 5 mg/m3 skin (as CN) with an ACGIH TLV of 5 mg/m3 (STEL) ceiling, skin, as CN. The OSHA PEL-TWA for hydrogen cyanide is 10 ppm with an ACGIH ceiling level of 4.7 ppm; also identified as a skin absorption hazard.

3.2.6 Hexane

If necessary to achieve adequate decontamination of equipment, a hexane rinse may be applied to remove hydrocarbon-type compounds. Exposure to high concentrations of hexane usually occurs by inhalation. Effects of inhalation may be slow and shallow breathing, possible tachycardia, vertigo or giddiness, nausea, and vomiting. Dermal exposure may result in dermatitis or conjunctival irritation. Eye exposure will cause irritation and requires irrigation.

3.2.7 Compounds of Concern Summary Table

Table 1 provides a summary profile for the compounds of concern (COC) for this project. As available, this profile is based on recent site history and site characterization information. For more detailed and specific information, always refer to the Material Safety Data Sheet (MSDS) or equivalent information for the compound.

3.3 Physical Hazards

3.3.1 Slips Trips and Falls

As with all fieldwork sites, caution should be exercised to prevent slips on slick surfaces. In particular, sampling from a floating platform requires careful attention to minimize the risk of falling down or falling overboard. The same care should be used in rainy conditions. Wearing boots with good tread, made of material that does not become overly slippery when wet, can minimize slips.

Trips are always a hazard on the uneven deck of a boat or in a cluttered work area. The deck of the vessel may have numerous stationary fittings and tie-downs that present potential tripping

hazards. Personnel will keep work areas as free as possible from items that interfere with walking and will be aware of stationary obstacles on deck.

Falls may be avoided by working as far away from exposed edges as possible. For this project, the potential for falling is associated primarily with deployment and recovery drill rig pipes, rods, and well casing through the "moonhole" of the vessel, boarding and disembarking the vessel at the dock, and while walking along the shoreline composed of loose rocks. Personnel will keep walkways and work areas clear when possible and use caution when walking along the shoreline.

3.3.2 Coring and Sampling Equipment

Soil and sediment samples will be collected using a direct-push or Rotosonic drill rig operated onshore or from a barge. Prior to initiation of sampling on the barge, there will be a training session for all field personnel pertaining to the equipment that will be onboard the sampling vessel. The captain will review vessel-specific hazards and safety procedures and will point out the location and proper use of all safety equipment. For example, field personnel will be shown the locations of all fire extinguishers, flotation rings, and first aid kits and their appropriate uses.

3.3.3 Falling Overboard

It is anticipated that the majority of the sampling will be conducted from a vessel. As with any work from a floating platform, there is a chance of falling overboard. A personal flotation device (PFD) for each crew person will be available in the boat at all times. PFDs will be worn while working from the vessel.

3.3.4 Manual Lifting

Equipment and samples must be lifted and carried both aboard the vessel and along the shoreline. Back strain can result if lifting is done improperly. During any manual handling tasks, personnel should lift with the load supported by their legs and not their backs. For heavy loads, an adequate number of people will be used, or if possible, a mechanical lifting/handling device.

3.3.5 Heat Stress

Scheduled sampling operations will be occurring in late Summer or Fall, so high temperatures may be encountered. The potential for heat stress may occur if impermeable PPE is worn or if strenuous work is performed under hot conditions with inadequate water. When the core body temperature rises above 100.4° F, the body cannot sweat to cool down, and heat stress can occur. Heat stress may be identified by the following symptoms: dizziness, profuse sweating, skin color change, vision problems, confusion, nausea, fatigue, fainting, and clammy skin. Personnel exhibiting such symptoms will be removed to a cool shady area, given water, and allowed to rest. Fresh drinking water will be provided aboard the vessel. All field team members will monitor their own condition and that of their co-workers to detect signs of heat stress.

3.3.6 Hypothermia

Hypothermia is abnormal lowering of the core body temperature caused by exposure to a cold environment. Wind chill as well as wetness or water immersion can play a significant role. Typical signs of hypothermia include fatigue, weakness, lack of coordination, apathy, and drowsiness. Confusion is a key symptom of hypothermia. Shivering and pallor are usually absent, and the face may appear puffy and pink.

Body temperatures below 90° F require immediate treatment to restore the temperature to normal. Current medical practice recommends slow warming of the individual followed by professional medical care. Moving the person to a sheltered area and wrapping them in a blanket can accomplish this portion of the task. If possible, the person should be placed in a warm room. In emergency situations where body temperature falls below 90° F and shelter is not available, a sleeping bag, blankets, and body heat from another individual can be used to help raise body temperature.

3.3.7 Weather

In general, field team members will be equipped for the normal range of weather conditions. The FC will be aware of current weather conditions, and of the potential for those conditions to pose a hazard to the field crew. Some conditions that might force work stoppage are electrical storms, high winds, or high waves resulting from winds.

3.3.8 Flammable Hazards

Petroleum hydrocarbons are flammable in moderate to high concentrations. Therefore smoking, open flames, and unprotected ignition sources will not be allowed in the work area. An OVM will be used to measure concentrations of organic vapors (i.e., benzene) in the work area. If elevated OVM measurements persist, work will be suspended until corrective measures are taken to ensure a safe work environment.

3.4 Activity Hazard Analysis

The activity hazard analysis summarizes the field activities to be performed during borehole drilling and soil sampling activities, outlines the hazards associated with each activity, and presents controls that can reduce or eliminate the risk of the hazard occurring.

Table 2 presents the activity hazard analysis for the following activities:

- Drilling activities including soil sample collection and well installation
- Well development groundwater purging
- Equipment decontamination

4 WORK ZONES AND ACCESS CONTROL

The vessel captain, onshore coring operator, and the FC will delineate the boundaries of the work zones aboard the vessel and shoreline and will inform the field crews of the arrangement. The purpose of the zones is to limit the migration of sample material out of the zones and to restrict access to active work areas by defining work zone boundaries.

4.1 Work Zones

Two work zones will be observed aboard the vessel. One will encompass the "moonhole" of the vessel where the samplers will be deployed and recovered. Only the coring crew may enter this zone unless assistance is required by other personnel. The second work zone will be a sample processing area on the vessel. The drill contractor crew will deliver sediment core tubes to this zone and open them. Anchor QEA, LLC (Anchor QEA) personnel will log and process the sediment cores.

Two work zones will be observed while working onshore. One will enclose the drill rig where sampling is taking place. Only the coring crew may enter this zone unless assistance is required by other personnel. The second work zone will be a nearby core processing area. The drill contractor coring crew will transport the sediment core to this. Anchor QEA personnel will log and process the sediment cores.

Both the collection and processing areas on the vessel and onshore will have a support (i.e., exclusion) zone outside the contamination reduction zone to stage clean equipment, don PPE, take rest breaks, or perform any other site activities that do not involve potentially contaminated materials.

4.2 Decontamination Area

A station will be set up for decontaminating sample processing equipment and personnel gear such as boots or PPE. The station will have the buckets, brushes, soapy water, rinse water, or wipes necessary to perform decontamination operations. Plastic bags will be provided for expendable and disposable materials. The decontamination fluids will be stored in sealable containers and will be disposed of in accordance with the procedures presented in Section 9.4.

4.3 Access Control

Security and control of access to the sampling vessel and onshore area will be the responsibility of the captain, FC and/or HSO. Additional security measures may be placed into affect by NW Natural, as required by national security threat levels determined by the federal government. Access to the vessel and onshore areas will only be granted to necessary project personnel and authorized visitors. Any security or access control problems will be reported to the client or appropriate authorities.

5 SAFE WORK PRACTICES

Following common sense rules will minimize the risk of exposure or accidents at a work site. These general safety rules will be followed on site:

- Always use the buddy system
- Be aware of overhead and underfoot hazards at all times
- Do not eat, drink, smoke, or perform other hand-to-mouth transfers in the work zones
- Get immediate first aid for all cuts, scratches, abrasions, or other minor injuries
- Report all accidents and close calls, no matter how minor, to the FC
- Be alert to your own and other workers' physical condition
- Do not climb over or under obstacles of questionable stability
- Make eye contact with equipment operators before moving into the range of their equipment
- Work during daylight hours. If work after dusk becomes necessary due to an emergency, adequate lighting must be provided.
- An emergency eyewash unit shall be located immediately adjacent to employees who handle hazardous or corrosive materials, including sample preservation and decontamination fluids.
- Personnel working on or near bodies of water shall wear U.S. Coast Guard approved personal flotation devices.
- All temporary electrical power must have a ground fault circuit interrupter (GFCI) as part of its circuit if the circuit is not part of permanent wiring.

6 PERSONAL PROTECTIVE EQUIPMENT AND SAFETY EQUIPMENT

Appropriate PPE will be worn as protection against potential hazards. In addition, a PFD will be required when working on the vessel. Prior to donning PPE, the workers will inspect their equipment for any defects that might render the equipment ineffective.

Fieldwork will be conducted in Level D, modified Level D, or Level C PPE as discussed below in Sections 6.1, 6.2, and 6.3, respectively. Situations requiring PPE beyond Level C are not anticipated for this project. Should the FC determine that PPE beyond Level C is necessary at a given sampling station, the FSC will notify the HSM to select an appropriate corrective action.

6.1 Level D Personal Protective Equipment

Workers performing general activities in which skin contact with contaminated materials is unlikely and in which inhalation risks are not expected will wear Level D PPE. Level D PPE includes the following:

- Chemical-resistant, steel-toed boots
- Leather, cotton, or chemical-resistant gloves, as the type of work requires
- Safety glasses
- Hard hat (if overhead hazard exists)
- Hearing protection, if necessary

6.2 Modified Level D Personal Protective Equipment

Workers performing activities where skin contact with contaminated materials is possible will wear chemical-resistant outer gloves and an impermeable outer suit. The type of outerwear will be chosen according to the types of chemical contaminants that might be encountered.
Modified Level D PPE includes the following:

- Outer garb such as rain gear or rubber or vinyl aprons
- Chemical-resistant steel-toed boots
- Surgical rubber inner gloves
- Chemical-resistant outer gloves
- Safety glasses (or face shield, if significant splash hazard exists)
- Hard hat (if overhead hazard exists)
- Hearing protection, if necessary

6.3 Level C Personal Protective Equipment

If elevated (see Section 7.2) concentrations of vapors are measured with the OVM, significant contaminant odors are noted, or significant amounts of airborne particulate matter are generated, health and safety requirements may be upgraded to Level C if implementation of engineering controls (i.e., fans) do not decrease the airborne concentrations to acceptable levels. Level C PPE includes the equipment listed under modified Level D plus the following:

- Half-face or full face respirator
- Organic vapor/acid gas cartridges, if appropriate
- Particulate filter cartridge, if appropriate

6.4 Safety Equipment

In addition to PPE that will be worn by shipboard personnel, basic emergency and first aid equipment will also be provided. Equipment will include:

- A copy of this HASP
- PFD
- First aid kit adequate for the number of personnel
- Emergency eyewash

Anchor QEA and/or subconsultants will provide this equipment, which must be at the location(s) where field activities are being performed. Equipment will be checked daily to ensure its readiness for use.

7 MONITORING PROCEDURES FOR SITE ACTIVITIES

A monitoring program that addresses the potential site hazards will be maintained. The monitoring program includes self-monitoring by the field crew and monitoring with instruments.

7.1 Crew Self Monitoring

All personnel will be instructed to look for and inform each other of any deleterious changes in their physical or mental condition during the performance of all field activities. Examples of such changes are as follows:

- Headaches
- Dizziness
- Nausea
- Blurred vision
- Cramps
- Irritation of eyes, skin, or respiratory system
- Changes in complexion or skin color
- Changes in apparent motor coordination
- Increased frequency of minor mistakes
- Excessive salivation or changes in papillary response
- Changes in speech ability or speech pattern
- Symptoms of heat stress or heat exhaustion (Section 4.2.6)
- Symptoms of hypothermia (Section 4.2.7)

If any of these conditions develop, the affected person(s) will be moved from the immediate work location and evaluated. If further assistance is needed, personnel at the local hospital will be notified, and an ambulance will be summoned if the condition is thought to be serious. If the condition is the result of sample collection or processing activities, procedures and/or PPE will be modified to address the problem.

7.2 Real-Time Air Monitoring Equipment

Organic vapor concentrations shall be monitored in the field using an organic vapor monitor such as a photoionization detector (PID) or flame ionization detector (FID). Organic vapor measurements shall be taken in the breathing zone of workers while additional area monitoring

may be conducted at the well head, auger point, etc. to gather background and environmental impact information.

Other real-time air monitoring equipment, such as hydrogen cyanide meters, may be utilized depending upon the scope of work and compounds of concern.

Air monitoring results shall be documented in the field logbook or daily log form.

7.3 Equipment Calibration and Maintenance

Calibration and maintenance of air monitoring equipment shall follow manufacturer specifications and must be documented. Re-calibration and adjustment of air monitoring equipment shall be completed as site conditions and equipment operation warrant. Record all air monitoring equipment calibration and adjustment information in the field logbook or daily log form.

7.4 Air Monitoring Action Levels

Refer to Table 4 for air monitoring action levels that have been developed for this project. The table stipulates the chemical concentrations in the worker's breathing zone that require an upgrade in level of PPE.

8 DECONTAMINATION

Decontamination is necessary to prevent the migration of contaminants from the work zone(s) into the surrounding environment and to minimize the risk of exposure of personnel to contaminated materials that might adhere to PPE. The following sections discuss personnel and equipment decontamination. The following supplies will be available to perform decontamination activities:

- Wash and rinse buckets
- Tap water and phosphate-free detergent
- Scrub brushes
- Distilled/deionized water
- Deck pump with pressurized freshwater hose (aboard the vessel)
- Paper towels and plastic garbage bags

8.1 Minimization of Contamination

The following measures will be observed to prevent or minimize exposure to potentially contaminated materials:

Personnel:

- Do not walk through spilled sediment
- Do not handle, touch, or smell sediment directly
- Make sure PPE has no cuts or tears prior to use
- Protect and cover any skin injuries
- Stay upwind of airborne dusts and vapors
- Do not eat, drink, chew tobacco, or smoke in the work zones

Sampling Equipment and Vessel:

- Use care to avoid getting sampled media on the outside of sample containers
- If necessary, bag sample containers before filling with sampled media
- Place clean equipment on a plastic sheet to avoid direct contact with contaminated media
- Keep contaminated equipment and tools separate from clean equipment and tools
- Fill sample containers over a plastic tub to contain spillage
- Clean up spilled material immediately to avoid tracking around the vessel

8.2 Personal Decontamination

The FC will ensure that all site personnel are familiar with personnel decontamination procedures. Personnel will perform decontamination procedures, as appropriate, when exiting work areas. Following is a description of the procedure:

Decontamination Procedure:

- Wash and rinse outer gloves and boots in portable buckets
- If suit is heavily soiled, rinse it off
- Remove outer gloves, inspect and discard if damaged, leave inner gloves on
- Remove inner gloves and wash hands if taking a break
- Don necessary PPE before returning to work
- Dispose of soiled PPE before leaving for the day

8.3 Handling of Investigation-Derived Waste

All remaining sediment, fluids used for decontamination of sampling equipment, and core collection disposable wastes (e.g., gloves, paper towels, foil, etc.) will be placed into appropriate containers and staged on-site for disposal. Sediments remaining following collection and processing will be placed into sealable containers and disposed offsite. The decontamination fluids will be stored in sealable containers and will be disposed based on the amount of visibly apparent oil. If the fluid contains only a small amount of visibly apparent oil it will be transferred into an on-site aboveground storage tank (AST) for treatment via the Gasco facility carbon treatment unit. Alternatively, fluids containing a visibly appreciable amount of oil will be transferred into an AST located at the MW-6 dense non-aqueous phase liquid (DNAPL) extraction system. All disposable wastes will be placed into two heavy duty plastic bags (i.e., double-bagged) and disposed at a permitted solid waste disposal facility.

9 TRAINING REQUIREMENTS

Individuals performing work at locations where potentially hazardous materials and conditions may be encountered must meet specific training requirements. It is not anticipated that personnel will encounter hazardous concentrations of contaminants in sampled material, so training will consist of site-specific instruction for all personnel and oversight of inexperienced personnel for one working day. The following sections describe the training requirements for work at this site.

9.1 Project Specific Training

All Anchor QEA personnel must read this HASP and be familiar with its contents before beginning work. They shall acknowledge reading the HASP by signing the field team HASP review form contained in Appendix A. The form will be kept in the project files.

The FC or a designee will provide and document project-specific training during the project kickoff meeting and whenever new Anchor QEA workers arrive for fieldwork. Anchor QEA personnel will not be allowed to begin work until project-specific training is completed and documented by the FC. Training will address the HASP and all health and safety issues and procedures pertinent to field operations. Training will include, but will not be limited to, the following topics:

- Activities with the potential for chemical exposure
- Activities that pose physical hazards, and actions to control the hazards
- Ship access control and procedures
- Use and limitations of PPE
- Decontamination procedures
- Emergency procedures
- Use and hazards of sampling equipment
- Location of emergency equipment on the vessel
- Vessel safety practices

In addition, since field activities are occurring within the Portland Harbor Superfund Site, all workers must have 40-hour Hazardous Waste Operations and Emergency Response (HAZWOPER) training in accordance with Occupational Safety and Health Administration (OSHA), and an updated 8-hour refresher training certification, if applicable.

9.2 Daily Safety Briefings

The FC or a designee will present safety briefings before the start of each day's activities. These safety briefings will outline the activities expected for the day, update work practices and hazards, address any specific concerns associated with the work location, and review emergency procedures and routes. The safety briefings will be documented in the logbook or daily log form.

10 RECORDING AND RECORD KEEPING

The FC or a designee will record health- and safety-related details of the project in the field logbook or daily log form. Entries will be made with indelible ink. At a minimum, each day's entries must include the following information:

- Project name or location
- Names of all personnel
- Level of PPE worn and any other specifics regarding PPE
- Weather conditions
- Type of fieldwork being performed

The person maintaining the entries will initial and date the bottom of each completed page. Blank space at the bottom of an incompletely filled page will be lined out. Each day's entries will begin on the first blank page after the previous workday's entries.

As necessary, other documentation will be obtained or initiated by the FC. Other documentation may include field change requests, medical and training records, exposure records, accident/incident report forms, OSHA Form 200s, and material safety data sheets. Appendix A contains copies of key health and safety forms.

11 EMERGENCY RESPONSE PLAN

As a result of the health and safety hazards associated with the field sampling and sample handling activities, the potential exists for an emergency situation to occur. Emergencies may include personal injury, exposure to hazardous substances, fire, explosion, or release of toxic or non-toxic substances (spills). OSHA regulations require that an emergency response plan be available for use onboard to guide actions in emergency situations.

Onshore organizations will be relied upon to provide response in emergency situations. The local fire department and ambulance service can provide timely response. Anchor QEA personnel and subcontractors will be responsible for identifying an emergency situation, providing first aid if applicable, notifying the appropriate personnel or agency, and evacuating any hazardous area. Shipboard personnel will attempt to control only very minor hazards that could present an emergency situation, such as a small fire, and will otherwise rely on outside emergency response resources.

The following sections address pre-emergency preparation, identify individual(s) who should be notified in case of emergency, provide a list of emergency telephone numbers, offer guidance for particular types of emergencies, and provide directions and a map for getting from any sampling location to a hospital.

11.1 Pre-Emergency Preparation

Before the start of field activities, the FC will ensure that preparation has been made in anticipation of emergencies. Preparatory actions include the following:

- Meeting with the captain and equipment handlers concerning the emergency procedures in the event that a person is injured. Appropriate actions for specific scenarios will be reviewed. These scenarios will be discussed and responses determined before the sampling event commences.
- A training session given by the captain informing all field personnel of emergency procedures, locations of emergency equipment and their use, and proper evacuation procedures.
- A training session given by senior staff operating field equipment, to apprise field personnel of operating procedures and specific risks associated with that equipment.
- Ensuring that field personnel are aware of the existence of the emergency response plan, its location as Section 12 of the HASP, and ensuring that a copy of the HASP accompanies the field team(s).

11.2 Site Emergency Coordinator

The FC will serve as the Project Emergency Coordinator (PEC) in the event of an emergency. The FC will designate a replacement for times when he is not onboard or is not serving as the PEC. The designation will be noted in the logbook or daily log form. The PEC will be notified immediately when an emergency is recognized. The PEC will be responsible for evaluating the emergency situation, notifying the appropriate emergency response units, coordinating access with those units, and directing interim actions onboard before the arrival of emergency response units. The PEC will notify the HSM and the PM as soon as possible after initiating an emergency response action. The PM will have responsibility for notifying the client.

11.3 Emergency Response Contacts

All personnel must know whom to notify in the event of an emergency situation, even though the FC has primary responsibility for notification. Table 3 lists the names and phone numbers for emergency response services and individuals.

11.4 Recognition of Emergency Situations

Emergency situations will generally be recognizable by observation. An injury or illness will be considered an emergency if it requires treatment by a medical professional and cannot be treated with simple first-aid techniques.

11.5 Decontamination

In the case of evacuation, decontamination procedures will be performed only if doing so does not further jeopardize the welfare of site workers. If an injured individual is also heavily contaminated and must be transported by emergency vehicle, the emergency response team will be told of the type of contamination. To the extent possible, contaminated PPE will be removed, but only if doing so does not exacerbate the injury. Plastic sheeting will be used to reduce the potential for spreading contamination to the inside of the emergency vehicle.

11.6 Fire

Shipboard personnel will attempt to control only small fires, should they occur. If an explosion appears likely, personnel will follow evacuation procedures specified by the captain in the training session. If a fire cannot be controlled with a fire extinguisher on board that is part of the required safety equipment, personnel will either withdraw from the vicinity of the fire or

use additional fire fighting equipment, or evacuate the boat as specified by the captain in the training session.

11.7 Personal Injury

In the event of serious personal injury, including unconsciousness, possibility of broken bones, severe bleeding or blood loss, burns, shock, or trauma, the first responder will immediately do the following:

- Administer first aid, if qualified
- If not qualified, seek out an individual who is qualified to administer first aid, if time and conditions permit
- Notify the PEC of the incident, the name of the individual, the location, and the nature of the injury

The PEC will immediately do the following:

- Notify the captain and the appropriate emergency response organization
- Assist the injured individual
- Follow the emergency procedures for retrieving or disposing equipment reviewed in the training session, and leave the site en route to the predetermined land-based emergency pick-up
- Designate someone to accompany the injured individual to the hospital
- If an emergency situation (i.e., broken bones or injury where death is imminent without immediate treatment) occurs, the FC or captain will call 911 and arrange to meet the response unit at the nearest accessible dock
- Notify the HSM and the PM

If the PEC determines that emergency response is not necessary, he may direct someone to decontaminate and transport the individual by vehicle to the nearest hospital. Directions and a map showing the route to the hospital are in Section 12.10.

If a worker leaves the ship to seek medical attention, another worker should accompany him or her to the hospital. When in doubt about the severity of an injury or exposure, always seek medical attention as a conservative approach and notify the PEC.

The PEC will have responsibility for completing all accident/incident field reports, OSHA form 200s, and other required follow-up forms.

11.8 Overt Personal Exposure or Injury

If an overt exposure to toxic materials occurs, the first responder to the victim will initiate actions to address the situation. The following actions should be taken, depending on the type of exposure:

Skin Contact:

- Wash/rinse the affected area thoroughly with copious amounts of soap and water
- If eye contact has occurred, eyes should be rinsed for at least 15 minutes using the eyewash that is part of the emergency equipment onboard and in the lab
- After initial response actions have been taken, seek appropriate medical attention

Inhalation:

- Move victim to fresh air
- Seek appropriate medial attention

Ingestion:

- Seek appropriate medical attention

Puncture Wound or Laceration:

- Seek appropriate medical attention

11.9 Spills and Spill Containment

Sources of bulk chemicals are not expected to be used during this project. Accordingly, a spill containment procedure is not required for this project.

11.10 Emergency Route to the Hospital

The name, address, and telephone number of the hospital that will be used to provide medical care is as follows:

Legacy Good Samaritan Hospital and Medical Center
1015 NW 22nd Avenue
Portland, Oregon 97210
(503) 413-7711

Figure 1 is a map of the route from the project site (7900 NW St. Helens Road, Portland, Oregon, 97210) to the Legacy Good Samaritan Hospital and Medical Center. Directions are as follows (travel time is approximately 11 minutes):

1. Start out going Southeast on NW ST HELENS RD/LOWER COLUMBIA RIVER HWY/US-30 toward NW BRIDGE AVE/US-30 BYP W/ST JOHN BRIDGE. Continue to follow NW ST HELENS RD/US-30.
2. Turn SLIGHT RIGHT onto NW ST HELENS RD/COLUMBIA RIVER HWY/US-30. Continue to follow COLUMBIA RIVER HWY/US-30.
3. Turn SLIGHT RIGHT onto NW WARDWAY ST.Turn LEFT on MARIONA ST.
4. NW WARDWAY ST becomes NW VAUGHN ST.Turn LEFT onto JAMES ST.
5. Turn RIGHT onto NW 23RD AVE.
6. Turn LEFT onto NW NORTHRUP ST.
7. Turn RIGHT onto NW 22nd Ave.
8. End at 1015 NW 22nd Ave.

12 HEALTH AND SAFETY PLAN APPROVAL RECORD

By their signature, the undersigned certify that this HASP is approved and that it will be used to govern health and safety aspects of fieldwork conducted by Anchor QEA personnel to investigate areas associated within the RAA.

Anchor QEA Project Health and Safety Manager (HSM) Date

Anchor QEA Field Coordinator (FC) Date

Anchor QEA Health and Safety Officer (HSO) Date

13 REFERENCES

Anchor Environmental, L.L.C., 2001. "Northwest Natural 'Gasco' Site Ecological and Human Health Risk Assessment – Level II Screening Report." Prepared for Oregon Department of Environmental Quality, February 2001.

Anchor Environmental, L.L.C., 2004. "NW Natural 'Gasco' Site – Removal Action Work Plan." Prepared for the US Environmental Protection Agency, May 2004.

U.S. Environmental Protection Agency (EPA), 2004. Administrative Order on Consent for Removal Action between NW Natural and the U.S. Environmental Protection Agency. April 28, 2004.

U.S. Environmental Protection Agency (EPA), 2001. *Methods for Collection, Storage and Manipulation of Sediments for Chemical and Toxicological Analyses: Technical Manual*. EPA/823/B-01-022, October 2001.

TABLES

Table 1
Compounds of Concern Summary Table

Compound	Physical/Chemical Characteristics (Target Organs/ Route of Entry)	OEL (STEL)	Odor Threshold	LEL (%)	IP (eV)
Hydrogen Sulfide (H_2S) (7783-06-04) 1 ppm = 1.40 mg/m^3	Colorless gas with a strong odor of rotten eggs. Eye, upper respiratory tract irritant; high concentrations (200+ppm) causes paralysis of sense of smell, (500+ppm) respiratory paralysis, collapse and coma, (>1000 ppm) can be fatal in minutes. Strongly corrosive to electrical connections and equipment; reacts with copper, oxidizing agents, nitric acid, soda lime, and peroxides; flammable gas, can build up in excavations and low lying areas .	10 ppm TWA (15 ppm) 300 ppm IDLH	0.03 ppm	4.0%	10.46
Volatile Organic Compounds					
Benzene (71-43-2) 1 ppm = 3.19 mg/m^3	Skin, eye, inhalation, and ingestion hazard. Colorless liquid with an aromatic odor. Prolonged skin contact or excessive inhalation of its vapor may cause headache, weakness, loss of appetite, and lassitude. A human carcinogen. Extremely flammable, keep sources of ignition away. Incompatible with fluorides, chlorides, oxygen, permanganates, acids, and peroxides.	0.5 ppm TWA; (2.5 ppm) Skin IDLH: 500 ppm Ca	61 ppm	1.2%	9.25
Ethylbenzene (100-41-4) 1 ppm = 4.34 mg/m^3	Skin, eye, inhalation, and ingestion hazard. Colorless liquid with an aromatic odor. Moderately toxic by ingestion, inhalation, mucous membranes, and skin absorption. Irritant to the skin and eyes.	100 ppm TWA (125 ppm) 800 ppm IDLH	0.60 ppm	0.8%	8.76
Petroleum Distillates (Naphtha) (8002-05-09)	Skin, eye, inhalation, and ingestion hazard. Mucous membrane irritant; headache, dizziness, euphoria, unconsciousness; a CNS	350 mg/m^3 TWA 1,800 mg/m^3 Ceiling (15-	N/A	1.1%	N/A

Table 1
Compounds of Concern Summary Table

Compound	Physical/Chemical Characteristics (Target Organs/ Route of Entry)	OEL (STEL)	Odor Threshold	LEL (%)	IP (eV)
1 ppm = 4.05 mg/m^3	depressant; pulmonary edema from aspiration. Reacts violently with oxidizers and oxidizing acids; emits toxic smoke and gas during combustion.	minute) 1,100 ppm IDLH			
Toluene (108-88-3) 1 ppm = 3.77 mg/m^3	Inhalation, absorption, ingestion and eye hazard. Colorless liquid with a sweet, pungent, benzene-like odor. Poison by intraperitional route. Moderately toxic by inhalation and subcutaneous routes. A skin and eye irritant. Central nervous system effects. May cause impairment of coordination and reaction time.	20 ppm TWA (150 ppm) 300 ppm Ceiling; 500 ppm IDLH	1.7 ppm	1.1%	8.82
Xylenes, total (1330-20-7) 1 ppm = 4.34 mg/m^3	Inhalation, absorption, ingestion and eye hazard. Colorless liquid with an aromatic odor. Moderately toxic by ingestion and inhalation. An eye irritant. May be narcotic at high concentrations.	100 ppm TWA (150 ppm) 900 ppm IDLH	5 ppm	1%	8.44
Semi-Volatile Organic Compounds					
Polycyclic aromatic hydrocarbons (PAHs) – as coal tar pitch volatiles. (Includes chrysene, phenanthrene, fluoranthene, pyrene, acenaphthene, methylnaphthalenes, and anthracene)	Skin, eye, inhalation, and ingestion hazard. The pitch of coal tar is black or dark brown amorphous residue that remains after the re-distillation process. Odor thresholds vary. Direct contact or exposure to the vapors may be irritating to the eyes. Direct contact can be highly irritating to the skin and can cause dermatitis. Exposure to high vapor concentrations may cause headaches, nausea, vomiting, and other symptoms. Includes human carcinogens. Reacts with acids and oxidizers; produces acrid	0.2 mg/m^3 TWA 0.1 mg/m^3 TWA (Cyclohexane-extractable fraction) Ca	N/A	N/A	Not known

Table 1
Compounds of Concern Summary Table

Compound	Physical/Chemical Characteristics (Target Organs/ Route of Entry)	OEL (STEL)	Odor Threshold	LEL (%)	IP (eV)
	smoke, toxic gases when involved in fires, thermal decomposition. Exposure to all routes should be carefully controlled to levels as low as possible. Confirmed Animal Carcinogen.				
Metals / Inorganics					
Arsenic	A human carcinogen; a powerful allergen, inhalation and contact causes burning, swelling and redness in the eyes, nose, throat and skin; ingestion causes nausea, vomiting, nervous system effects in the extremities (numbness, tingling, weakness); long term exposure can cause liver, kidney, and blood damage. A fire hazard in the form of dust or contact with oxidizers; thermal decomposition produces toxic gases	0.01 mg/m^3 5 mg/m^3 IDLH	N/A	N/A	N/A
Chromium	Some Chromium (VI) compounds are confirmed human carcinogens; corrosive irritant to skin, eyes, respiratory tract; deep skin ulcers; not (always) immediately painful; an allergic sensitizer; 5 grams ingested can be fatal. Reacts with strong oxidizers, alkalis, can react with, ignite oils, grease, paper and plastics.	0.5 mg/m3 Cr (VI) Soluble 0.05 mg/m^3 Insoluble mg/m^3 Ca	N/A	N/A	N/A
Copper	A mucous membrane, respiratory irritant; conjunctivitis; nausea, vomiting, abdominal pain. Reacts with acids and oxidizers, copper reactions may release flammable gas (hydrogen).	1.0 mg/m^3	N/A	N/A	N/A
Cyanides, as CN (57-12-5)	Skin, eye, inhalation, and ingestion hazard. Very poisonous. Death	5 mg/m^3 TWA Skin	N/A	N/A	N/A

Table 1
Compounds of Concern Summary Table

Compound	Physical/Chemical Characteristics (Target Organs/ Route of Entry)	OEL (STEL)	Odor Threshold	LEL (%)	IP (eV)
	can occur within seconds of inhalation or ingestion. A chemical asphyxiant; headache, weakness, confusion, unconsciousness, convulsions, coma and death; cyanide salts, liquids are corrosive to all body tissues; characteristic almond odor. Reacts violently with acids, nitrates and peroxides; release highly flammable and toxic HCN gas.				
Lead	Inhalation and ingestion hazard. Weakness, insomnia; loss of appetite, loss of weight, abdominal pain; anemia; tremors; weakness of wrists/ ankles; kidney damage; low blood pressure. Incompatible with strong oxidizers, hydrogen peroxide and acids.	0.050 mg/m^3	N/A	N/A	N/A
Nickel compounds	An upper respiratory irritant; skin eruptions and allergic dermatitis; nausea, vomiting, giddiness from ingestion; insoluble compounds are confirmed human carcinogens. Nickel salts can react with potassium, strong oxidizers, or mineral acids to form toxic, flammable or explosive gases.	Elemental 1.5 mg/m3 soluble 0.1 mg/m3 insoluble 0.2 mg/m3	N/A	N/A	N/A
Zinc	A skin, eye, and respiratory irritant; a nuisance dust; health effects primarily from fume inhalation, metal fume fever; chromates of zinc are human carcinogens. Zinc salts are incompatible with reactive cyanides and sulfides.	10.0 mg/m^3	N/A	N/A	N/A

Table 2
Activity Hazard Analysis

Activity	Hazard	Control
Drilling activities including soil sample collection and well installation on barge or on land	Falling overboard	Avoid working near the edge of the vessel, if possible. Stay away from edge of barge deck.
	Back or muscle strain	Use appropriate lifting technique when handling heavy equipment. Enlist help if necessary.
	Skin or eye contact with potentially contaminated sediments or liquids	Wear modified Level D PPE, including eye protection.
	Slipping/tripping on slick or uneven deck	Wear steel-toed boots with gripping tread. Be aware of obstacles and wet patches on deck and select a path to avoid them.
	Injury from equipment falling or swinging	Wear a hard hat and steel-toed boots at all times; be in the appropriate position on deck when equipment is in operation.
	Fire	Avoid fueling operations near hot engines. Mop up any spilled flammable liquids and dispose of absorbent. No smoking or flame sources on the vessel. Evacuate the vessel according to procedures outlined in the training session given by the captain.
	Rotating or percussive drilling equipment	Stay clear of area around borehole while drilling activities are underway.
Purging of groundwater during well development	Skin or eye contact with potentially contaminated liquids	Wear modified Level D PPE, including eye protection
	Inhalation of vapors	Use an OVM, and benzene sample tubes as necessary, to determine if VOC levels remain below identified thresholds.
Decontaminating equipment	Inhalation of, or eye contact with, airborne mists or vapors	Wear safety glasses. Perform decontamination activities outdoors or in a well-ventilated area. Stay upwind when spray-rinsing equipment.
	Skin contact with potentially contaminated materials	Wear modified Level D PPE.
	Ingestion of contaminated materials	Decontaminate clothing and skin prior to eating, drinking, smoking, or other hand-to-mouth activities. Follow the decontamination procedure for personal decontamination.

Table 3

Emergency Response Contacts

Contact	Telephone Number
Emergency Numbers	
Ambulance	911
Police	911
Fire	911
Legacy Good Samaritan Hospital and Medical Center	(503) 413-7711
Emergency Responders	
U.S. Coast Guard Willamette River Station General information	 (503) 240-9311 (503) 247-4018
National Response Center	(800) 424-8802

Table 4
Air Monitoring Action Levels

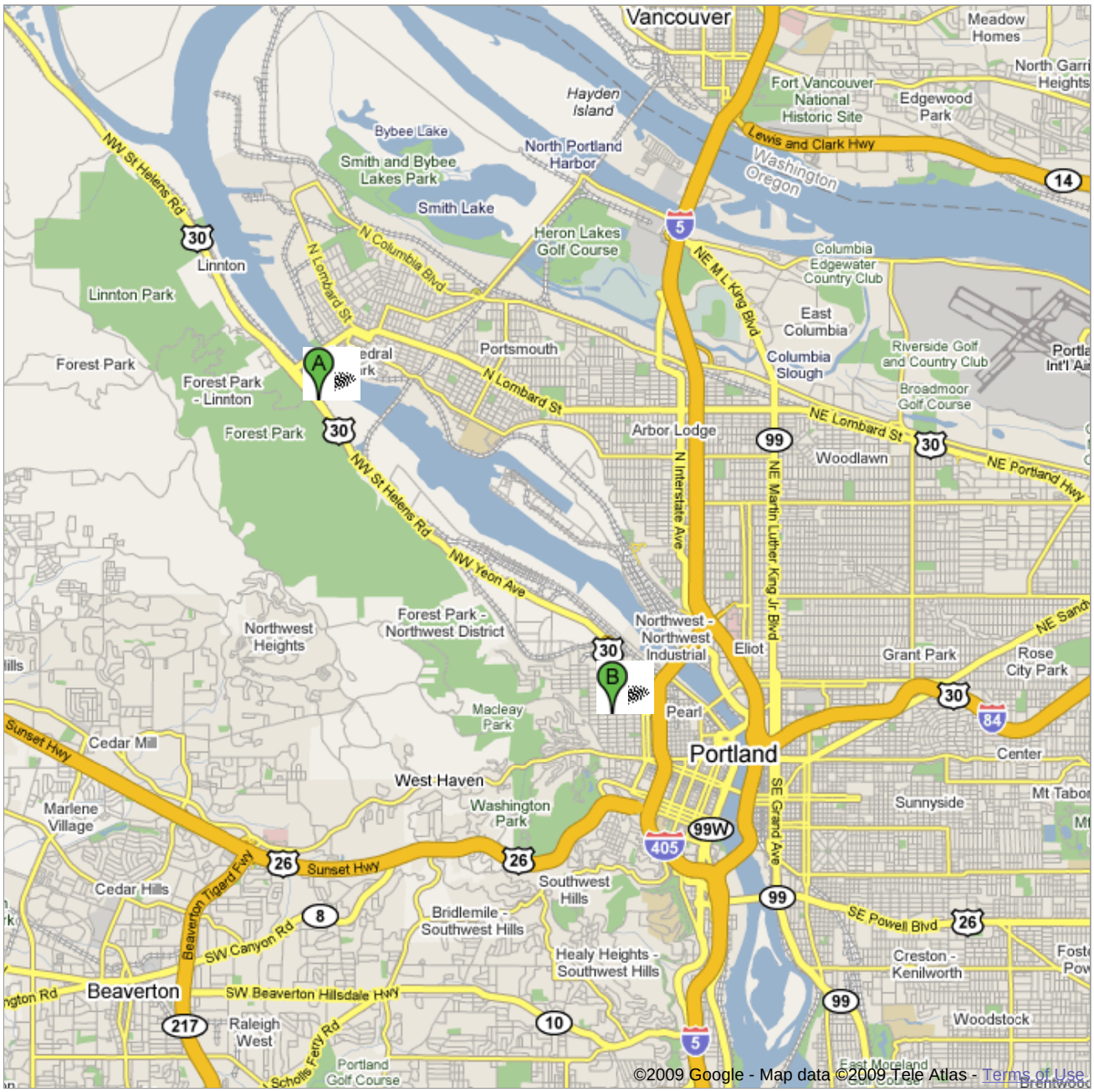
Instrument*	Job Tasks / Functions	Measurement	Monitoring Schedule[3]	Actions[1]
FID and/or PID (11.7*eV lamp) - Measures Total Organic Vapors	Conduct air monitoring for volatile organic compounds during activities where contaminated media are present. Make sure that a background reading is taken before the start up of activities and periodically thereafter.	0 - 5 ppm above background in breathing zone	Periodically (every 15-30 minutes)	Continue work
		>5 - 40 ppm above background	Periodically (every 15 minutes)	Upgrade to Level C[4] protection. Monitor for benzene using colorimetric detector tubes.
		>40 ppm above background in breathing zone		Stop work required[2]. Leave work area, contact PM for guidance
Hydrogen Cyanide Monitor	Conduct air monitoring for HCN during activities where contaminated media are present. Monitor in the workers' breathing zone.	Detectable up to 4 ppm hydrogen cyanide	Periodically (every 15 minutes)	Continue work
		>4 ppm hydrogen cyanide		Stop work required[2]. Leave work area, contact PM for guidance

*Note: Instruments must be calibrated according to manufacturer's recommendations.
[1]For VOCs, sustained reading for greater than 2 minutes in excess of the action level will trigger a protective measure.
[2]Contact with the PM must be made prior to continuance of work. A hazard review must be conducted before proceeding with work.
[3]Monitoring frequency is at beginning of each task and at specified intervals thereafter, or when detectable soil contamination is encountered (as indicated by strong, sustained odor, visual evidence of product or petroleum discolored soils).
[4]Contact the PM for respiratory protection fit testing and air purifying cartridge change-out requirements.

FIGURE

Directions to Legacy Good Samaritan Hospital & Medical Center
1015 NW 22nd Ave, Portland, OR 97210 - (503) 413-7711
6.4 mi – about **13 mins**

Save trees. Go green!
Download Google Maps on your phone at **google.com/gmm**



7900 NW St Helens Rd, Portland, OR 97210

1.	Head **northwest** on **NW St Helens Rd/US-30** toward **NW Knappton-General Rd** About 1 min	go 0.6 mi total 0.6 mi
2.	Make a **U-turn** at **NW Knappton-General Rd** Continue to follow US-30 About 8 mins	go 4.7 mi total 5.3 mi
3.	Turn **right** at **NW Nicolai St**	go 0.2 mi total 5.5 mi
4.	Turn **left** at **NW 24th Ave** About 4 mins	go 0.8 mi total 6.2 mi
5.	Turn **left** at **NW Lovejoy St** Destination will be on the left	go 0.1 mi total 6.4 mi

Legacy Good Samaritan Hospital & Medical Center
1015 NW 22nd Ave, Portland, OR 97210 - (503) 413-7711

These directions are for planning purposes only. You may find that construction projects, traffic, weather, or other events may cause conditions to differ from the map results, and you should plan your route accordingly. You must obey all signs or notices regarding your route.

Map data ©2009 , Tele Atlas

APPENDIX A
SAFETY RECORD FORMS

Field Team Health and Safety Plan Review

Anchor QEA, LLC

NW Natural Gasco Site

I have read a copy of the HASP, which covers field activities that will be conducted to investigate specified areas on and adjacent to the NW Natural Gasco Site, Portland, Oregon. I understand the health and safety requirements of the project, which are detailed in this HASP.

Signature Date

Signature Date

Signature Date

Signature Date

Signature Date

APPENDIX H
TARGOST LOGS

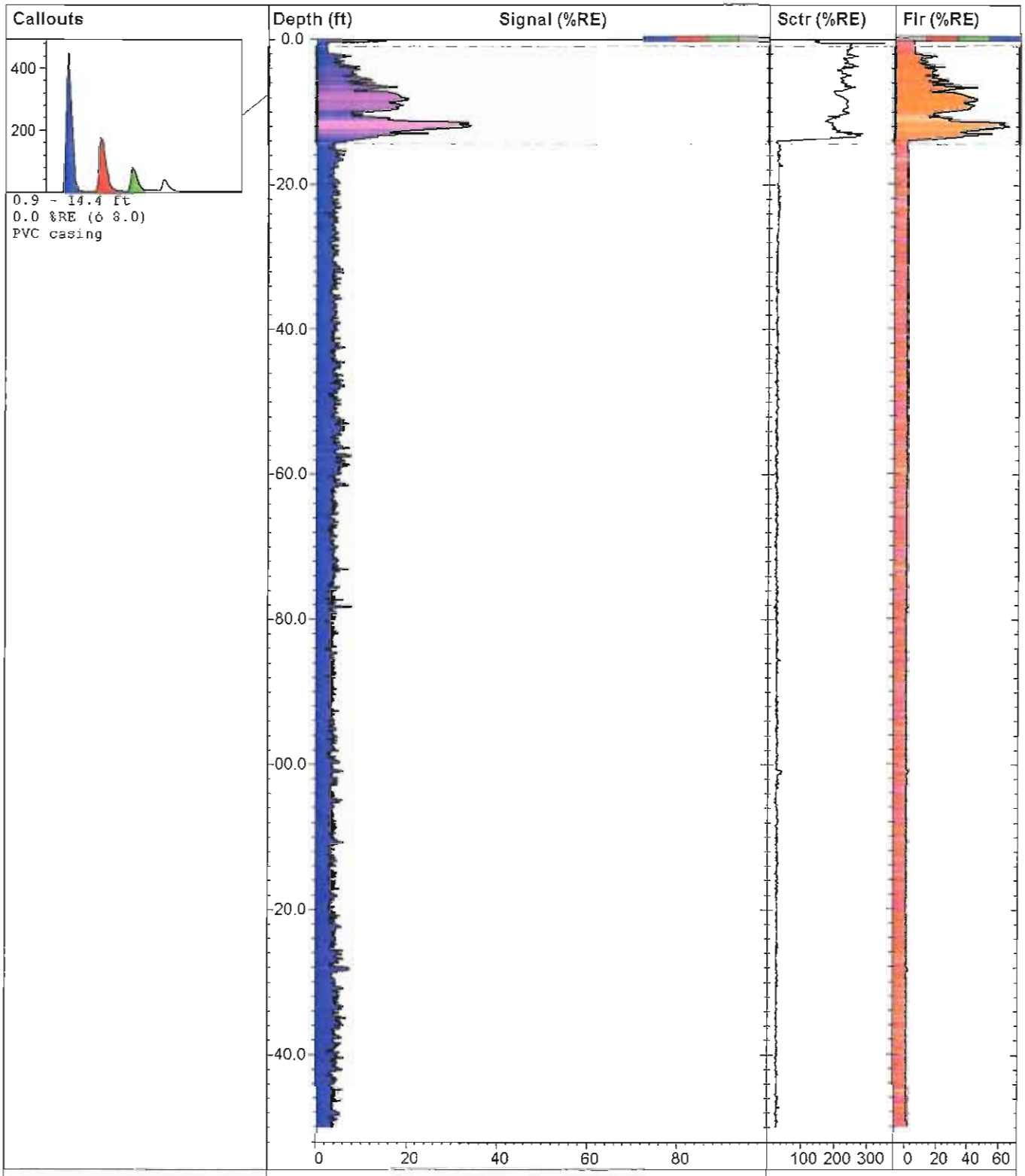
TABLE 1 - TarGOST Boring Summary

BORING	PROPERTY	DATE	COORDINATES[1] NORTHING	EASTING	GS ELEVATION (feet MSL)[2]	Fill Penetration Method[3]	Pre-Drill Hole or PVC Casing Depth (feet)[3]	Estimated Fill Thickness (feet)[4]	DEPTH (feet)
TG-1	Gasco	27-Aug-07	705521.3	7623806	19.6	PVC Casing	15	13	150.1
TG-2	Gasco	24-Aug-07	705401.7	7623941.3	32.5	PVC Casing	27	25	150.3
TG-3	Gasco	23-Aug-07	705336.2	7624102	32.5	PVC Casing	28	27	150.3
TG-4	Gasco	26-Aug-07	705276.1	7624230.2	28.6	PVC Casing	30	20	150
TG-5	Gasco	26-Aug-07	705198.1	7624321.9	25.3	PVC Casing	20	16	99.1
TG-5A	Gasco	9-Sep-07	705187.5	7624332.5	25.3	PVC Casing	20	16	150.3
TG-6	Gasco	28-Aug-07	705594.2	7623523.2	21.5	PVC Casing	5	10	125.5
TG-7	Gasco	24-Aug-07	705316.3	7623879.7	33.7	PVC Casing	30	25	150.4
TG-8	Gasco	25-Aug-07	705110.4	7624222.5	36.7	PVC Casing	25	25	150.2
TG-9	Gasco	28-Mar-08	705454.6	7623852.7	31.4	Pre-Drill Hole	26.0	27	148.2
TG-10	Gasco	29-Mar-08	705258.1	7624361.7	25.0	PVC Casing	19.0	16	150.9
TG-11	Gasco	29-Mar-08	705189.6	7624150.2	36.9	TarGOST	-	25	150.2
TG-12	Gasco	28-Mar-08	705032.5	7624318.8	27.0	TarGOST	-	25	149.5
TG-13	Gasco	30-Mar-08	704889.6	7624102.7	36.1	Pre-Drill Hole	24.0	26.5	101.7
TG-14	Gasco	28-Mar-08	704736.1	7624073.5	34.1	TarGOST	-	23	100.5
TG-15	Gasco	29-Mar-08	705332.3	7623961.9	33.6	TarGOST	-	22.5	149.4
TG-16	Gasco	30-Mar-08	705157.6	7623823.8	35.6	TarGOST	-	26.5	149.1
TG-1S	Siltronic	5-Sep-07	705123.1	7624613.2	35.2	PVC Casing	30.0	31	151.3
TG-2S	Siltronic	7-Sep-07	704953.2	7624856.6	35.7	PVC Casing	38.0	32-37	151
TG-3S	Siltronic	8-Sep-07	704877.7	7624265.5	35.0	PVC Casing	34.0	38	150.2
TG-4S	Siltronic	7-Sep-07	705112.8	7624436.7	33.6	PVC Casing	36.0	30	150.3
TG-5S	Siltronic	6-Sep-07	704719.1	7624443.6	34.5	PVC Casing	30.0	<30	150.6
TG-6S	Siltronic	8-Sep-07	704598.5	7624577.8	34.6	PVC Casing	36.0	30	149.8
TG-7S	Siltronic	26-Mar-08	705069.4	7624690.9	35.3	Pre-Drill Hole	26.0	28.5	150
TG-8S	Siltronic	31-Aug-07	704895.4	7624770.2	35.2	Pre-Drill Hole	23.0	23	146.8
TG-9S	Siltronic	26-Mar-08	704601.9	7624289.8	34.8	PVC Casing	31.0	30	101.3
TG-10S	Siltronic	26-Mar-08	704397.8	7624017.4	37.1	PVC Casing	18.0	20.2	90.5
TG-11S	Siltronic	26-Mar-08	704290.4	7624227.4	34.9	PVC Casing	22.5	25	78.5
TG-12S	Siltronic	27-Mar-08	705195.5	7624494.2	34.0	TarGOST	-	31	156

Notes: 1 = State Plane Coordinates, NAD83
2 = City of Portland Datum
3 = TarGOST data collected across depth interval of PVC casing or a pre-drilled open hole are not usable.
4 = Fill thickness estimate is based on co-located / nearby boring, or in certain cases depth to silt was verified as part of TarGOST pre-drill or casing emplacement.

TARGOST BORING LOGS

TG-1 THROUGH TG-16
NW NATURAL – GASCO PROPERTY



TG001		**TarGOST By Dakota** www.DakotaTechnologies.com
Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 150.10 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 34.1 % @ 11.43 ft
Job: 2708	*Operator/Unit:* Steve Adamek/DTI01	*Date & Time:* 8/27/2007 8:48:44 AM

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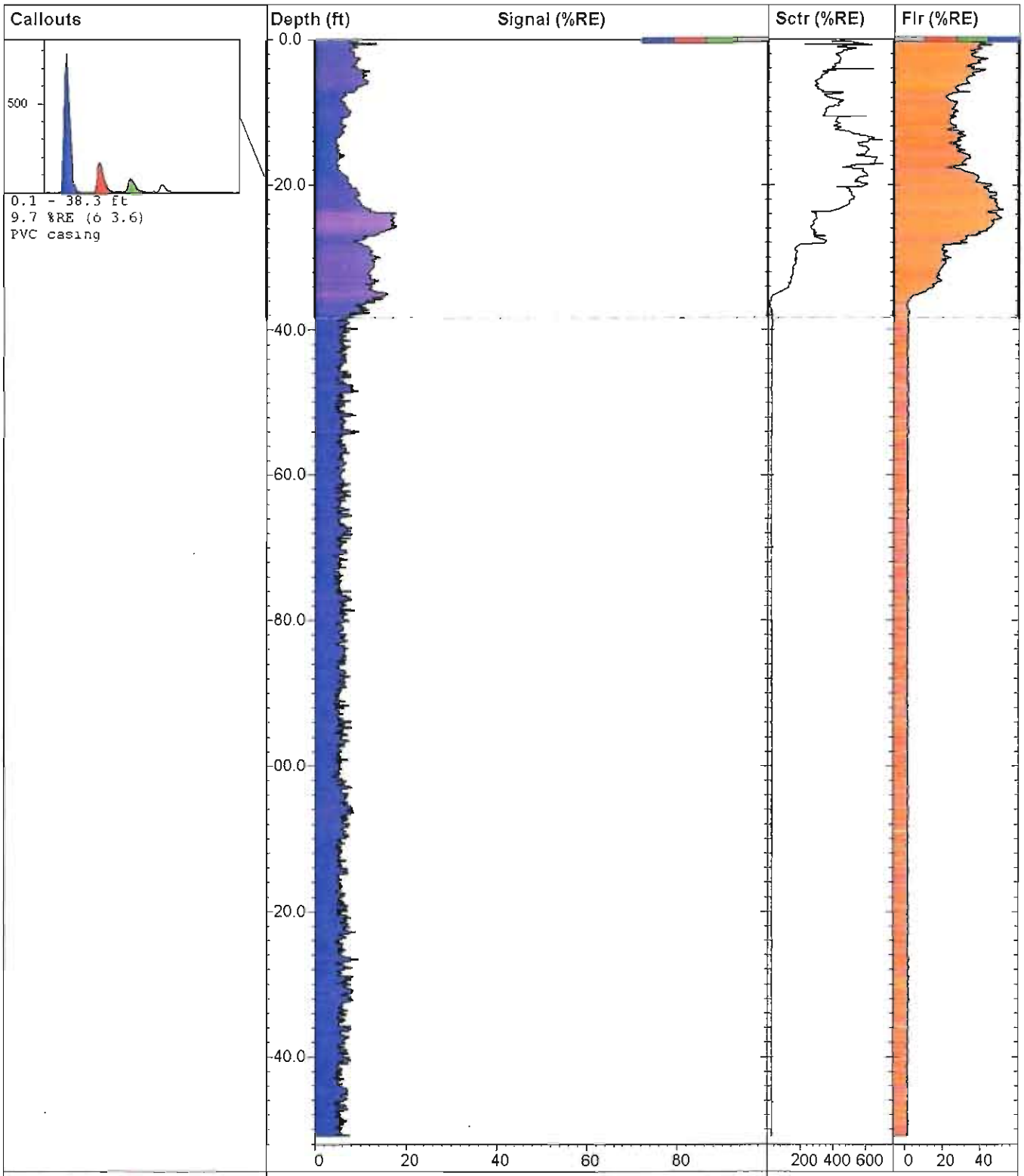

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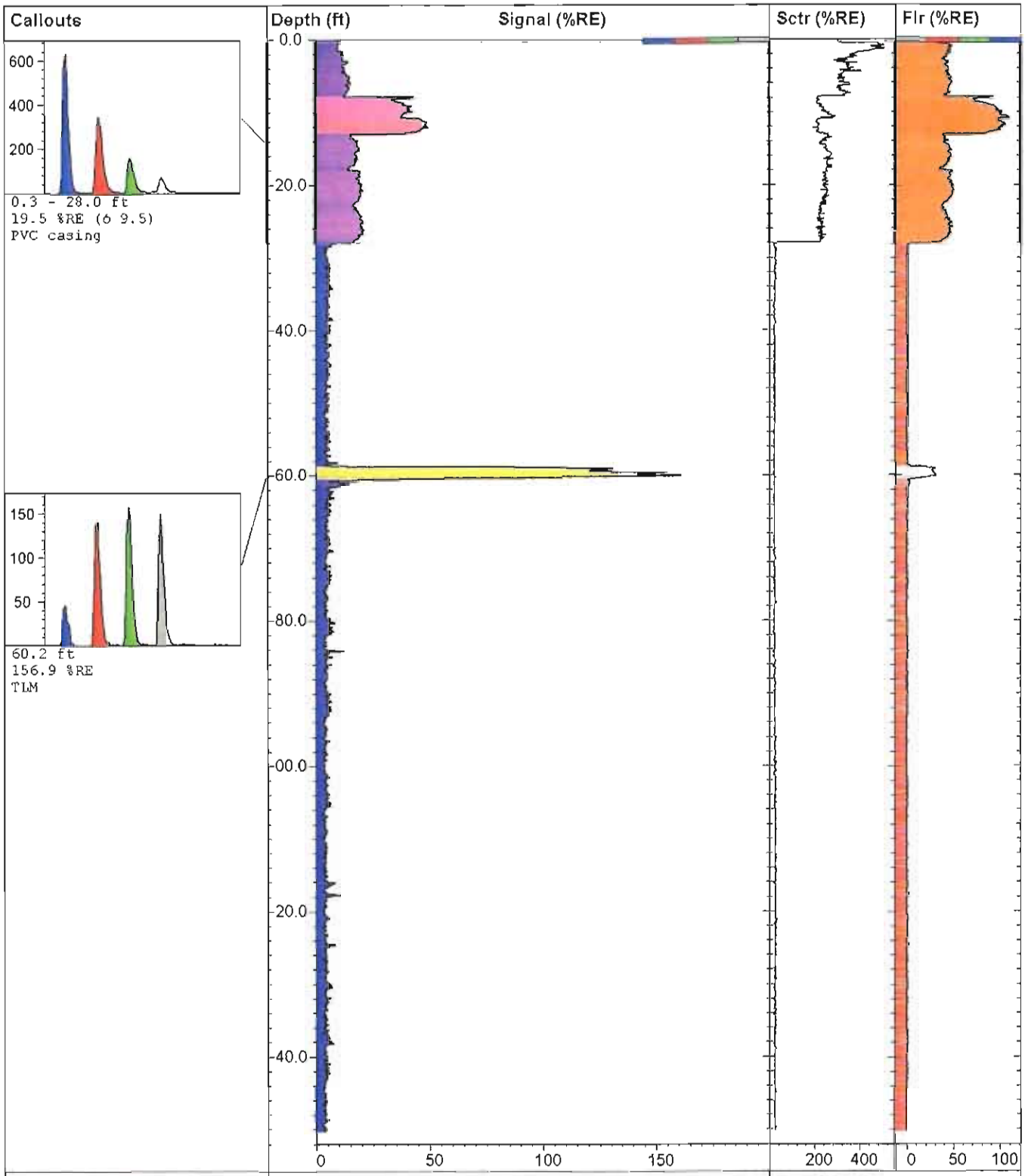
www.DakotaTechnologies.com

TG02Sc		TarGOST By Dakota www.DakotaTechnologies.com
Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 151.04 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 19.4 % @ 35.72 ft
Job: 2708	*Operator/Unit:* Steve Adamek/DTI01	*Date & Time:* 9/7/2007 10:14:17 AM



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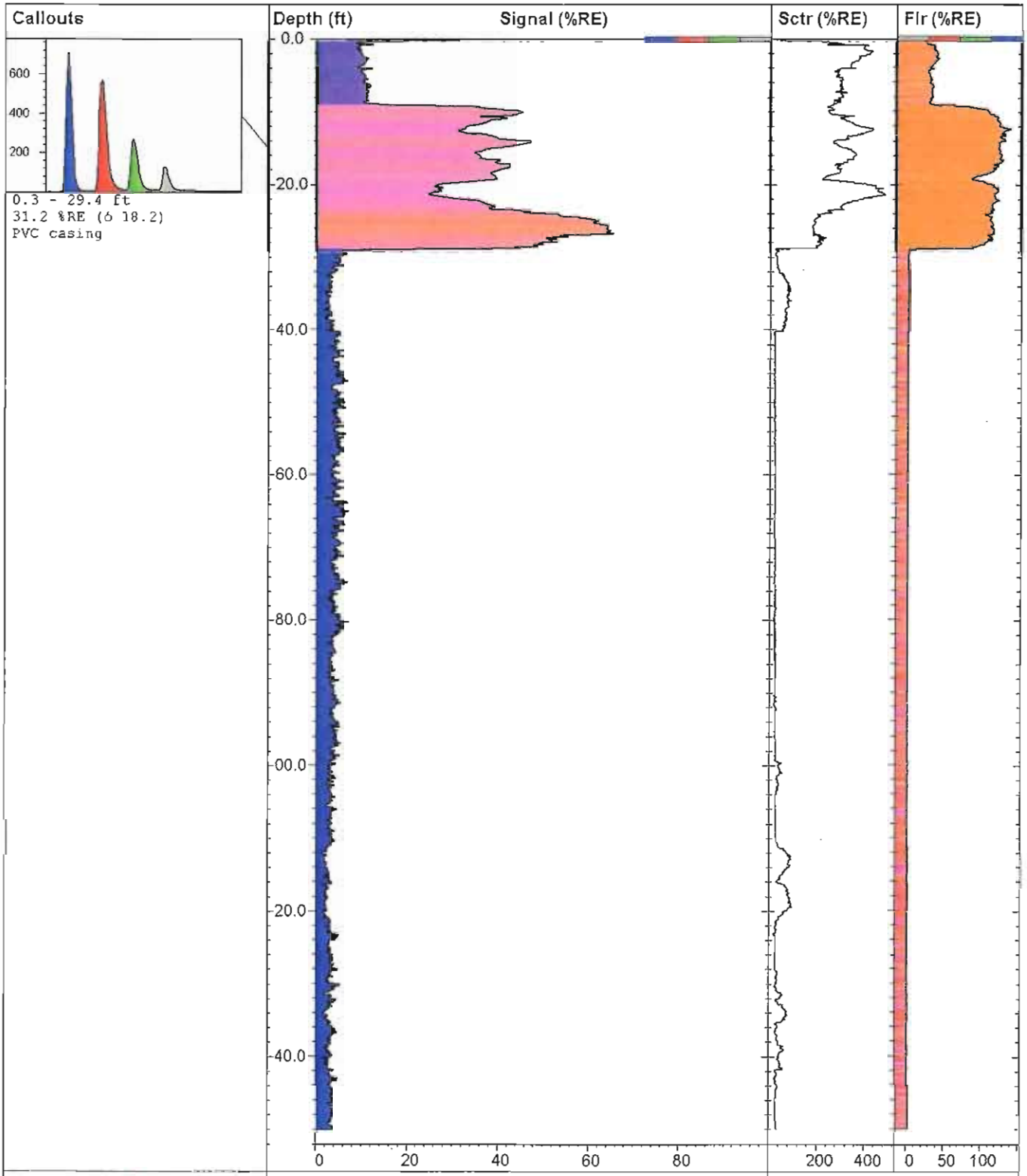
TG003

TarGOST By Dakota
www.DakotaTechnologies.com

Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 150.32 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 165.2 % @ 59.93 ft
Job: 2708	*Operator/Unit:* Steve Adamek/DTI01	*Date & Time:* 8/23/2007 10:06:34 AM



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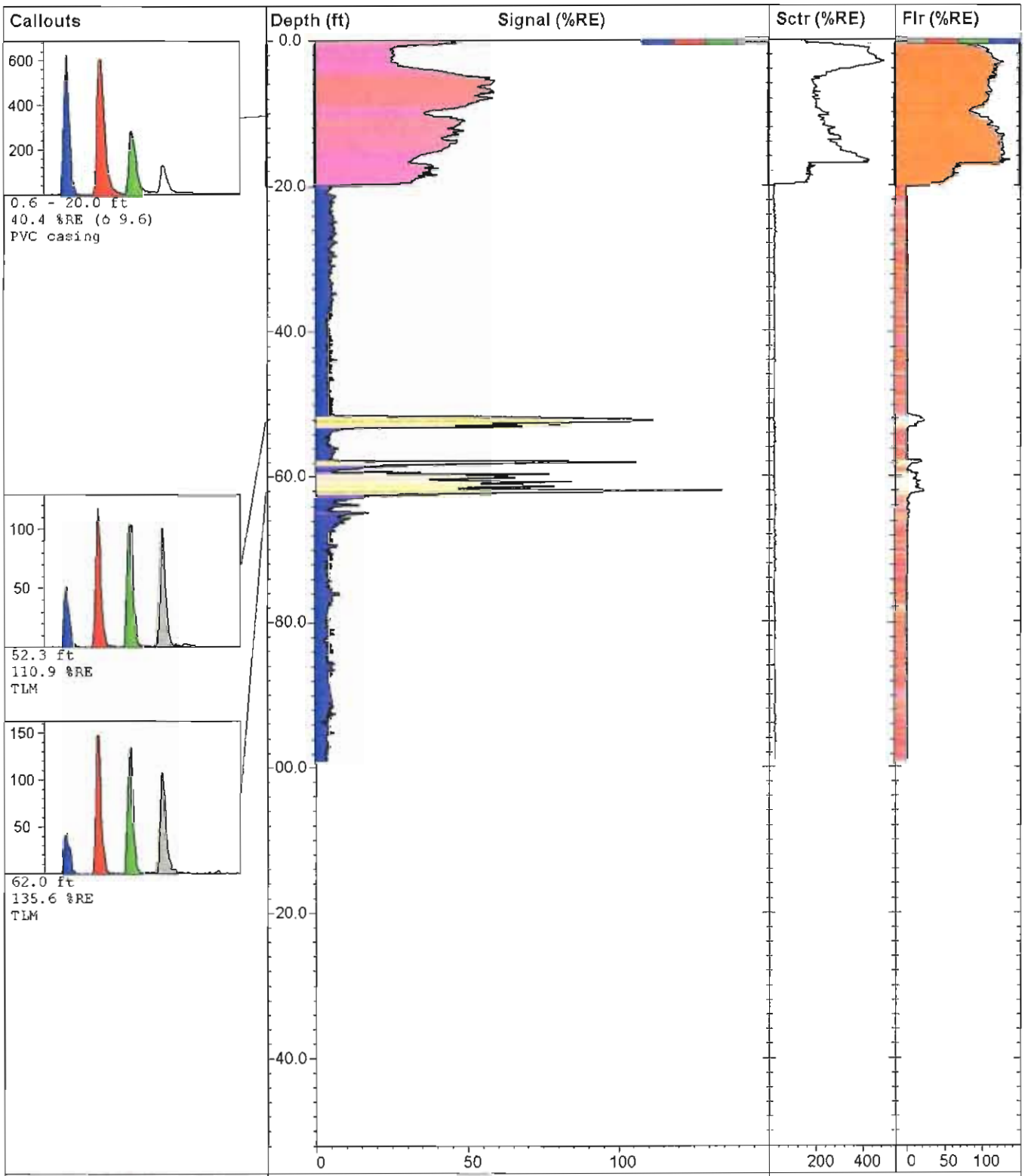
TG004

TarGOST By Dakota
www.DakotaTechnologies.com

Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 150.01 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 66.1 % @ 26.64 ft
Job: 2708	*Operator/Unit:* Steve Adamek/DTI01	*Date & Time:* 8/26/2007 12:05:47 PM



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TG005

TarGOST By Dakota
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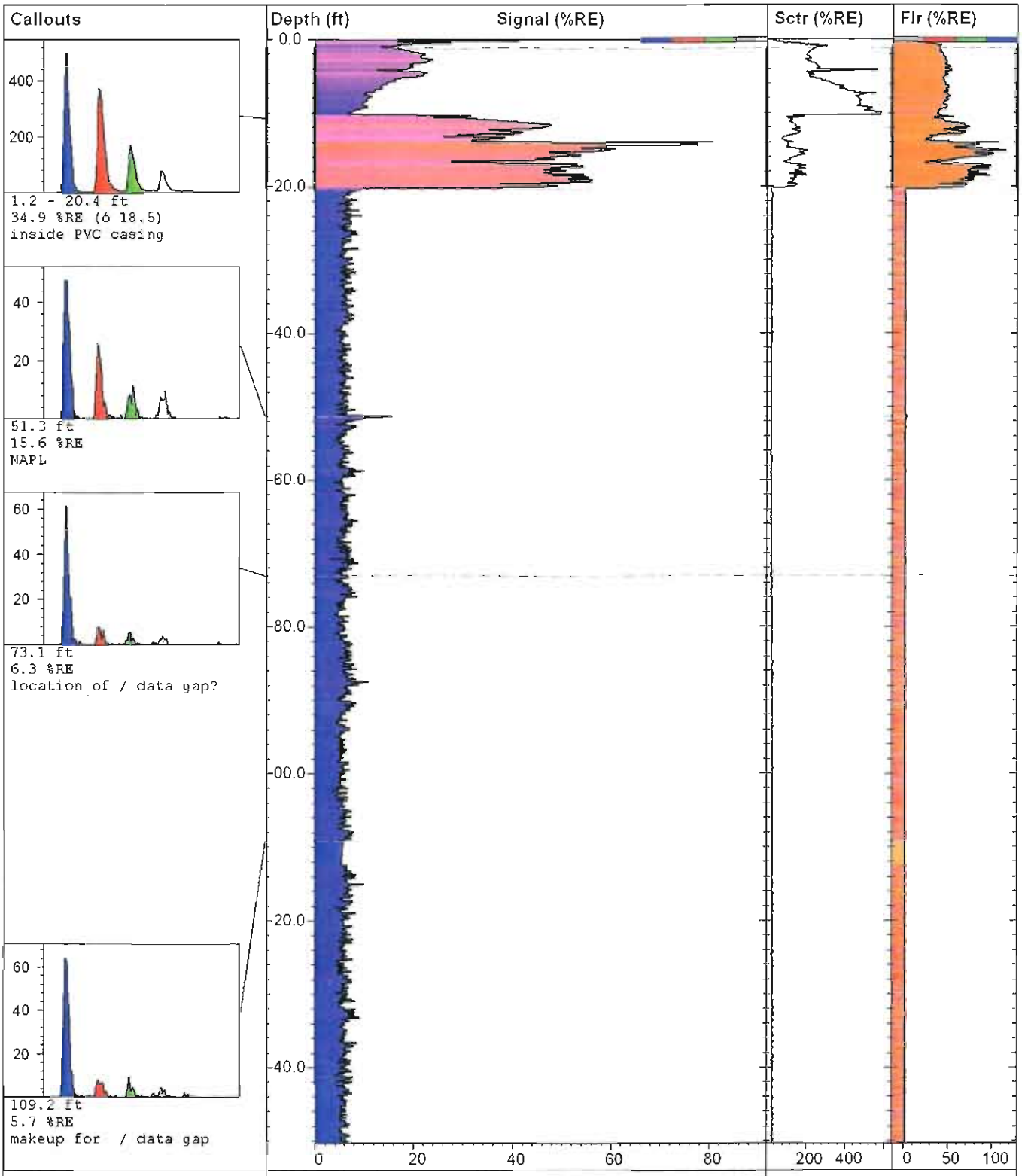
Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 99.06 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 135.6 % @ 61.97 ft
Job: 2708	*Operator/Unit:* Steve Adamek/DTI01	*Date & Time:* 8/26/2007 8:10:34 AM



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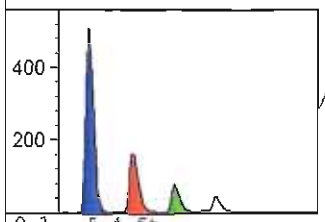
TG005A

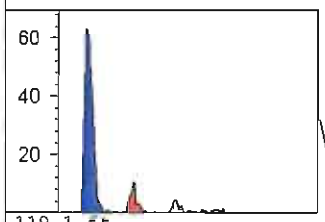
TarGOST

Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 150.27 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 83.3 % @ 13.99 ft
Job: 2708	*Operator/Unit:* Steve Adamek/DTI01	*Date & Time:* 9/9/2007 8:16:33 AM

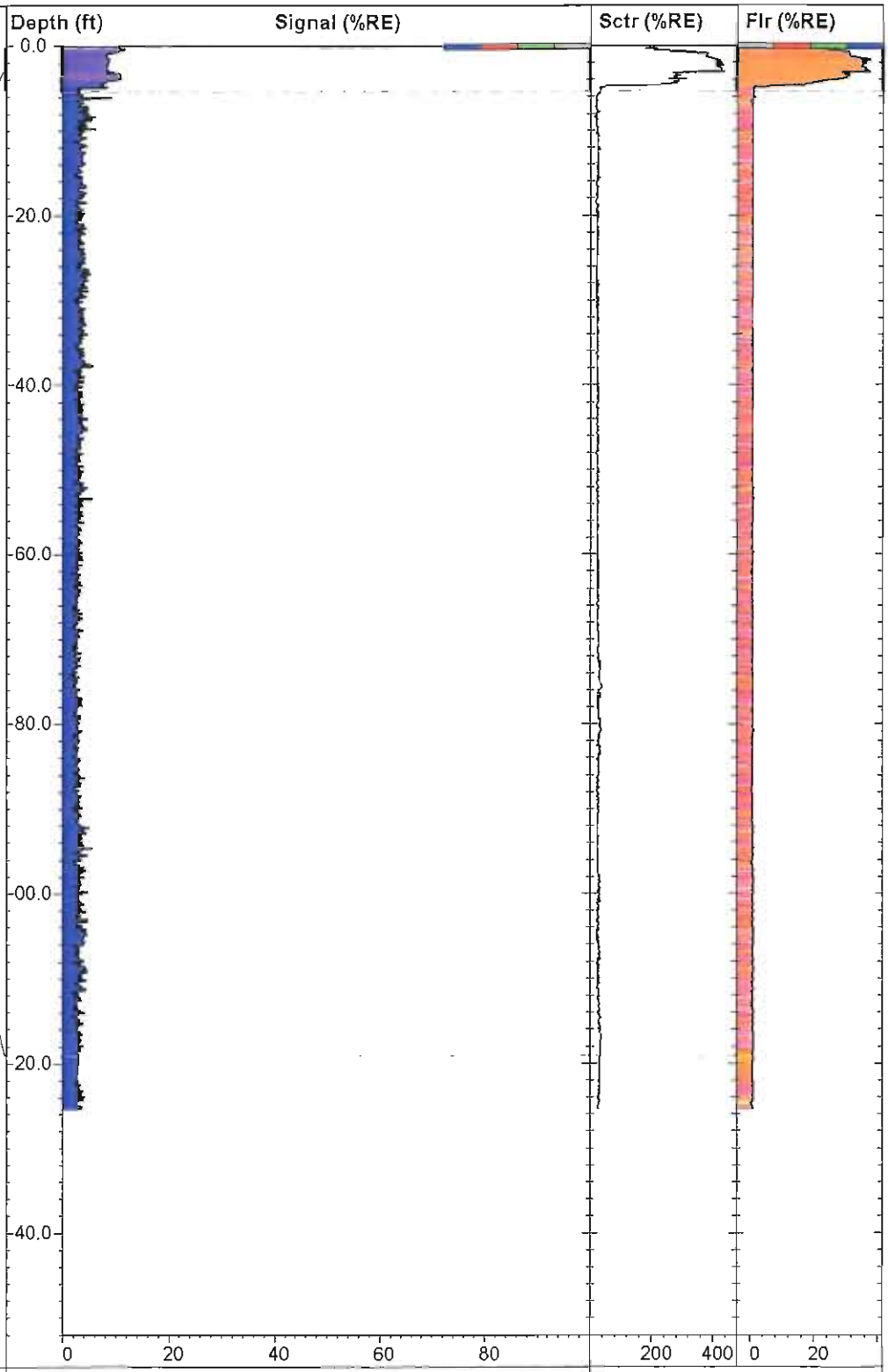
Callouts



0.1 - 5.4 ft
9.3 %RE (6 2.6)
PVC casing



119.1 ft
3.0 %RE
compensated for 1M / of
missing data



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TG006

TarGOST By Dakota
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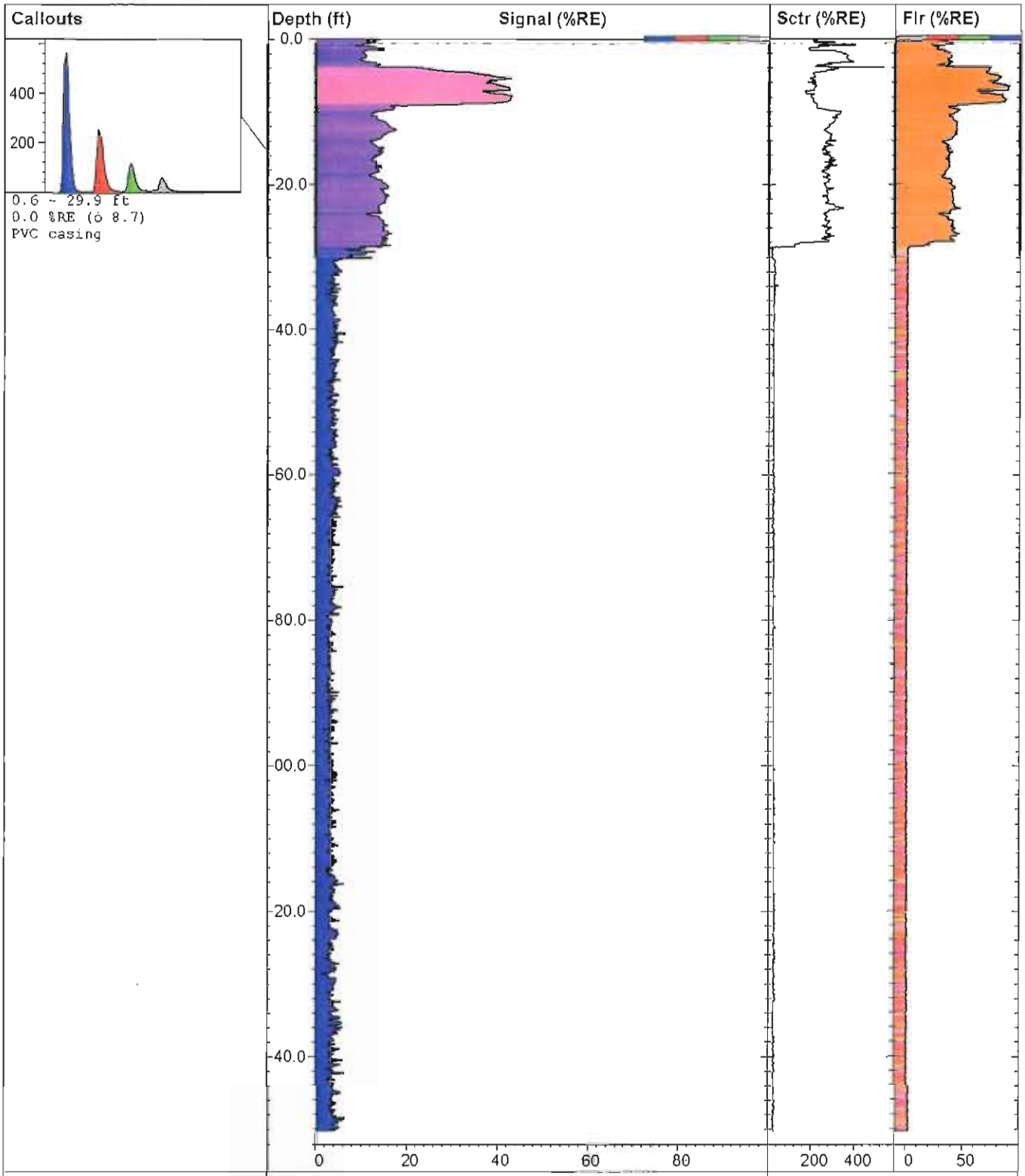
Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 125.50 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 12.8 % @ 0.39 ft
Job: 2708	*Operator/Unit:* Steve Adamek/DTI01	*Date & Time:* 8/28/2007 1:01:59 AM



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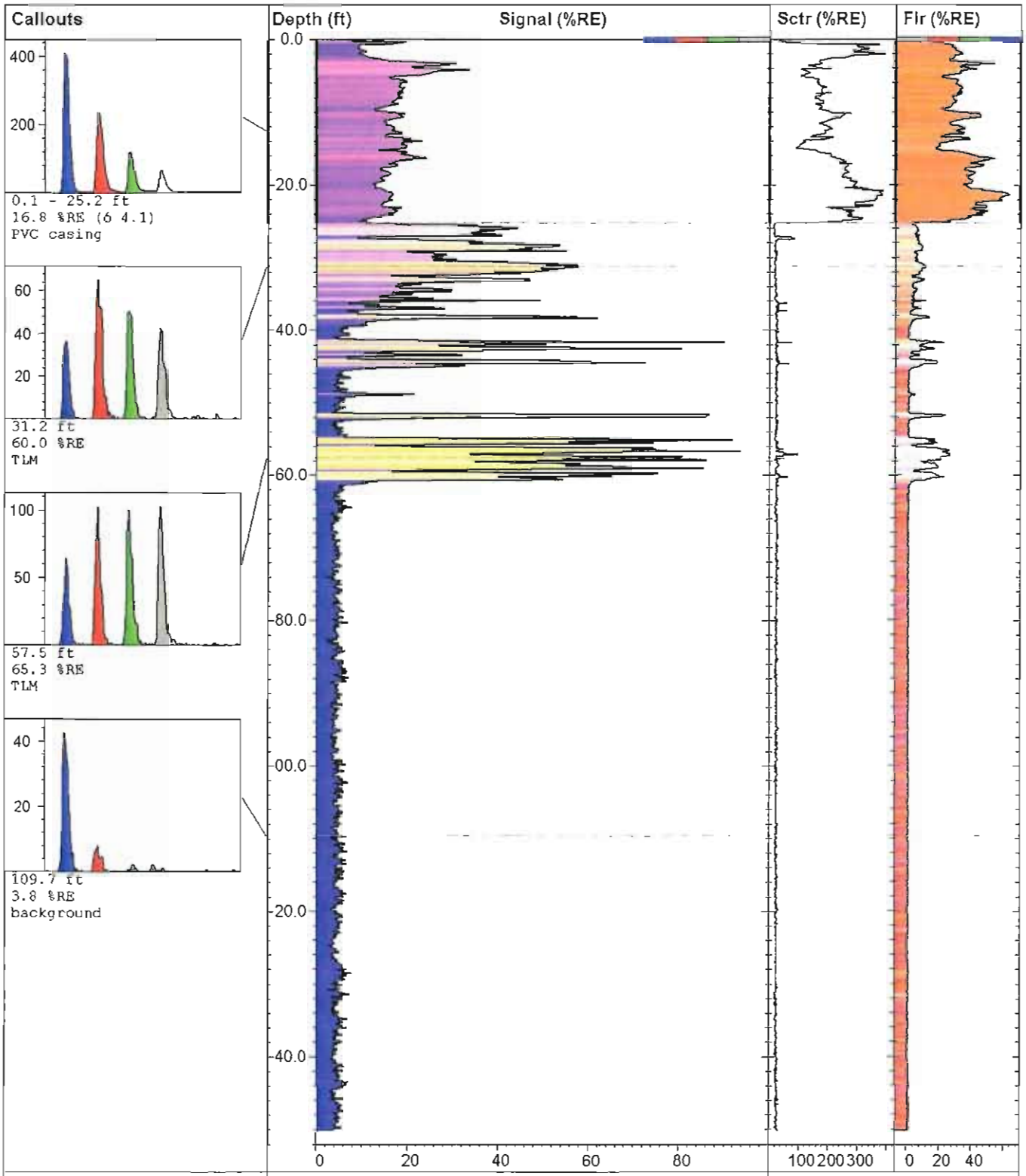
TG007

TarGOST By Dakota
www.DakotaTechnologies.com

Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 150.37 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 43.1 % @ 7.77 ft
Job: 2708	*Operator/Unit:* Steve Adamek/DTI01	*Date & Time:* 8/24/2007 1:53:18 PM



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TG008

TarGOST By Dakota
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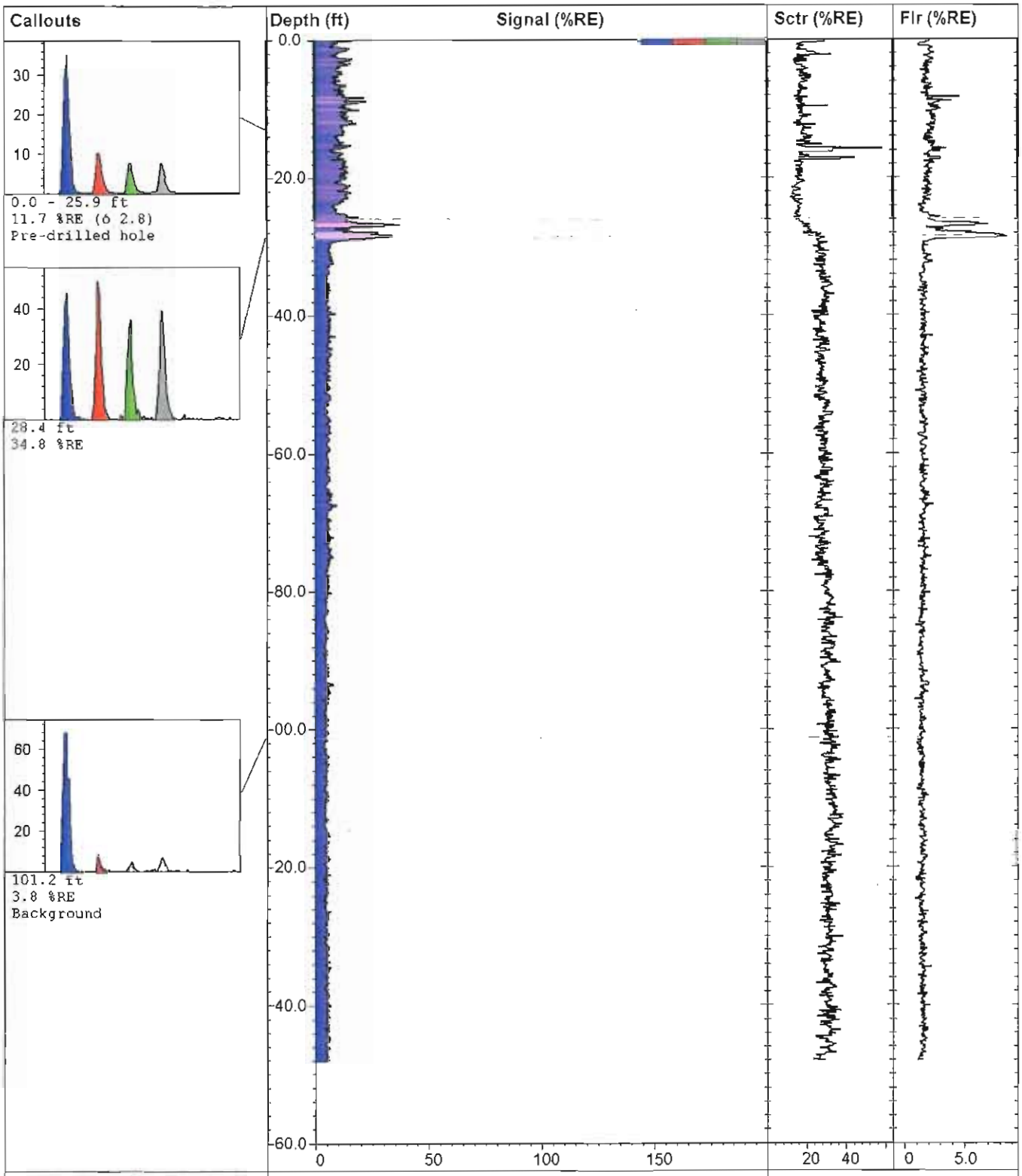
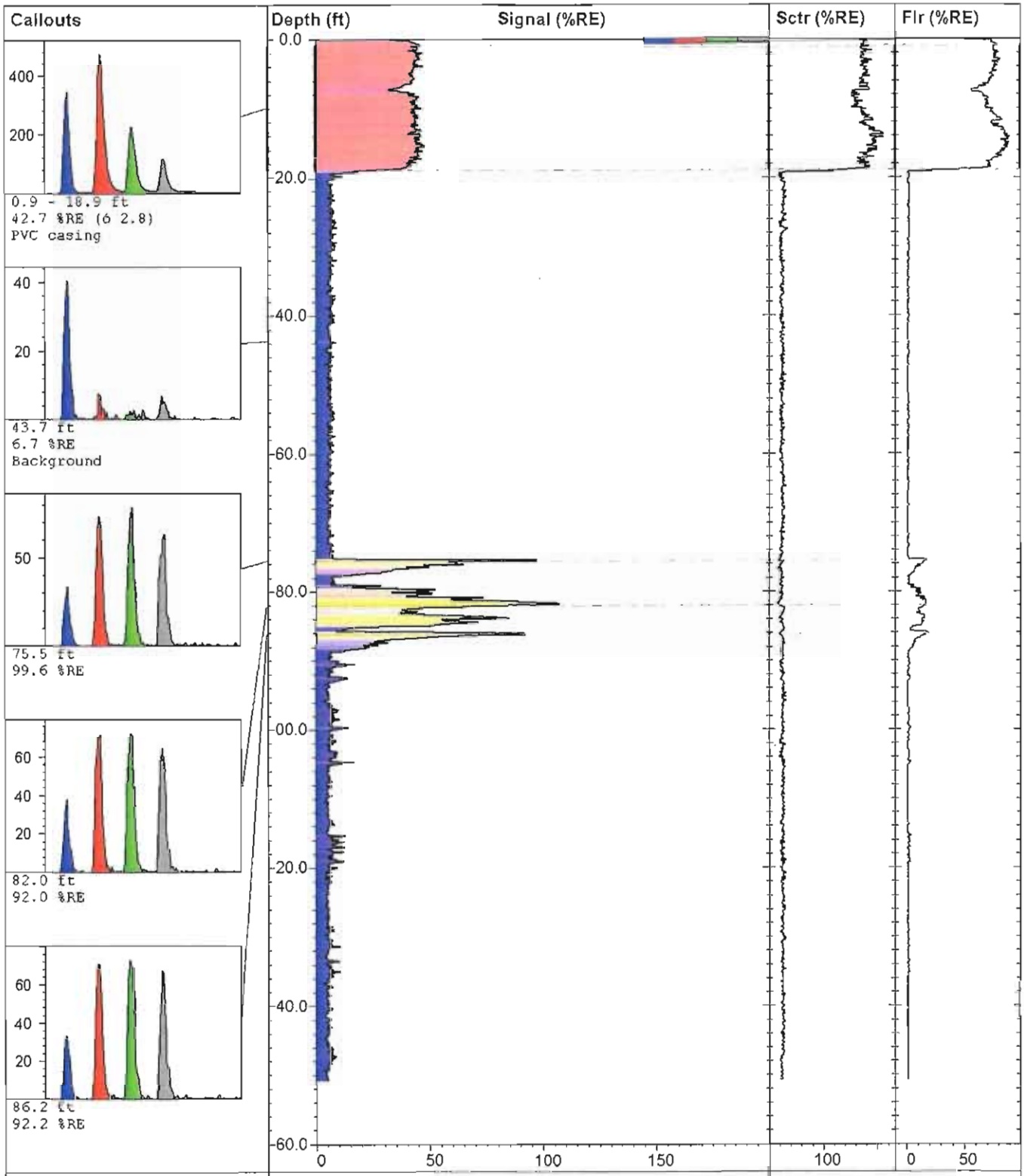
Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 150.16 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 102.3 % @ 41.66 ft
Job: 2708	*Operator/Unit:* Steve Adamek/DTI01	*Date & Time:* 8/25/2007 8:26:38 AM



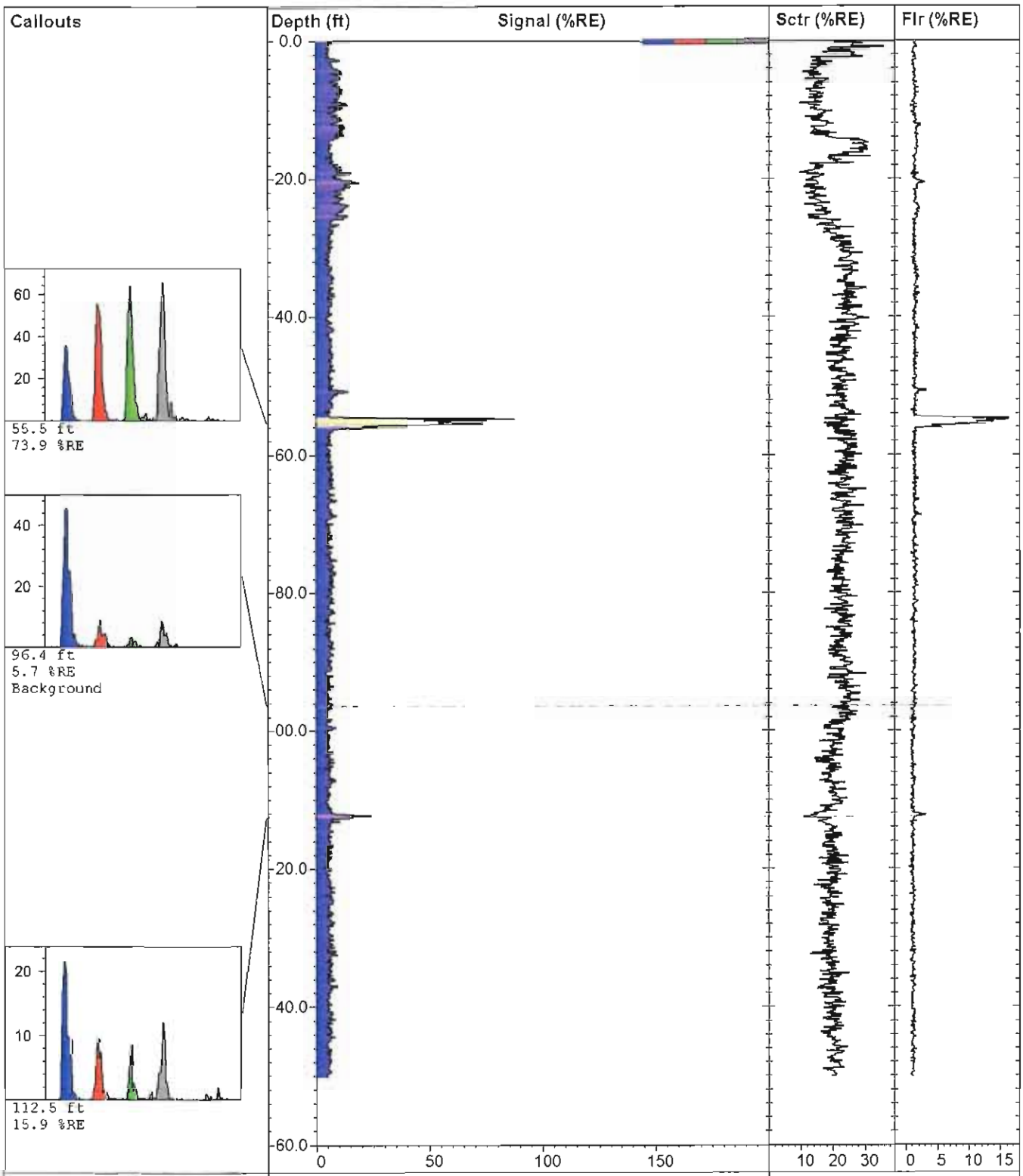
TG-9		**TarGOST By Dakota** www.DakotaTechnologies.com
Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 148.18 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 38.9 % @ 26.75 ft
Job:	*Operator/Unit:* T.Rudolph/DTI01	*Date & Time:* 3/28/2008 2:18:09 PM



TG-10

TarGOST By Dakota
www.DakotaTechnologies.com

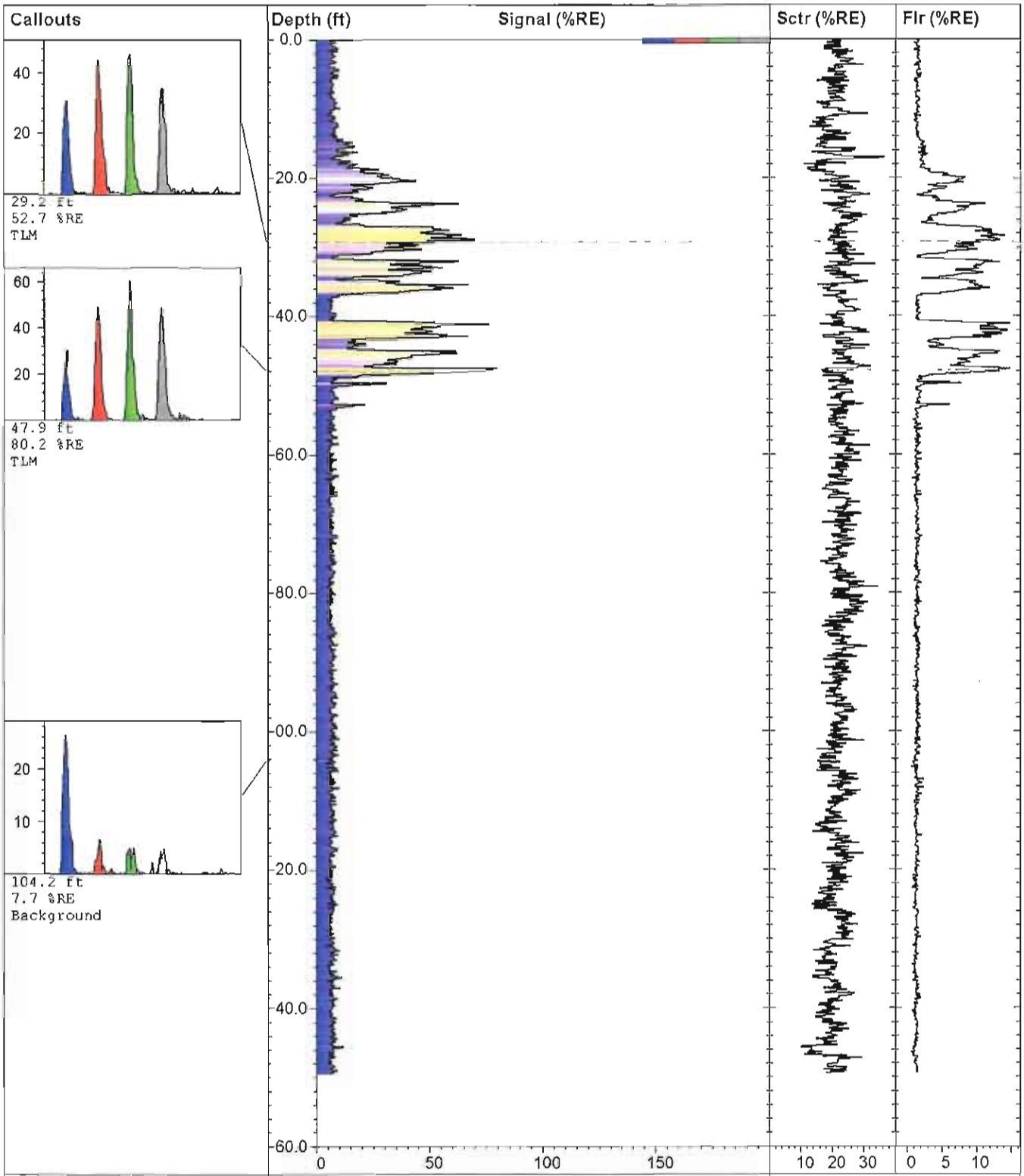
Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 150.85 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 107.3 % @ 81.81 ft
Job:	*Operator/Unit:* T.Rudolph/DTI01	*Date & Time:* 3/29/2008 3:24:36 PM



TG-11

TarGOST By Dakota
www.DakotaTechnologies.com

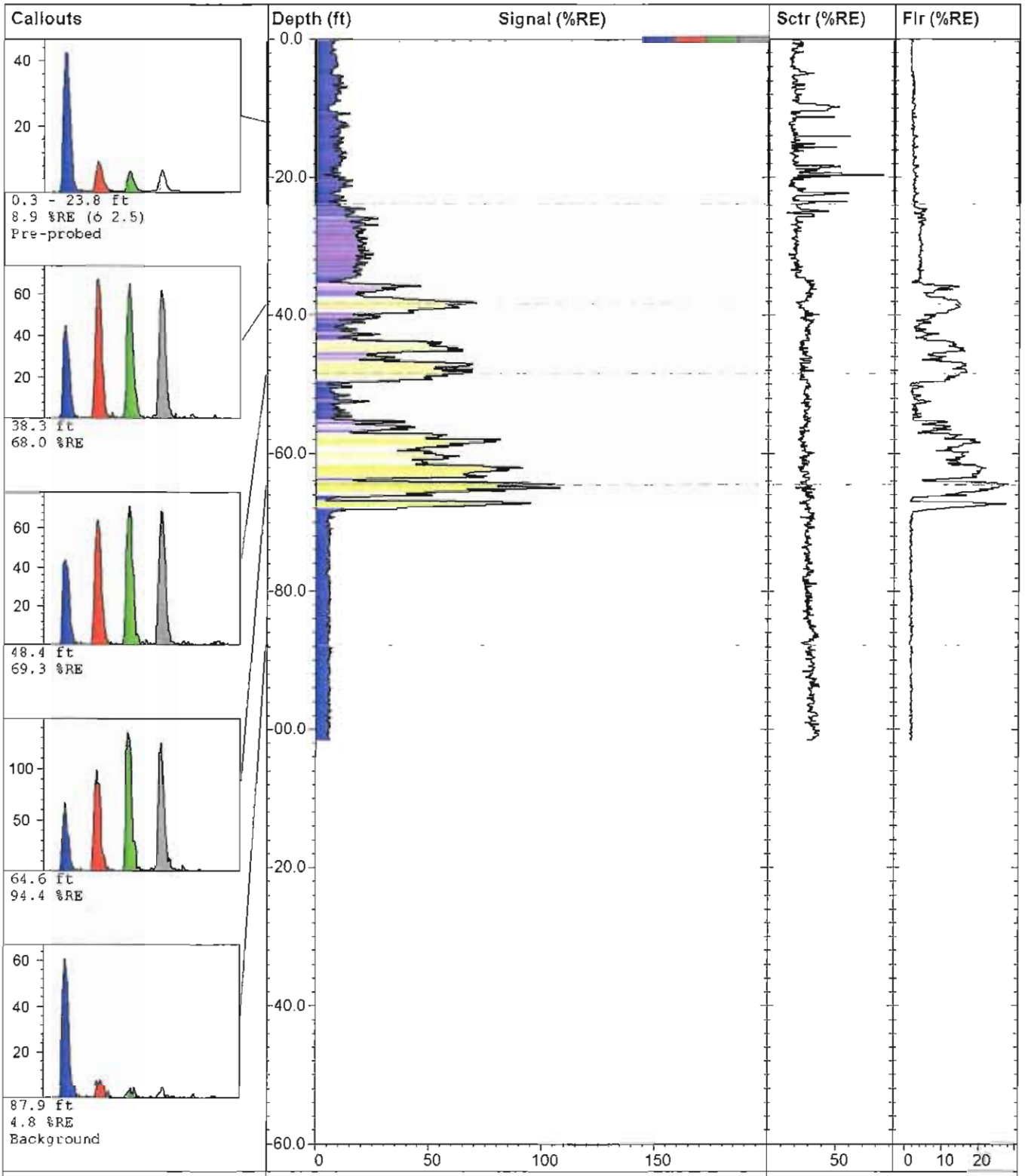
Site: **Portland, OR MGP**	*Latitude / System:* **Unavailable / NAD83**	*Final depth:* **150.18 ft**
Client: **Hahn & Associates, Inc.**	*Longitude:* **Unavailable**	*Max signal:* **94.0 % @ 54.78 ft**
Job:	*Operator/Unit:* **T.Rudolph/DTI01**	*Date & Time:* **3/29/2008 9:26:04 AM**



TG-12

TarGOST By Dakota
www.DakotaTechnologies.com

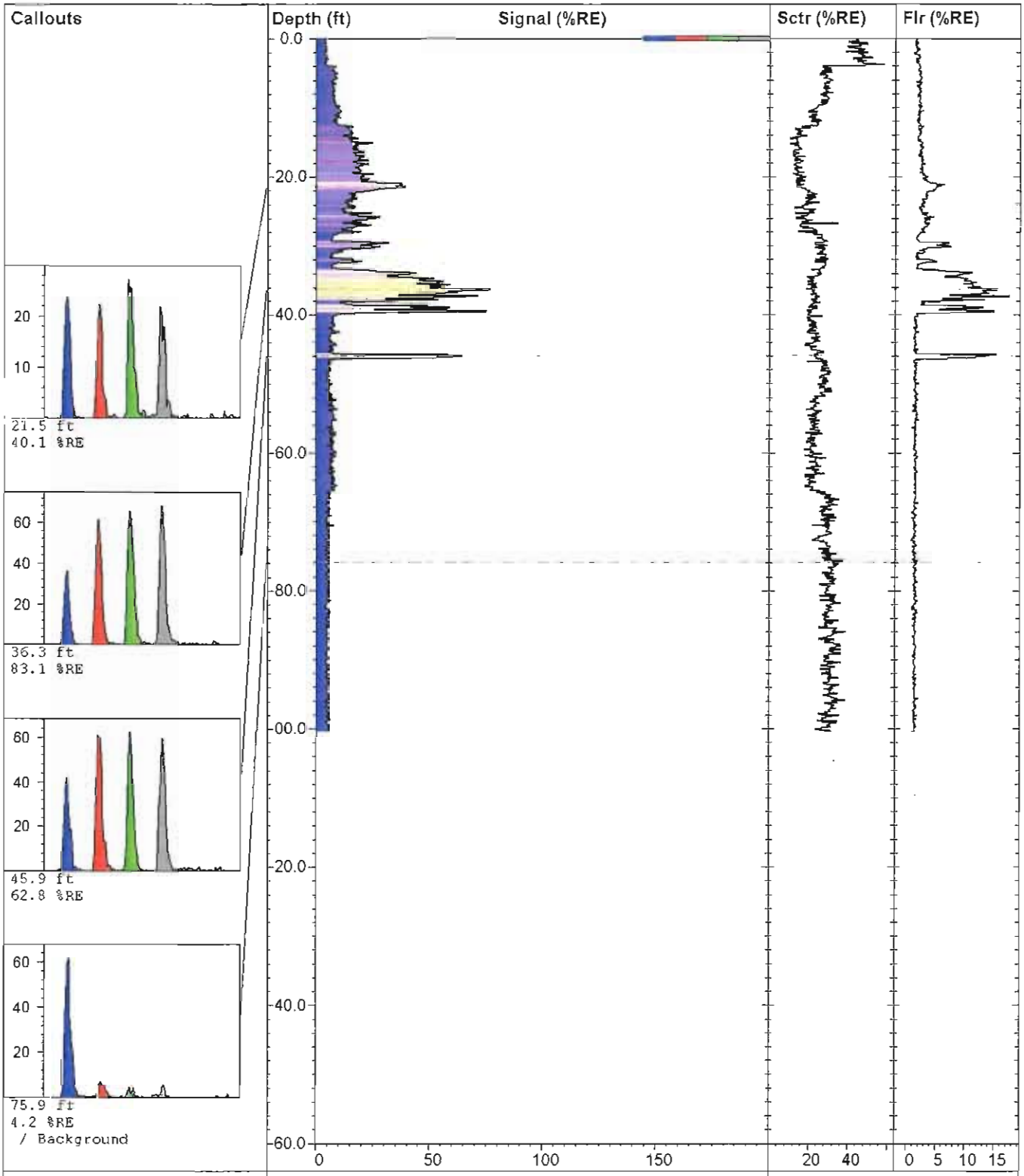
Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 149.52 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 82.7 % @ 47.61 ft
Job:	*Operator/Unit:* T.Rudolph/DTI01	*Date & Time:* 3/28/2008 9:51:28 AM



TG-13

TarGOST By Dakota
www.DakotaTechnologies.com

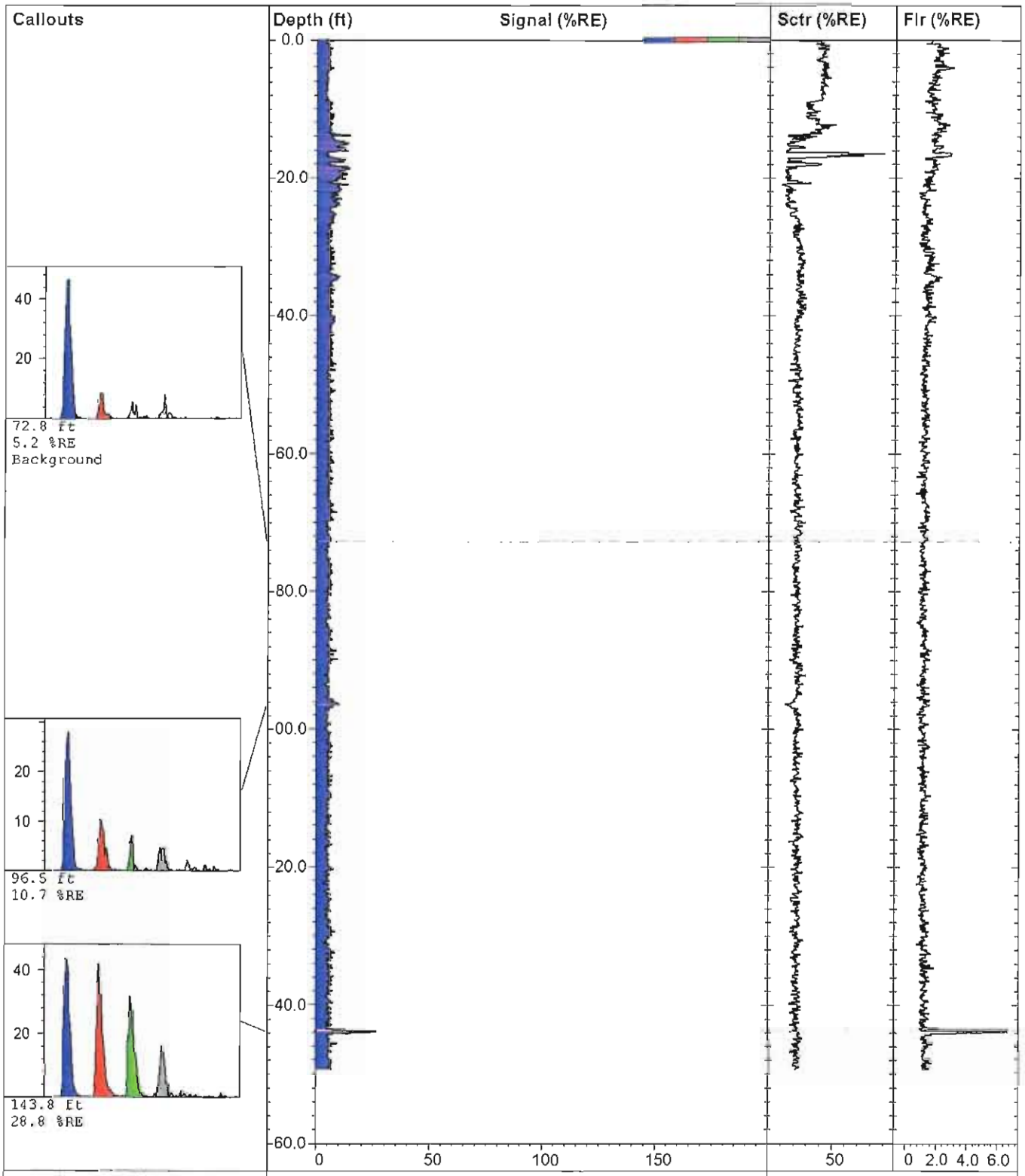
Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 101.70 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 113.6 % @ 64.97 ft
Job:	*Operator/Unit:* T.Rudolph/DTI01	*Date & Time:* 3/30/2008 1:52:57 PM



TG-14

TarGOST By Dakota
www.DakotaTechnologies.com

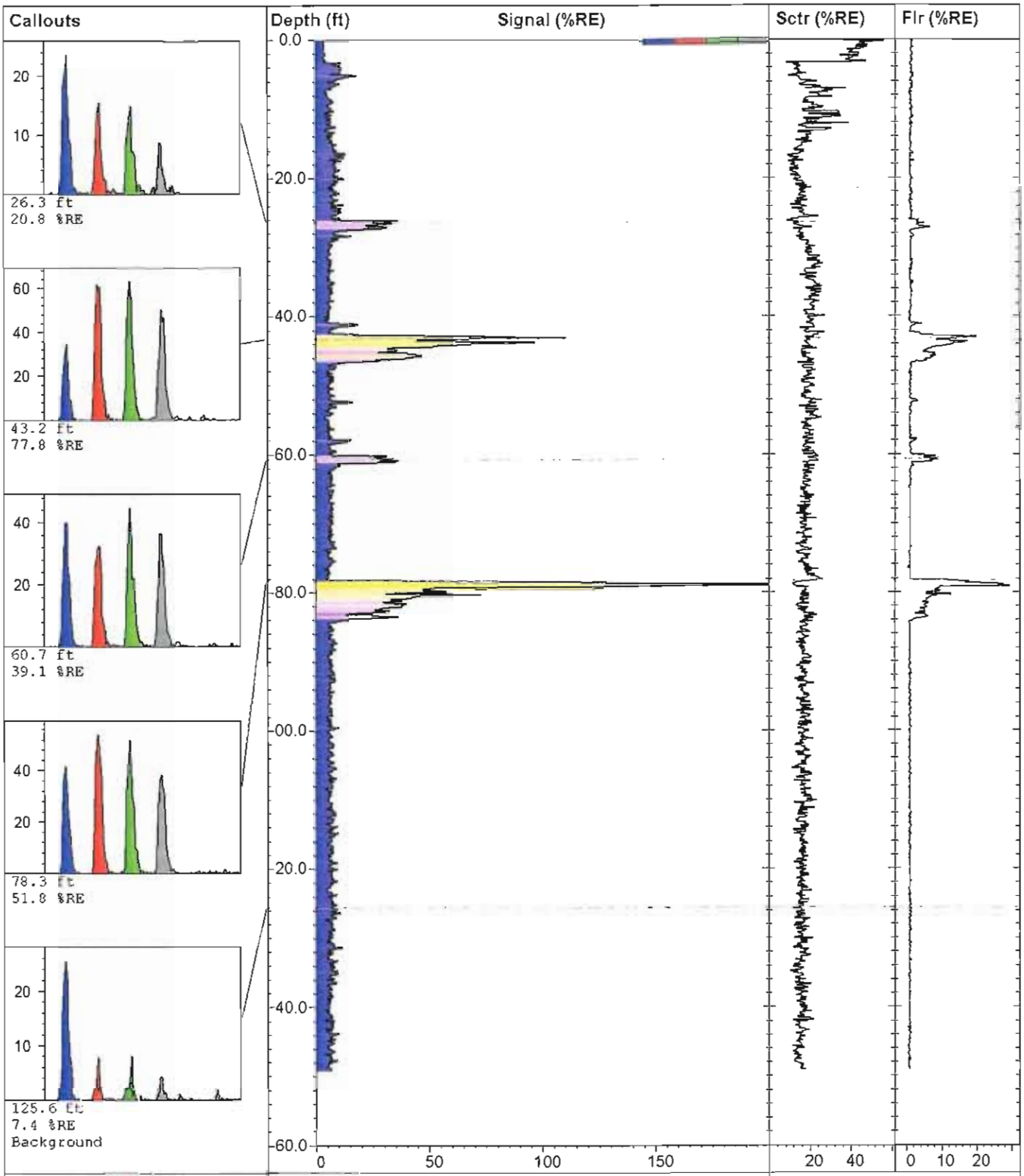
Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 100.48 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 83.1 % @ 36.28 ft
Job:	*Operator/Unit:* T.Rudolph/DTI01	*Date & Time:* 3/28/2008 12:23:14 PM



TG-15

TarGOST By Dakota
www.DakotaTechnologies.com

Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 149.42 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 28.8 % @ 143.81 ft
Job:	*Operator/Unit:* T.Rudolph/DTI01	*Date & Time:* 3/29/2008 1:16:56 PM



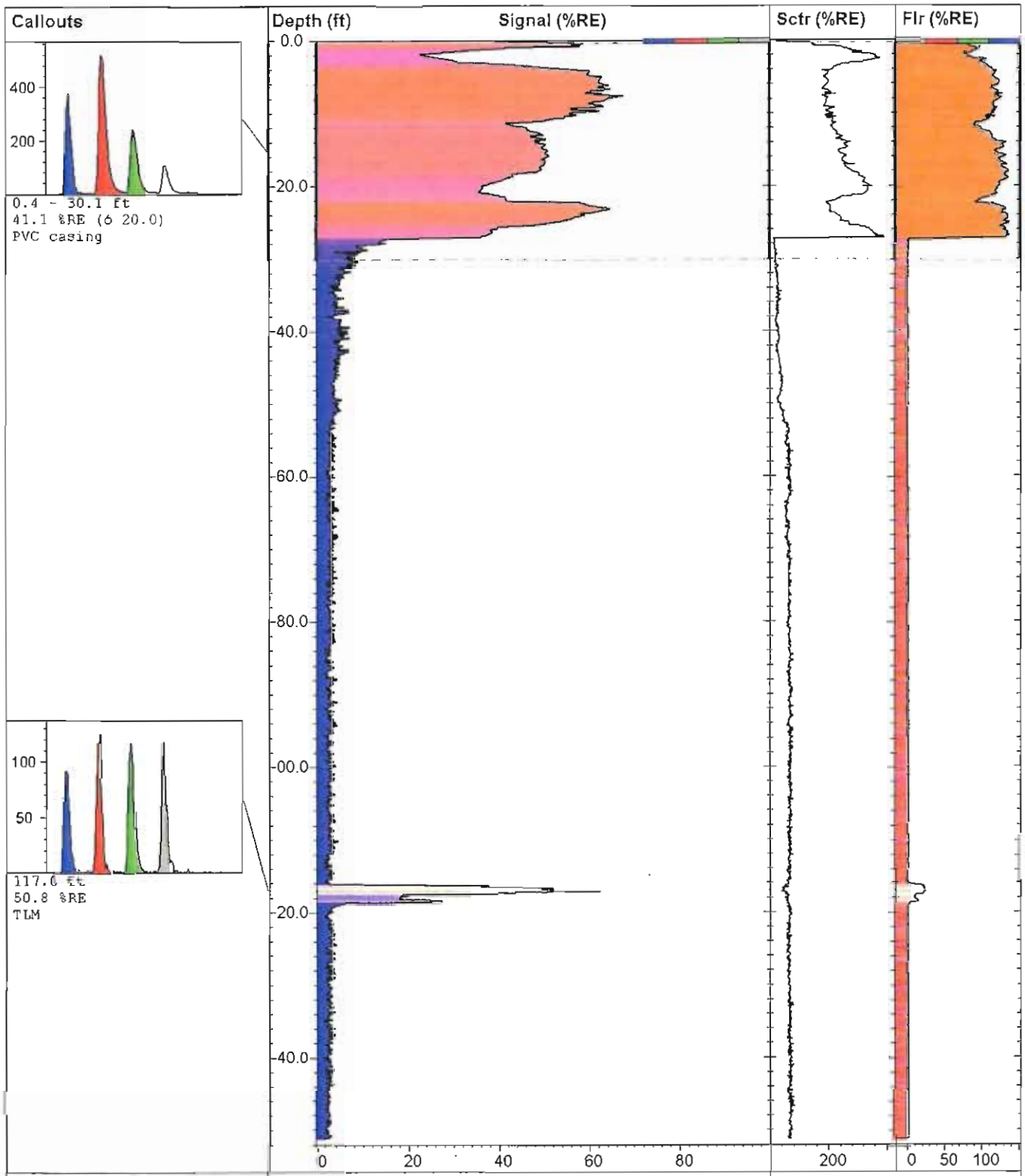
TG-16b

TarGOST By Dakota
www.DakotaTechnologies.com

Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 149.14 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 232.1 % @ 78.99 ft
Job:	*Operator/Unit:* T.Rudolph/DTI01	*Date & Time:* 3/30/2008 11:02:55 AM

TARGOST BORING LOGS

TG-1S THROUGH TG-12S
SILTRONIC CORPORATION PROPERTY



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TG01S

TarGOST By Dakota
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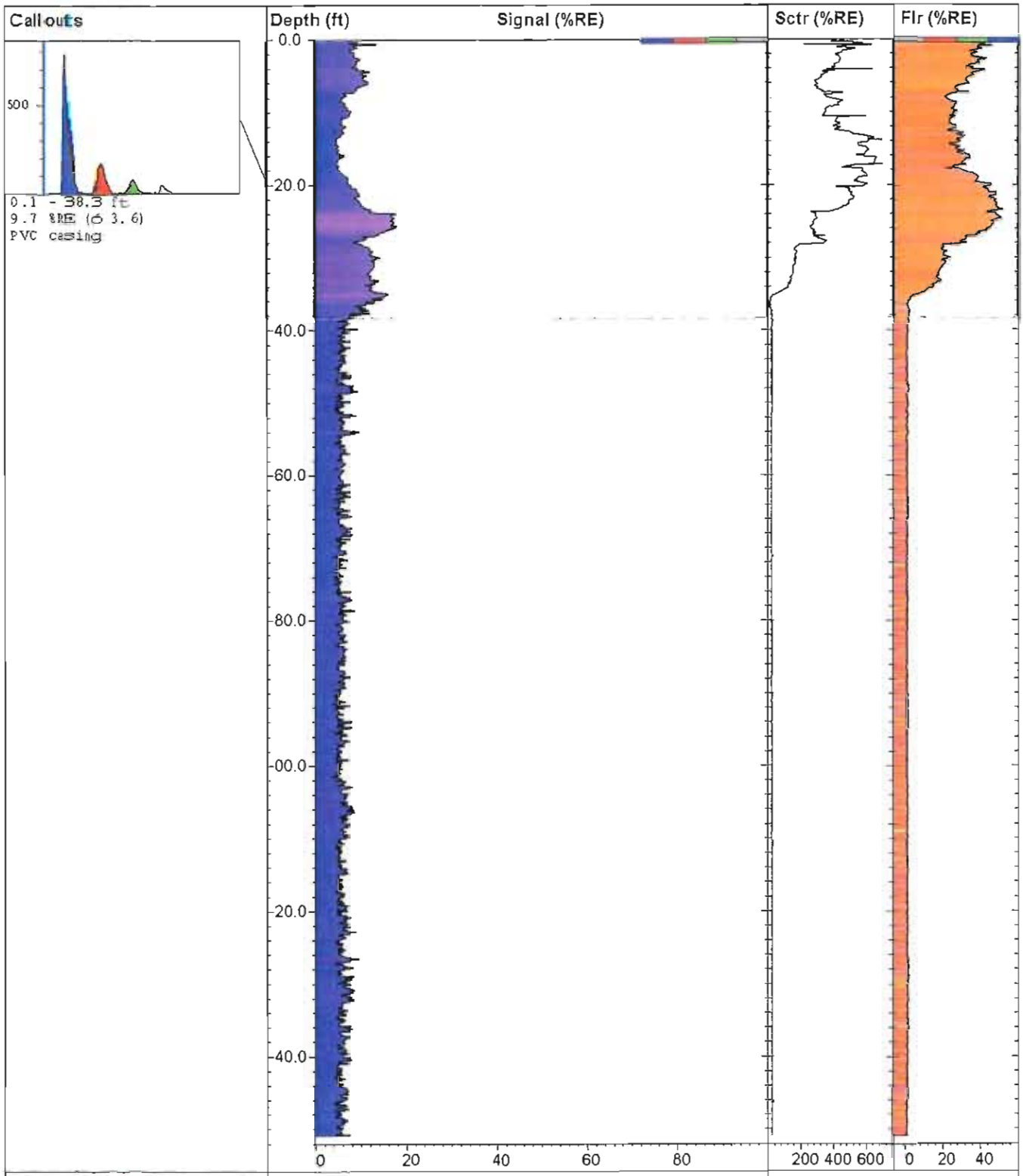
Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 151.27 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 67.7 % @ 7.64 ft
Job: 2708	*Operator/Unit:* Steve Adamek/DTI01	*Date & Time:* 9/5/2007 2:43:17 PM



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TG02Sc

TarGOST By Dakota
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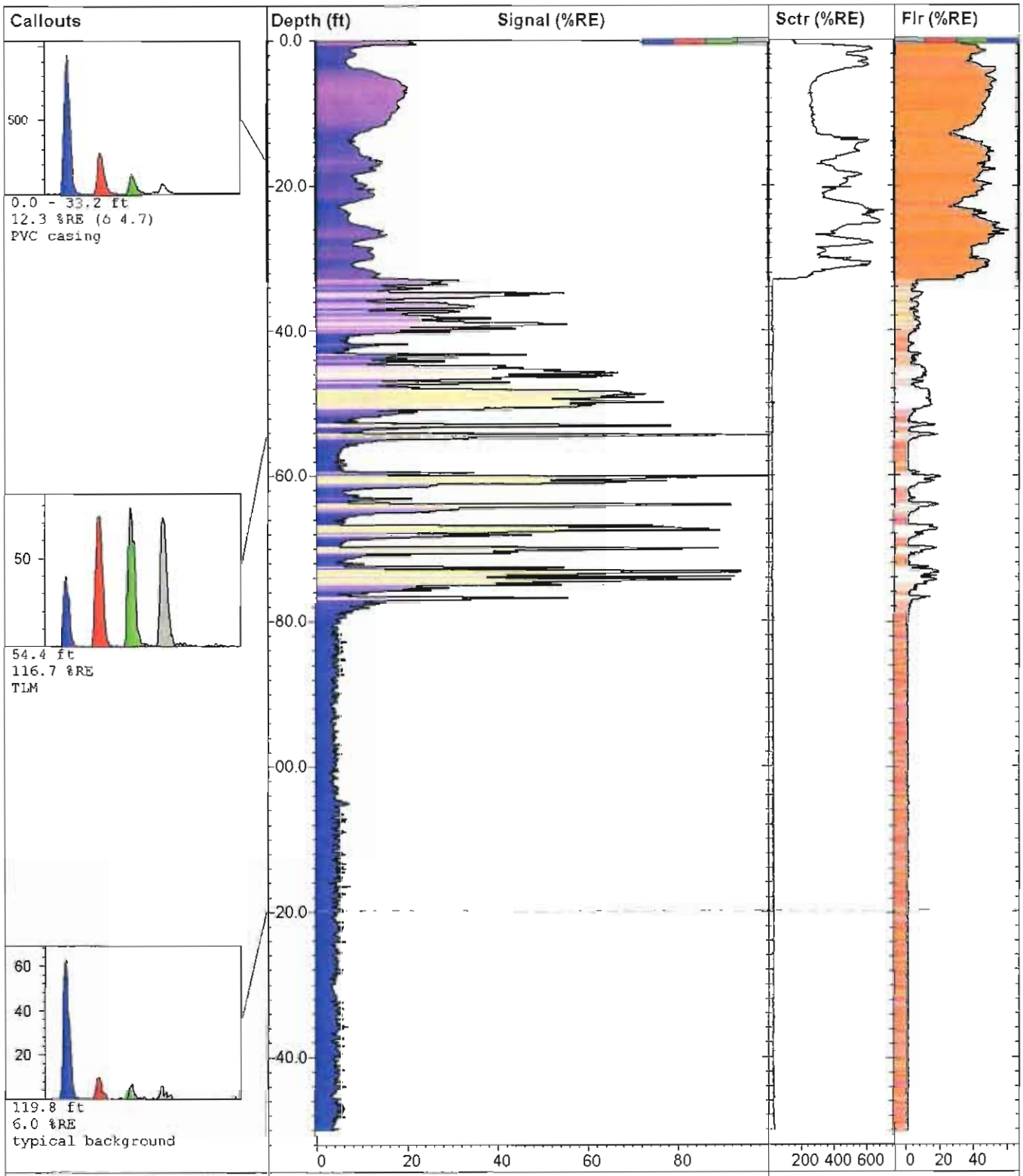
Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 151.04 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 19.4 % @ 35.72 ft
Job: 2708	*Operator/Unit:* Steve Adamek/DTI01	*Date & Time:* 9/7/2007 10:14:17 AM



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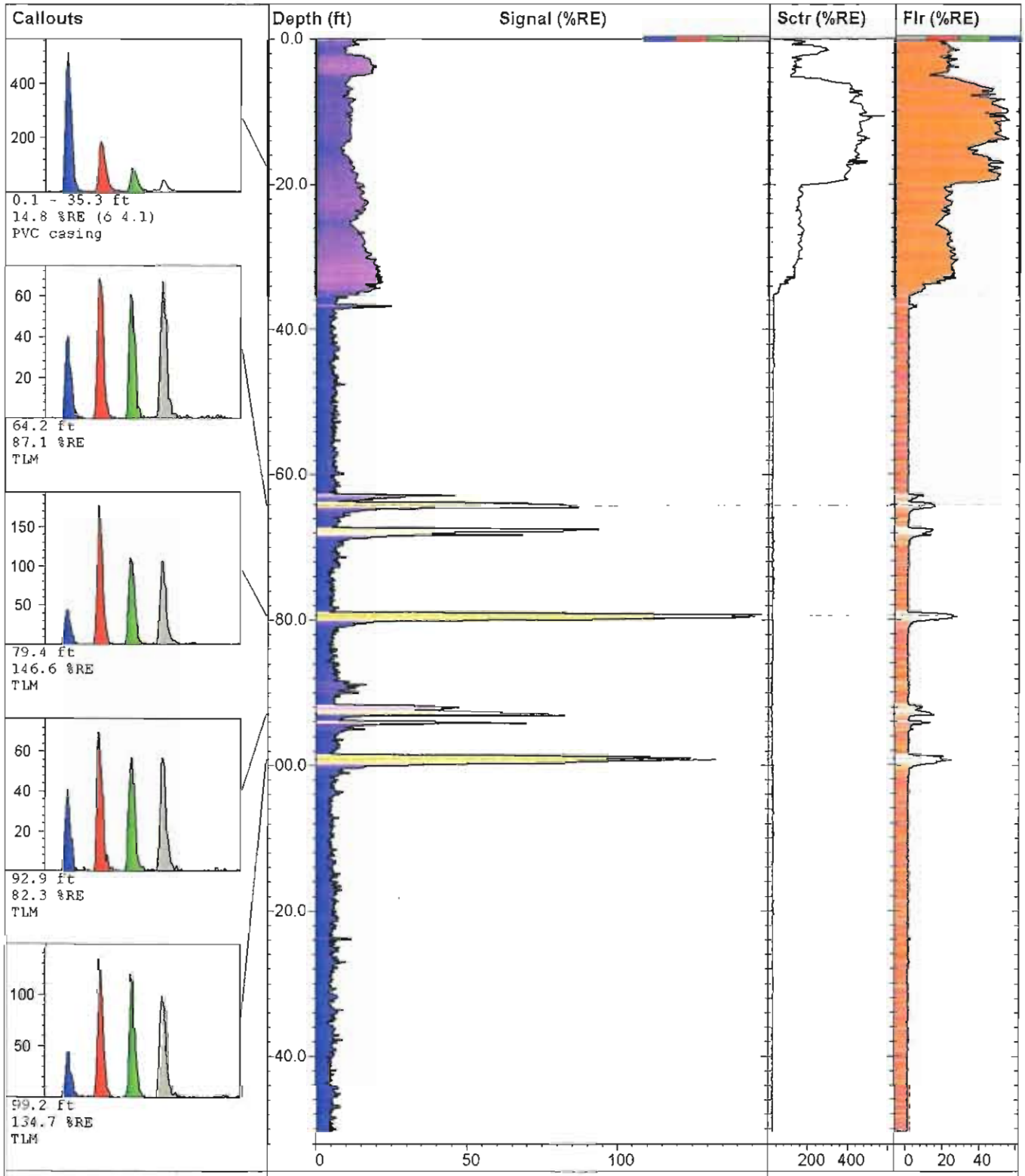
TG03S

TarGOST By Dakota
www.DakotaTechnologies.com

Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 150.19 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 116.7 % @ 54.40 ft
Job: 2708	*Operator/Unit:* Steve Adamek/DTI01	*Date & Time:* 9/8/2007 1:29:13 PM



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TG04S

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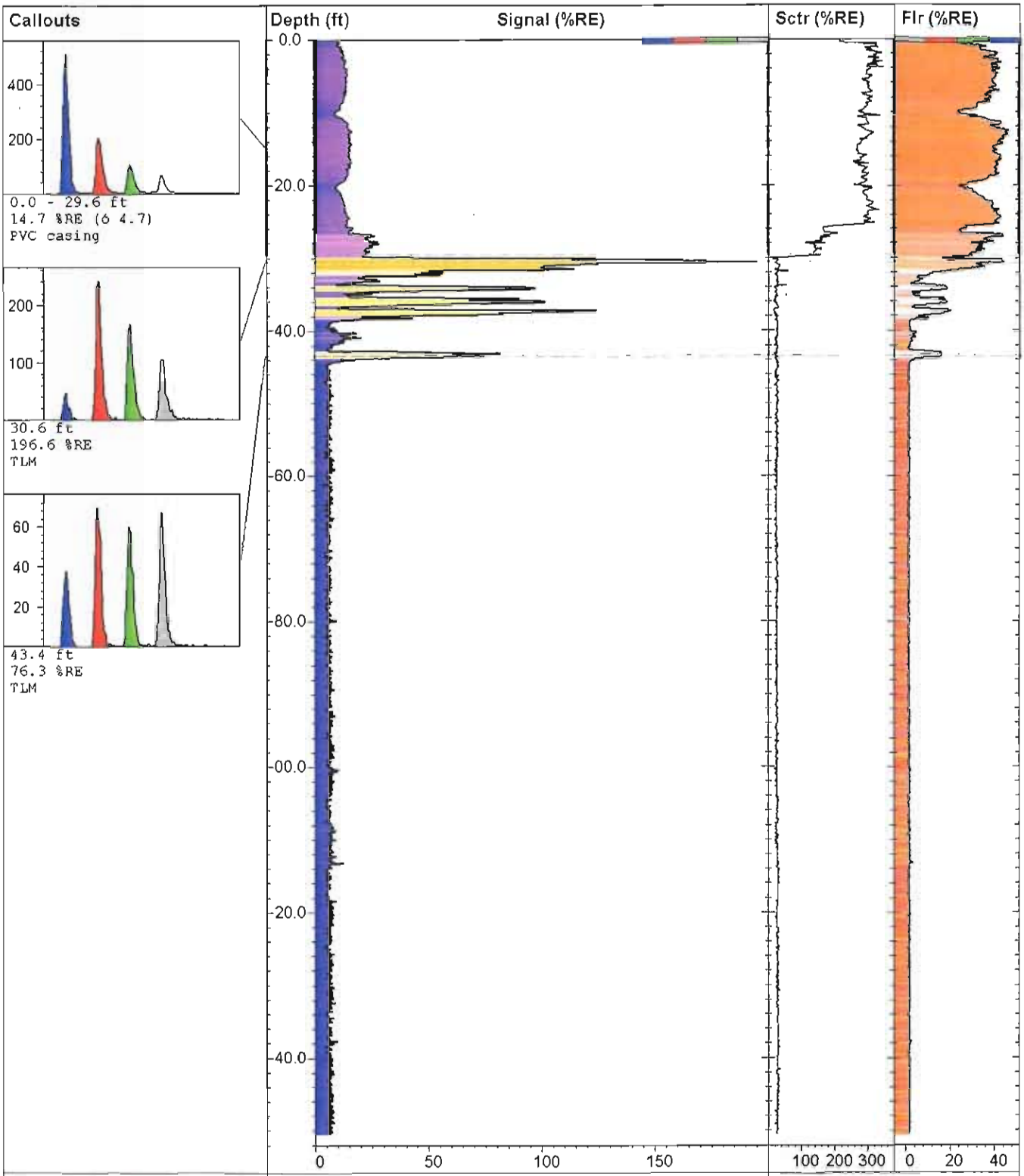
Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 150.33 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 150.2 % @ 79.23 ft
Job: 2708	*Operator/Unit:* Steve Adamek/DTI01	*Date & Time:* 9/7/2007 2:37:45 PM



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TG05S

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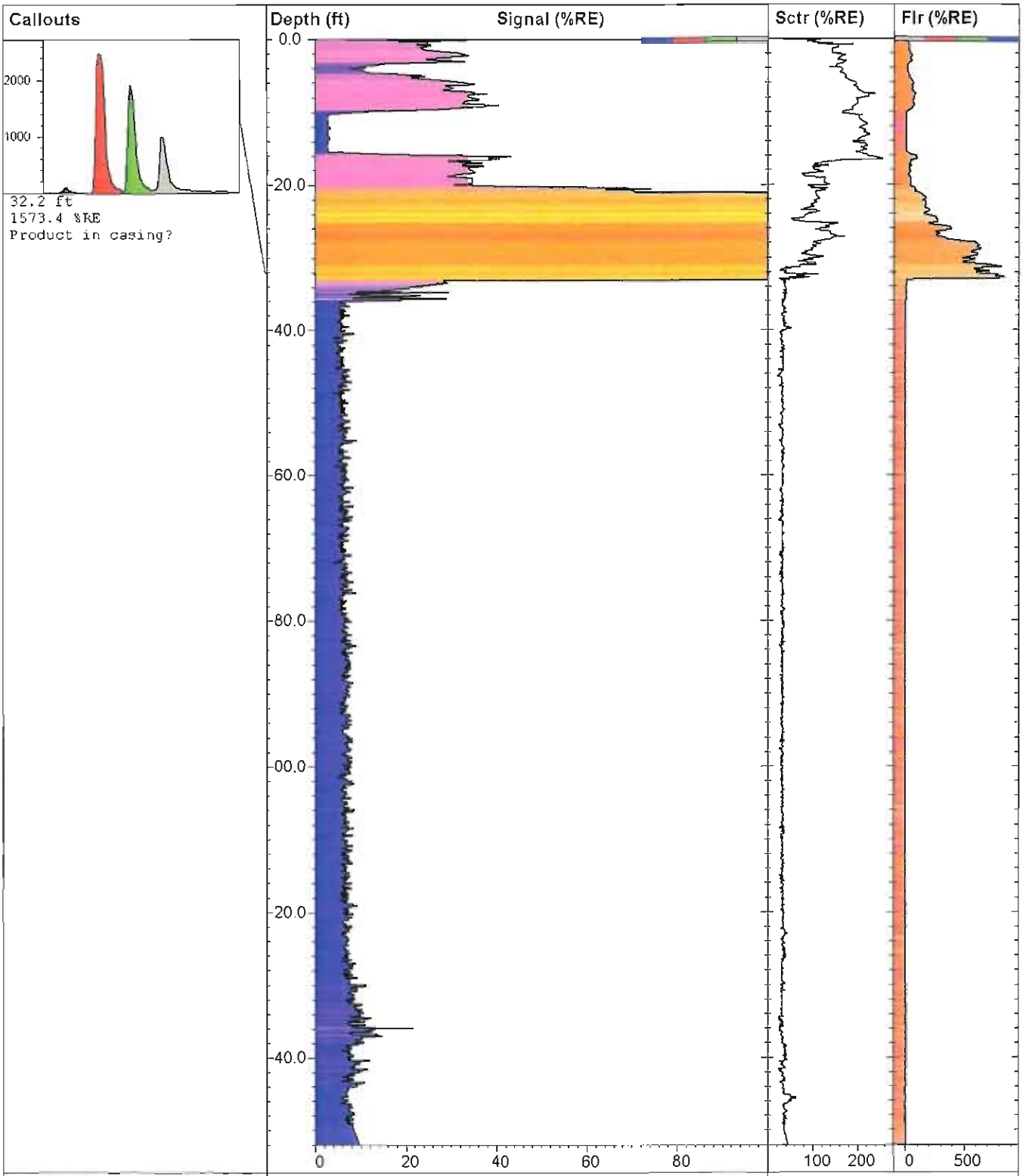
Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 150.57 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 210.4 % @ 30.24 ft
Job: 2708	*Operator/Unit:* Steve Adamek/DTI01	*Date & Time:* 9/6/2007 1:41:05 PM



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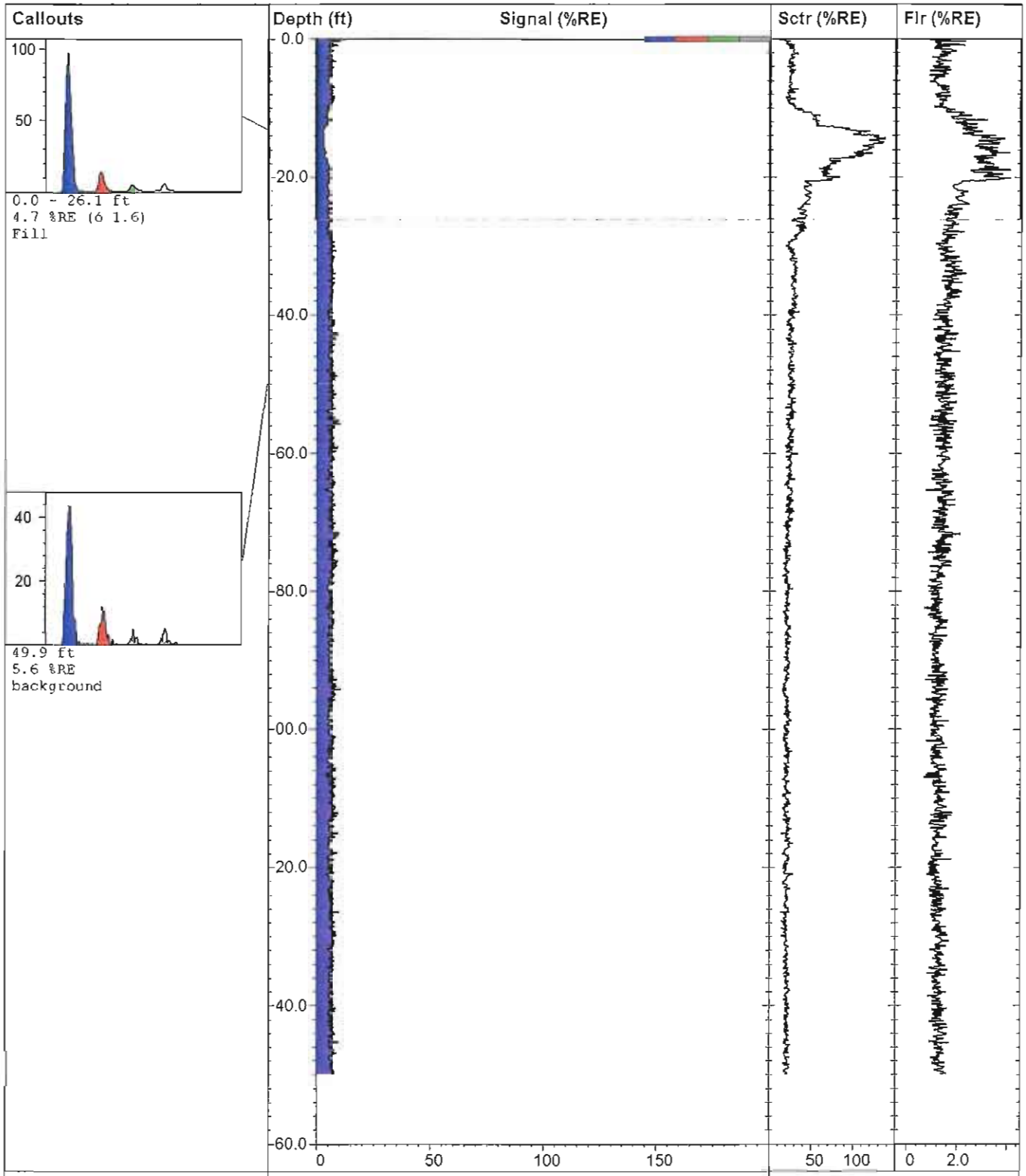
TG06S

TarGOST By Dakota
www.DakotaTechnologies.com

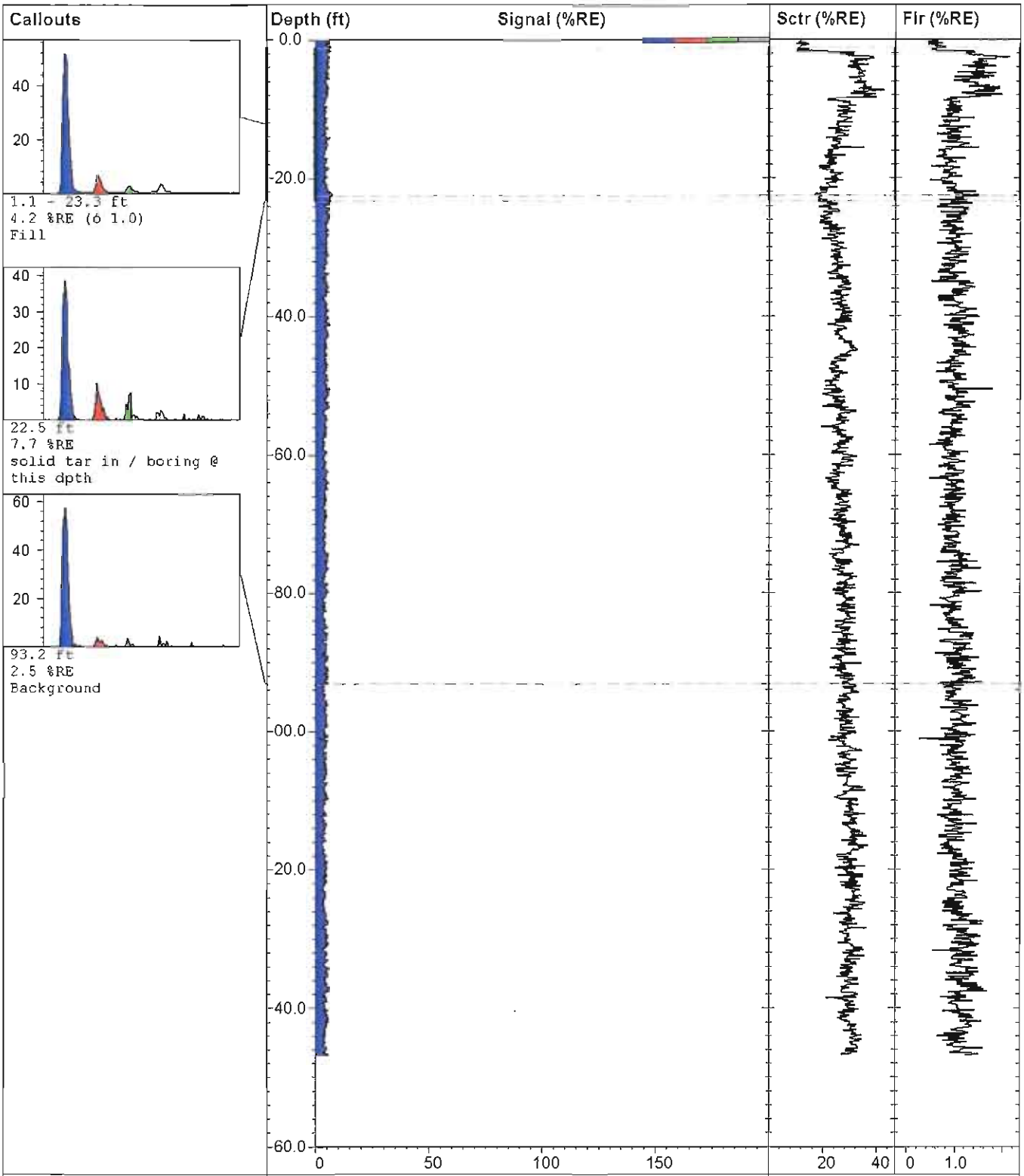
Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 152.00 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 2233.8 % @ 31.81 ft
Job: 2708	*Operator/Unit:* Steve Adamek/DTI01	*Date & Time:* 9/8/2007 8:54:59 AM



TG-7Sb

TarGOST By Dakota
www.DakotaTechnologies.com

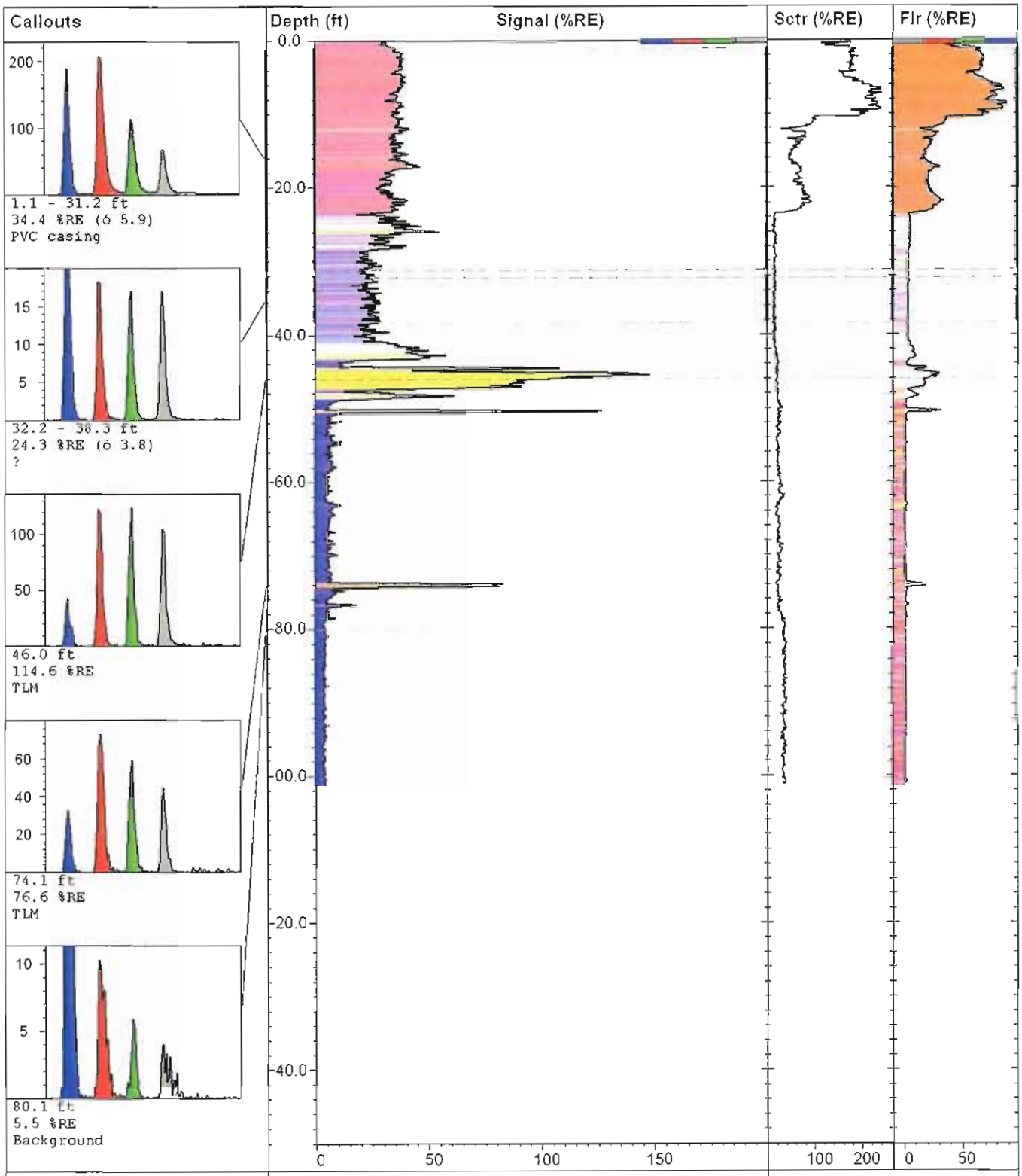
Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 149.98 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 12.1 % @ 0.00 ft
Job:	*Operator/Unit:* T.Rudolph/DTI01	*Date & Time:* 3/26/2008 9:36:29 AM



TG-8S

TarGOST By Dakota
www.DakotaTechnologies.com

Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 146.83 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 14.8 % @ 0.00 ft
Job:	*Operator/Unit:* T.Rudolph/DTI01	*Date & Time:* 8/31/2007 4:38:07 AM



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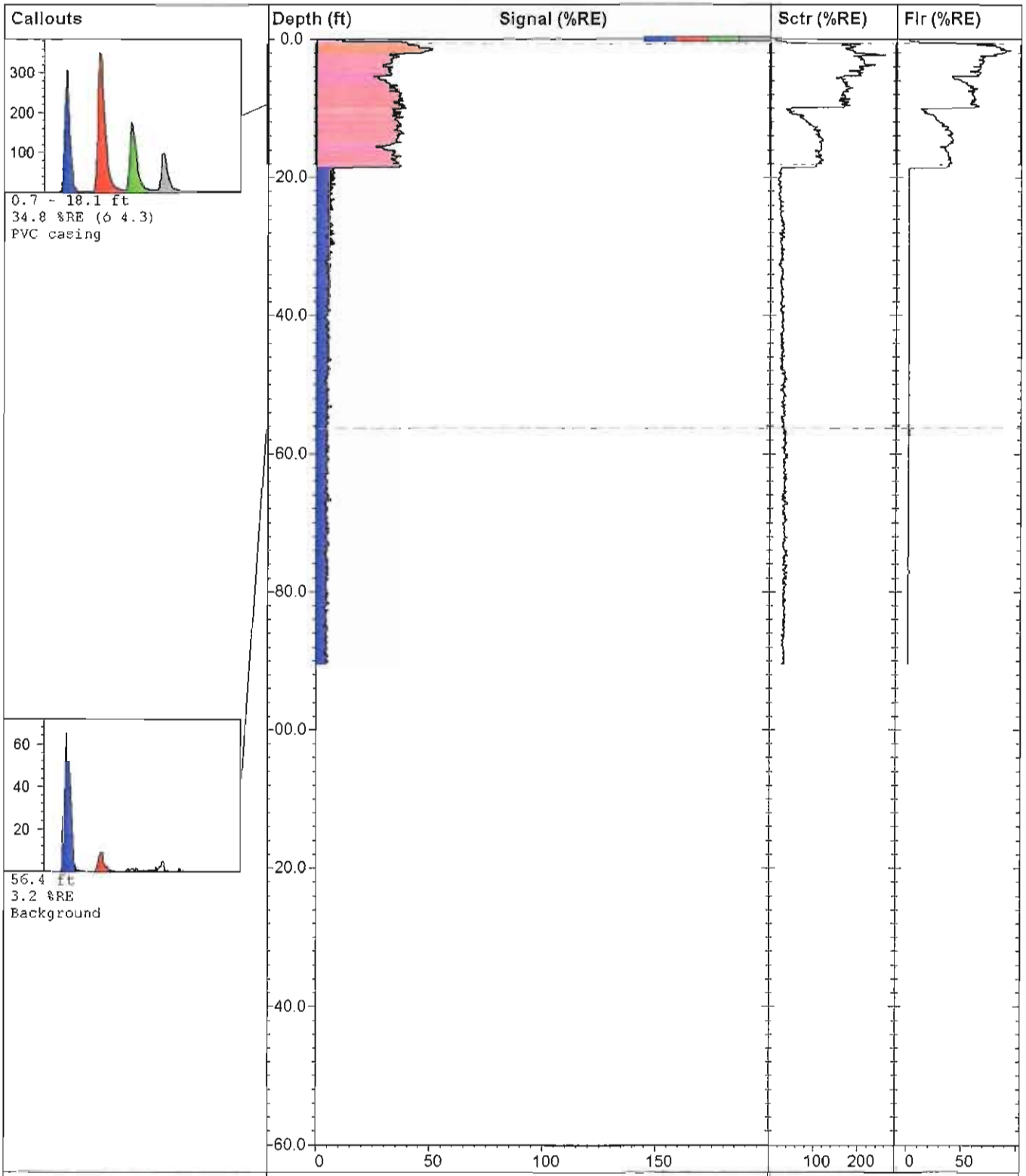
TG-9S		TarGOST
Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 101.32 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 148.4 % @ 45.48 ft
Job:	*Operator/Unit:* T.Rudolph/DTI01	*Date & Time:* 3/26/2008 11:59:35 AM



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Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 90.54 ft
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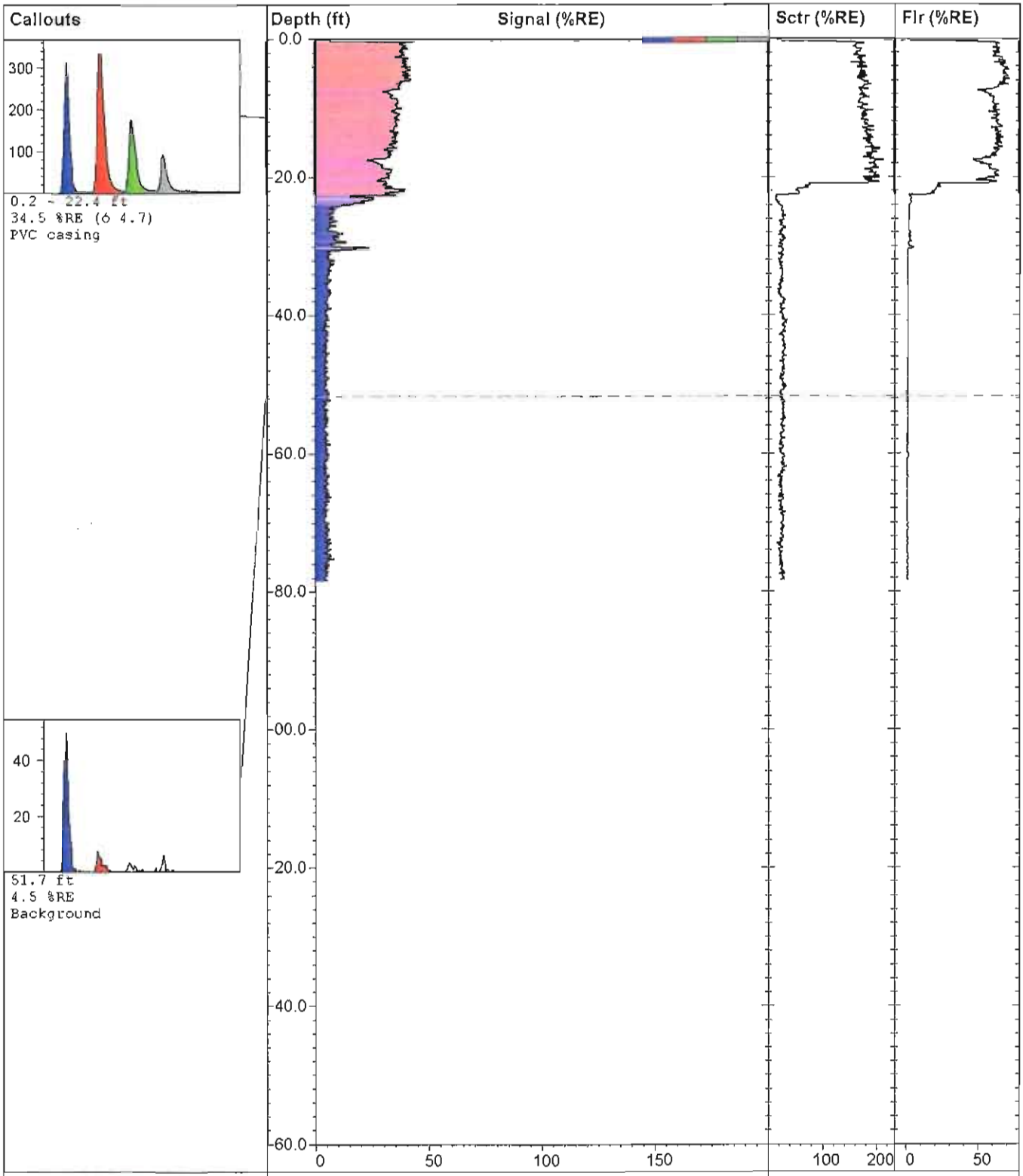
Job:	*Operator/Unit:* T.Rudolph/DTI01	*Date & Time:* 3/26/2008 3:07:54 PM



TG-11S

TarGOST By Dakota
www.DakotaTechnologies.com

Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 78.53 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 43.2 % @ 0.39 ft
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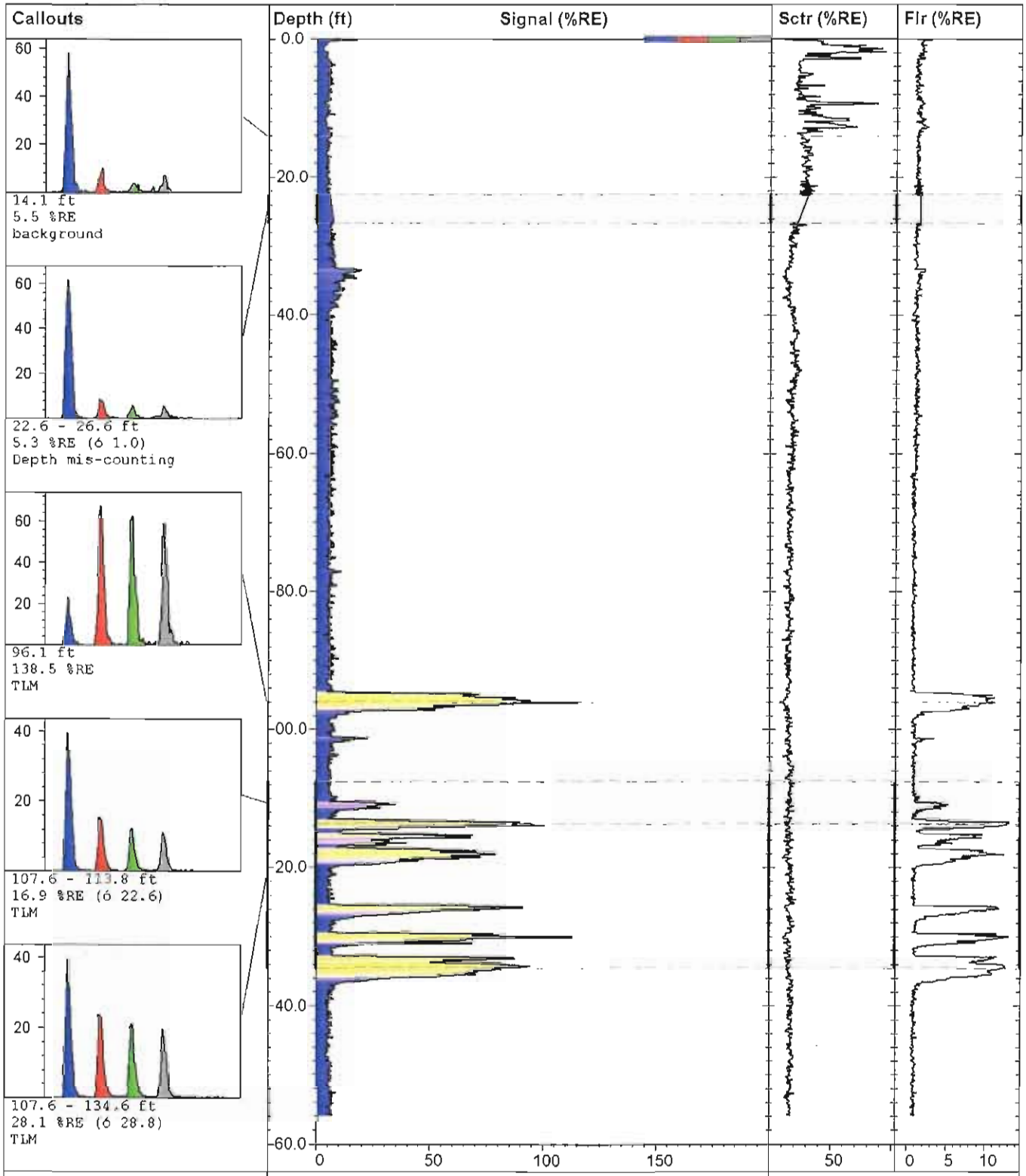

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Site: Portland, OR MGP	*Latitude / System:* Unavailable / NAD83	*Final depth:* 156.02 ft
Client: Hahn & Associates, Inc.	*Longitude:* Unavailable	*Max signal:* 138.5 % @ 96.05 ft
Job:	*Operator/Unit:* T.Rudolph/DTI01	*Date & Time:* 3/27/2008 10:38:21 AM

APPENDIX I
OCTOBER 2008 GROUNDWATER FLOW MODEL REPORT AND 2009 SUPPLEMENTAL FIGURES

GROUNDWATER FLOW MODEL AND DNAPL EVALUATION SUPPLEMENTAL REPORT

NW NATURAL GASCO SITE

Prepared for

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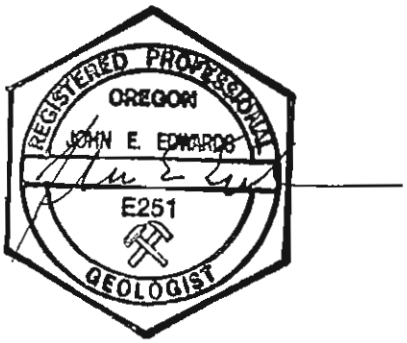
October 2008



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1 INTRODUCTION

This supplemental report summarizes the work completed and findings of groundwater model and dense non-aqueous phase liquid (DNAPL) evaluations completed as part of source control design at the NW Natural Gasco Site. Chapter four of the *Preliminary Design Report, Groundwater Source Control* (Anchor 2008) identified groundwater flow modeling tasks to be completed, including extraction well design-related issues and the impact of shutdowns and river flow variations. In previous meetings and correspondences, the Oregon Department of Environmental Quality (DEQ) has also requested evaluation of DNAPL mobility as it relates to design of the proposed vertical barrier. This report responds to all of the above technical issues, with the exception of the analysis of the impact of shutdowns. That analysis can more efficiently be addressed after DEQ and NW Natural have conferred on the findings in this report.

NW Natural proposes to meet with DEQ to present the findings of these studies, and this supplemental report is intended to provide DEQ with information to prepare for the meeting. The following sections describe development of reasonable worst case flow conditions, model recalibration, reasonable worst case scenarios, nearshore dredge scenarios, and potential effect on DNAPL.

2 REASONABLE WORST CASE HYDRAULIC GRADIENT DATA ANALYSIS

At DEQ's request a reasonable worst hydraulic gradient case condition was developed by analyzing existing site groundwater level data and comparing the water level data to measured river stage. The greatest difference between water levels at wells and river stage occurred at various times from well to well. However, the greatest difference occurred for 11 wells in the March 27, 2000, monitoring event. Consequently, the water level data from this event were selected as the reasonable worst case condition. More detail on this analysis is presented in Appendix B.

3 MODEL RECALIBRATION

The model was recalibrated to the selected worst case water level data from March 27, 2000. The river boundary condition was changed to the measured stage of 6.82 feet. Model calibration consisted of changing the upland boundary head and the aerial recharge rate to match the March 27, 2000, water level data. The only physical change to the model structure was addition of the MODFLOW Drain Package to represent groundwater seepage to the extraction system in the LNG Basin. This addressed the relatively low water level in MW-10-25, a well completed in the fill near the LNG Basin.

In the model recalibration, the recharge rate changed from the average base case of 0.029 inches per day to 0.054 inches per day. The higher rate yields 1.67 inches of recharge in the March 2000 calibration, which is over 50 percent of the precipitation recorded for March 2000. . This is a relatively high recharge rate and consequently quite conservative with respect to groundwater flow.

The upland boundary head changed in the alluvium from 33 feet in the average base case to 37 feet for the March 2000 calibration. The boundary head did not change in the fill as the calibration to water levels in the fill was accomplished by changing the recharge rate.

Following recalibration, the model was adjusted by extending the deep high hydraulic conductivity zone in the alluvium upland until it intersected bedrock. This same adjustment was done for the average base case to address DEQ's concerns that the model was under-representing groundwater flow from the upland boundary. This upland boundary flow to the alluvium is interpreted as being flow from the underlying basalt west of the Site.

Overall, the calibration to March 2000 worst case conditions with the change in the upland boundary head, recharge rate, and adjustment of the deep alluvium hydraulic conductivity zone increases the overall groundwater flow in the model by 30 percent from the average base case condition. This higher groundwater flow rate represents a transient condition that may only last for a few weeks during winter conditions. For instance, the gradients recorded in March 2000 were not observed in other February or March monitoring events. Therefore, using the model calibrated to the March 2000 data in a steady-state analysis of groundwater containment is a very conservative approach.

4 REASONABLE WORST CASE SCENARIOS

The recalibrated reasonable worst case MODFLOW model was used to simulate five source control scenarios. In all scenarios with the vertical barrier, it is constructed to a bottom elevation of -60 feet along the reach of shoreline recommended in the preliminary design report. The source control scenarios simulated are:

1. Base case with no vertical barrier or pumping.
2. Vertical barrier with no pumping.
3. Barrier with pumping from shallow extraction wells.
4. Barrier with pumping from intermediate depth extraction wells completed near the bottom of the barrier.
5. Barrier with combination of shallow and intermediate depth extraction wells.

The map on Figure 1 shows the locations of subsurface profiles A-A′ and B-B′. Results from all of the model runs are shown along profile A-A′ (Appendix A, Figures A-1 through A-7). Profile A-A′ extends from the river edge across the location of proposed Extraction Well PW-1 and extends approximately 700 feet upland of the shoreline. Results from one model run are also shown along profile B-B′, to assess gradients between extraction wells (Appendix A, Figure A-8).

The first two source control scenarios were analyzed for hydraulic gradients under ambient conditions and with the wall in the absence of pumping, such as in a situation where pumps were turned off. The groundwater gradients near the river and extending upland beyond the proposed location of the wall for these two scenarios are shown on the subsurface profiles in Figures 2 and 3. Figures 2 and 3 display the horizontal and vertical groundwater hydraulic gradients that are predicted when wells are not pumping, both with and without a vertical barrier.

Source control scenarios 3 through 5 were analyzed for the effect on hydraulic gradients and to estimate the pump rate necessary to capture upland groundwater. These scenarios evaluate the different groundwater gradients that result from shallow extraction wells, intermediate depth wells, and paired wells. A summary of the horizontal and vertical hydraulic gradients in the vicinity of and landward from the wall are presented on the subsurface profile in Figure 4. Subsurface profiles showing the detailed distributions of hydraulic gradients that underlie the

data on Figure 4 are provided in Appendix A. Combined pumping rates for all ten extraction well locations predicted to attain capture of groundwater from the Site are presented in the following table.

Model Scenario Current Bathymetry	Estimated Pump Rate (gpm)
Shallow wells	290
Intermediate Wells	250
Combined shallow and intermediate wells	252[1]

1) Pump rate evenly divided between shallow and intermediate wells

5 NEARSHORE DREDGE SCENARIOS

At DEQ's request, the reasonable worst case flow model was modified to represent an additional worst case possibility in which sediment offshore from the Site is dredged to a depth of 20 feet below existing mudline with no backfill material to fill the dredge prism. The assumption was made that the 20-foot dredge segment would extend along the entire alignment of the extraction wells (approximately 2,300 feet) and approximately 300 feet offshore.

The same five scenarios discussed above were analyzed under this condition. A summary of gradients is presented on the subsurface profile in Figure 5. Detailed gradient distributions for these scenarios are presented on the subsurface profiles in Appendix A. Combined pumping rates for all 10 extraction well locations predicted to attain capture of groundwater from the Site are presented in the following table.

Model Scenario Dredge Bathymetry	Estimated Pump Rate (gpm)
Shallow wells	320
Intermediate Wells	260
Combined shallow and intermediate wells	260[1]

1) Pump rate evenly divided between shallow and intermediate wells

6 POTENTIAL EFFECT ON DNAPL

One of the objectives for this evaluation is to determine if there is a potential for upward vertical migration of free-phase DNAPL product into the riverbed sediments and/or surface water as a result of the implementation of the proposed corrective measures at the Gasco Site. Specifically, DEQ asked if the installation of the proposed vertical barrier and associated pumping of groundwater extraction wells on the landward side of the barrier could induce DNAPL migration beneath the wall that could subsequently discharge into the Willamette River.

Fundamentally, the flow of DNAPL is not coincident with groundwater flow in magnitude or direction in saturated environments because of density/specific gravity differences between the two media. The three driving forces that act concurrently on subsurface DNAPL include the gravity gradient (weight of the fluids), the capillary pressure gradient (surface tension of the fluids), and the hydraulic gradient (Cohen and Mercer 1993). It is normally assumed that upward vertical hydraulic gradients associated with groundwater flow can prevent or slow the downward movement of DNAPL. For example, shallow recovery wells and drains can be used to create or increase vertical (upward) hydraulic gradients, particularly across an aquitard that separates two aquifers, and this mechanism has been considered to contain sinking DNAPL at several sites. However, reversing DNAPL flow for recovery is very difficult because of capillary effects between the fluid and surrounding aquifer matrix materials.

The equations used to evaluate the effect of hydraulic gradient and head differences required to prevent DNAPL from sinking vertically downward are given by Cohen and Mercer (1993):

$i_h = (\rho_n - \rho_w)/ \rho_w$ (equation 1.1)

and,

$\delta h = z_n(\rho_n - \rho_w)/ \rho_w$ (equation 1.2)

where:

i_h = hydraulic gradient

ρ_n = specific gravity of DNAPL

ρ_w = specific gravity of water

δh = hydraulic head difference

z_n = thickness of DNAPL body

These density driven forces would have to be overcome for upward vertical migration to occur before capillary forces could exert an additional significant effect on vertical migration tendencies. Therefore, as a first approximation, Equation 1.1 may be used to address the question of whether an upward groundwater hydraulic gradient may reverse the downward vertical migration of DNAPL at the site such that the DNAPL might be drawn to a recovery well or discharge to a surface water body.

Table 1 provides a summary of DNAPL properties at the Site (HAI 2007). This table shows that the specific gravity of DNAPL at the Gasco Site varies between 1.05 and 1.1. Solving equation 1.1 above, the upward vertical hydraulic gradient that is required to overcome or prevent the downward migration of DNAPL due to gravitational forces is between 0.05 and 0.10.

The vertical hydraulic gradients described in Sections 4 and 5 were examined at the bottom of the proposed vertical barrier to assess if upward hydraulic gradients could potentially overcome gravitational forces associated with the downward migration of DNAPL. Two areas were examined for each of the five Reasonable Worst Case scenarios outlined for the groundwater model above under existing and dredged conditions. The two areas that were evaluated are:

- The area on the landward side and adjacent to the proposed barrier—approximately at Stations 1200 to 1350 in the model grid
- The area on the river side and adjacent to the proposed barrier—approximately at Stations 1000 to 1150 in the model grid

The evaluations were performed on gradients predicted at the bottom of the proposed wall (the -60 foot elevation), and are centered on cross section A-A′. Subsurface profile B-B′ was offset from the pumping wells to evaluate how the magnitudes of predicted gradients change with distance away from the proposed pumping wells. In cases where the model well screen was located at the -60 foot level (combined and intermediate scenarios), the gradient from the -70 foot level was substituted at Station 1200.

The following conclusions can be derived from the above analysis:

- None of the modeled conditions have upward hydraulic gradients that could draw DNAPL upward towards the river on the river side of the barrier wall. The vertical gradients in this area are near zero, and mobile DNAPL in the area would tend to migrate in a downward direction since gravitational forces greatly exceed the hydraulic gradient (Figure 6).
- Based on differences between hydraulic and gravitational gradients, there is a potential that downward migration of DNAPL in the immediate vicinity of the pumping wells could be retarded or contained (Figure 7). This effect decreases rapidly moving away from extraction wells. Capillary effects may prevent the complete reversal of downward DNAPL migration in these areas, and heterogeneities in the aquifer matrix would play an important role in determining the magnitude of these effects.

7 SUMMARY OF MODEL FINDINGS

1. The groundwater elevation data for March 27, 2000, represents a reasonable worst case condition for future modeling and design purposes.
2. Overall, the calibration to March 2000 worst case conditions with the change in the upland boundary head, recharge rate, and adjustment of the deep alluvium hydraulic conductivity zone increases the overall groundwater flow in the model by 30 percent from the average base case condition for the period the worst case condition is in effect.
3. Modeled source control scenarios of shallow, intermediate, and paired extraction wells show that the use of shallow extraction wells requires the highest pump rate to achieve capture.
4. The intermediate extraction well scenario results in the highest upward vertical gradients on the landward side of the vertical barrier, but these gradients decrease more rapidly with distance from the pumping well than in the shallow extraction well scenario.
5. Model runs of the dredge bathymetry showed somewhat higher pumping rates to attain capture than the current bathymetry. However, modeling the dredge bathymetry in addition to the March 2000 reasonable worst case flow condition is believed to be overly conservative because the 20-foot dredge depth will likely be restored with engineered fill or filled in by natural river sedimentation processes. With the addition of post-dredge engineered fill or natural river sedimentation the resulting bathymetry will be close enough to current bathymetry to make the modeled groundwater flows essentially the same. Therefore, the March 2000 reasonable worst case model described in Section 4 is recommended as the worst case scenario to be considered in future design evaluations.
6. None of the modeled scenarios have upward hydraulic gradients that could draw DNAPL upward towards the river on the river side of the barrier wall. Based on differences between hydraulic and gravitational gradients, there is a potential that downward migration of DNAPL in the immediate vicinity of the pumping wells could be retarded or contained.
7. The modeling results demonstrate that the DEQ-proposed vertical barrier depth of -60 feet elevation has a large factor of safety to prevent DNAPL migration from the area upland of the vertical barrier into the river channel.

8 REFERENCES

Anchor Environmental, LLC 2008. *Preliminary Design Report, Groundwater Source Control, NW Natural GASCO Site*. Prepared for NW Natural. Portland, Oregon.

Cohen, R.M. and Mercer, J.W. 1993. *DNAPL Site Evaluation*. Office Research and Development, U.S. EPA.

HAHN and Associates, Inc. 2007. *Remedial Investigation Report, NW Natural Gasco Facility*. Prepared for NW Natural. Portland, Oregon.

TABLE

TABLE 1
Summary of DNAPL Testing Results: Physical and Chemical

Parameter	Unit of Measure	Gasco Property Wells					Siltronic Property Wells	
		Surficial Fill Unit			Alluvial Unit		Surficial Fill Unit	Alluvial Unit
		Well MW-6-32	Well MW-10-25	Well MW-11-32	Well MW-16-45	Well PW-01-80	Well WS-10-27	Well WS-11-125
		Screen: 22-32 feet bgs	Screen: 15-25 feet bgs	Screen: 22-32 feet bgs	Screen: 30-45 feet bgs	Screen: 40-80 feet bgs	Screen: 11-26 feet bgs	Screen: 110-125 feet bgs
		Sample No.2708-981214-MW6-32-01	Sample No. 2708-981214-MW10-25-02	Sample No. 2708-981214-MW11-32-03	Sample No. 2708-041011MW-16-45-Oil	Sample No. 2708-070221-PW01-Oil	Sample No. WS10070104	Sample No. WS11-125-N
Total Metals [1]	mg/kg (ppm)							
Arsenic		2.75	3.85	-	-	-	-	-
Barium		ND>0.500	0.700	-	-	-	-	-
Cadmium		ND>0.500	ND>0.500	-	-	-	-	-
Chromium		0.700	0.850	-	-	-	-	-
Lead		ND>10	ND>10	-	-	-	-	-
Mercury		0.059	ND>0.0500	-	-	-	-	-
Selenium		0.550	ND>0.500	-	-	-	-	-
Silver		ND>0.500	ND>0.500	-	-	-	-	-
Aromatic Hydrocarbons [2]	mg/kg (ppm)							
Benzene		589	14,400	2,740	ND>10.0	1,000	874	271
cis-1,2-DCE		-	-	-	ND>10	ND>764	ND>20	188
Ethylbenzene		2,220	5,320	1,760	34.4	2,228	807	925
Isopropylbenzene		-	-	-	ND>20	ND>1,590	69	ND>50
n-Propylbenzene		-	-	-	ND>10	ND>794	33	ND>50
1,2,4-Trimethylbenzene		-	-	-	54.9	976	394	434
1,3,5-Trimethylbenzene		-	-	-	16.2	ND>794	147	121
Naphthalene		-	-	-	1,720	75,400	39,500	114,000
Toluene		ND>5.00	21,900	2,950	17.8	ND>794	43	194
Trichloroethene		-	-	-	ND>10	ND>794	ND>20	59.6
Xylene		1,240	19,500	4,400	66.1	ND>1,590	664	720
PAHs [3]	mg/kg (ppm)							
Total PAHs		214,900	189,700	164,470	32,787	46,910		
Total Carcinogenic PAHs		9,300	19,490	16,210	2,647	ND		
Petroleum Hydrocarbon ID [4]	None							
Gasoline-Range (mg/kg)		Detected [12]	Detected [12]	Detected [12]	Not Detected	22,900	-	14.9
Diesel-Range (mg/kg)		Detected [12]	Detected [12]	Detected [12]	Detected [12]	545,000 [12]	-	347
Heavy Oil-Range (mg/kg)		Detected [12]	Detected [12]	Detected [12]	Detected [12]	175,000 [12]	-	73.1
Reactive Cyanide [5]	mg/kg (ppm)						-	-
		ND>0.200	ND>0.200	-	-	-	-	-
Reactive Sulfide [6]	mg/kg (ppm)						-	-
		434	ND>50.0	-	-	-	-	-
Specific Gravity [7]	gm/cc	1.05	1.05	1.09	1.084 @ 70F; 1.079 @100F; 1.080 @130F	1.1006 @ 70F; 1.0955 @10 1.0920 @130F	-	1.1
Viscosity [8]	cSt	7.2 @ 50C (122F)	14.7 @ 50C (122F)	45.7 @ 50C (122F)	105 @ 70F; 40.1@100F; 18.7@130F	65.6 @ 70F; 24.1@100F; 13.3 @130F	-	-
Ignitability [9]	degrees F	No Flash to 150 degrees F	94.0 degrees F	-	No Flash to 150 degrees F	No Flash to 150 degrees F	-	-
Heating Value [10]	BTU/lb	9,230	12,230	12,280	-	-	-	-
pH [11]	pH unit	6.26	4.30	-	8.28	7.10	-	7.01
Interfacial / Surface Tension [13]	dynes/centimeter							
Water with Air		-	-	-	66.7 @ 70F	66.9 @ 75F	-	-
DNAPL with Air		-	-	-	34.9 @ 70F	36.2 @ 75F	-	-
DNAPL with Water		-	-	-	14.2 @ 70F	15.8 @ 75F	-	-

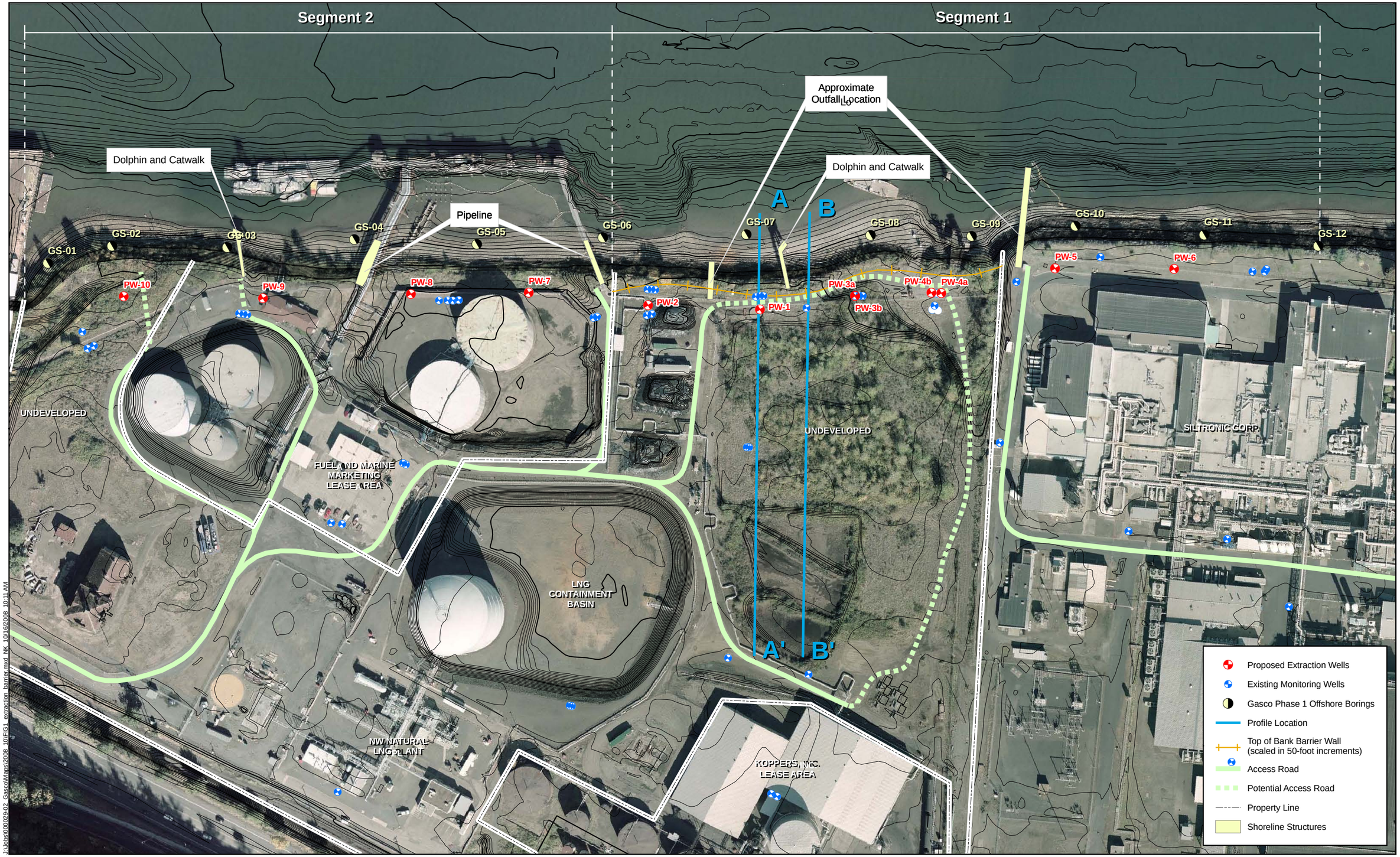
NOTE:

1 = EPA Method 6010/6020/7471
2 = EPA Method 8020A or EPA 8260B
3 = EPA Method 8270 SIM or 8270C
4 = EPA Method 8015M or NW-TPH Methodology or EPA 8015
5 = EPA Method 9010A
6 = EPA Method 9030
7 = SM 2710F
8 = ASTM Method D-445
9 = EPA Method 1010
10 = ASTM Method D2015
11 = EPA Method 150.1/9040A
12 = Laboratory reports that detected hydrocarbons have pattern and range consistent with creosotes
13 = DuNuoy Method - ASTM D971
J = Estimated concentration, results are between the Method Detection Limit (MDL) and the Method Reporting Limit (MRL).

bgs=below ground surface
cc=cubic centimeter
cSt = centistokes
BTU = british thermal unit
DNAPL = dense non-aqueous phase liquids
EPA = U. S. Environmental Protection Agency
gm = gram
lb = pound
mg/kg = milligrams/kilogram

ND = not detected above detection limit indicated
ppm = parts per million

FIGURES



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0 150
Scale in Feet
1 inch equals 150 feet

Figure 1
Cross Section Location Map
Gasco/Siltronic
Portland, Oregon

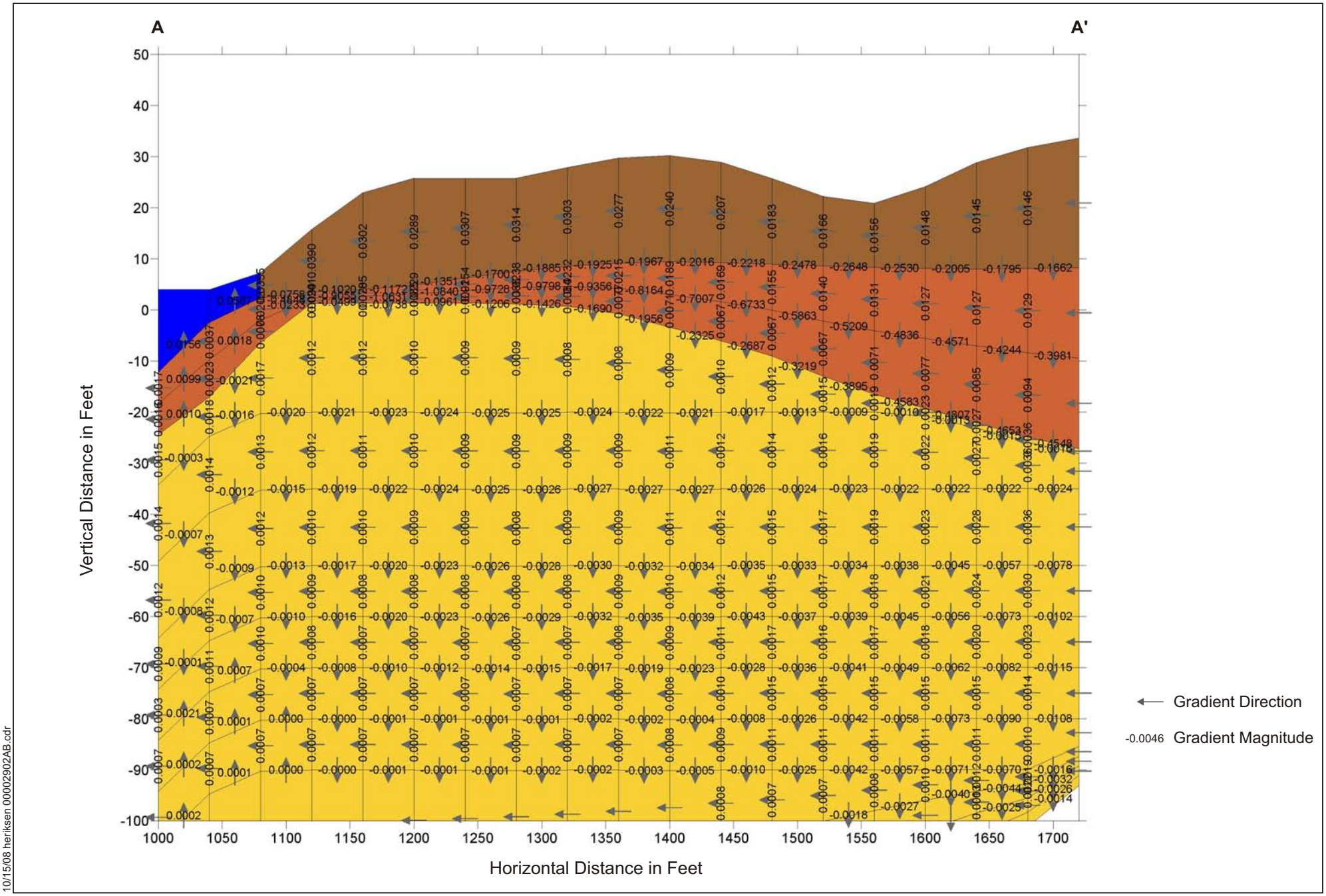

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Figure 2
Reasonable Worst Case Gradient Profile A-A' - Ambient without Vertical Barrier
NW Natural "Gasco" Site

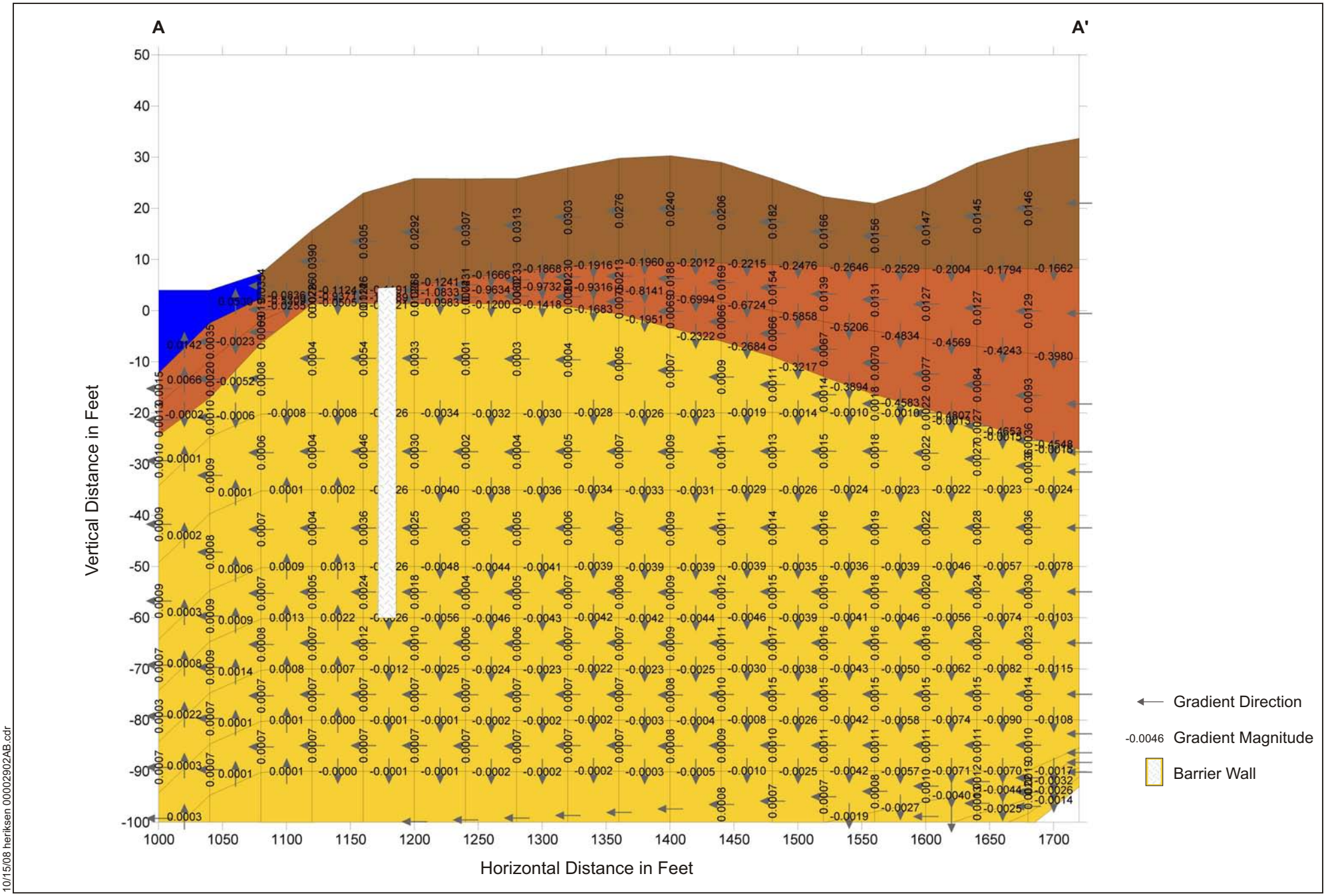

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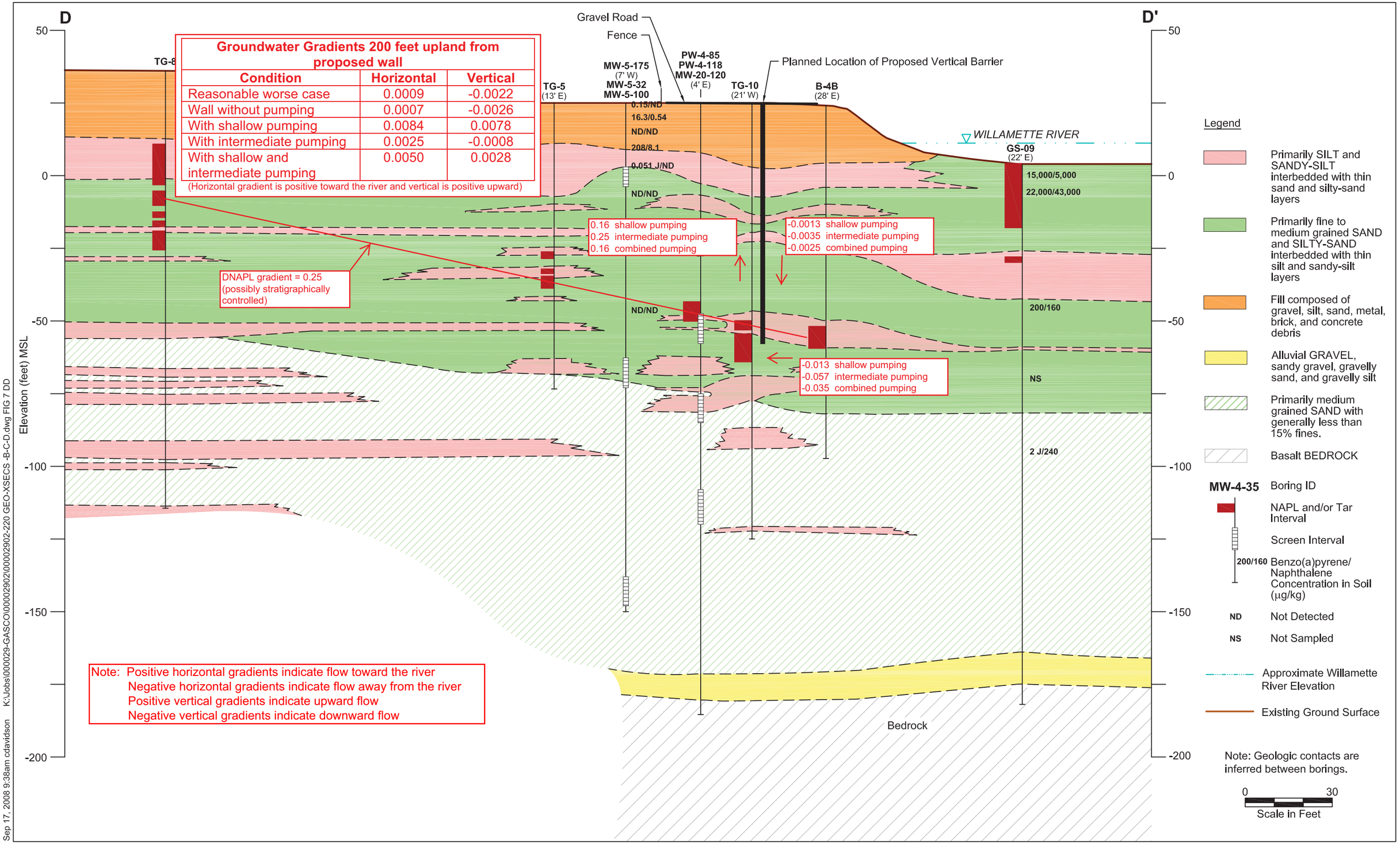
Figure 3
Reasonable Worst Case Gradient Profile A-A' - Ambient with Vertical Barrier
NW Natural "Gasco" Site



Groundwater Gradients 200 feet upland from proposed wall		
Condition	**Horizontal**	**Vertical**
Reasonable worse case	0.0009	-0.0022
Wall without pumping	0.0007	-0.0026
With shallow pumping	0.0084	0.0078
With intermediate pumping	0.0025	-0.0008
With shallow and intermediate pumping	0.0050	0.0028

(Horizontal gradient is positive toward the river and vertical is positive upward)

Note: Positive horizontal gradients indicate flow toward the river
Negative horizontal gradients indicate flow away from the river
Positive vertical gradients indicate upward flow
Negative vertical gradients indicate downward flow

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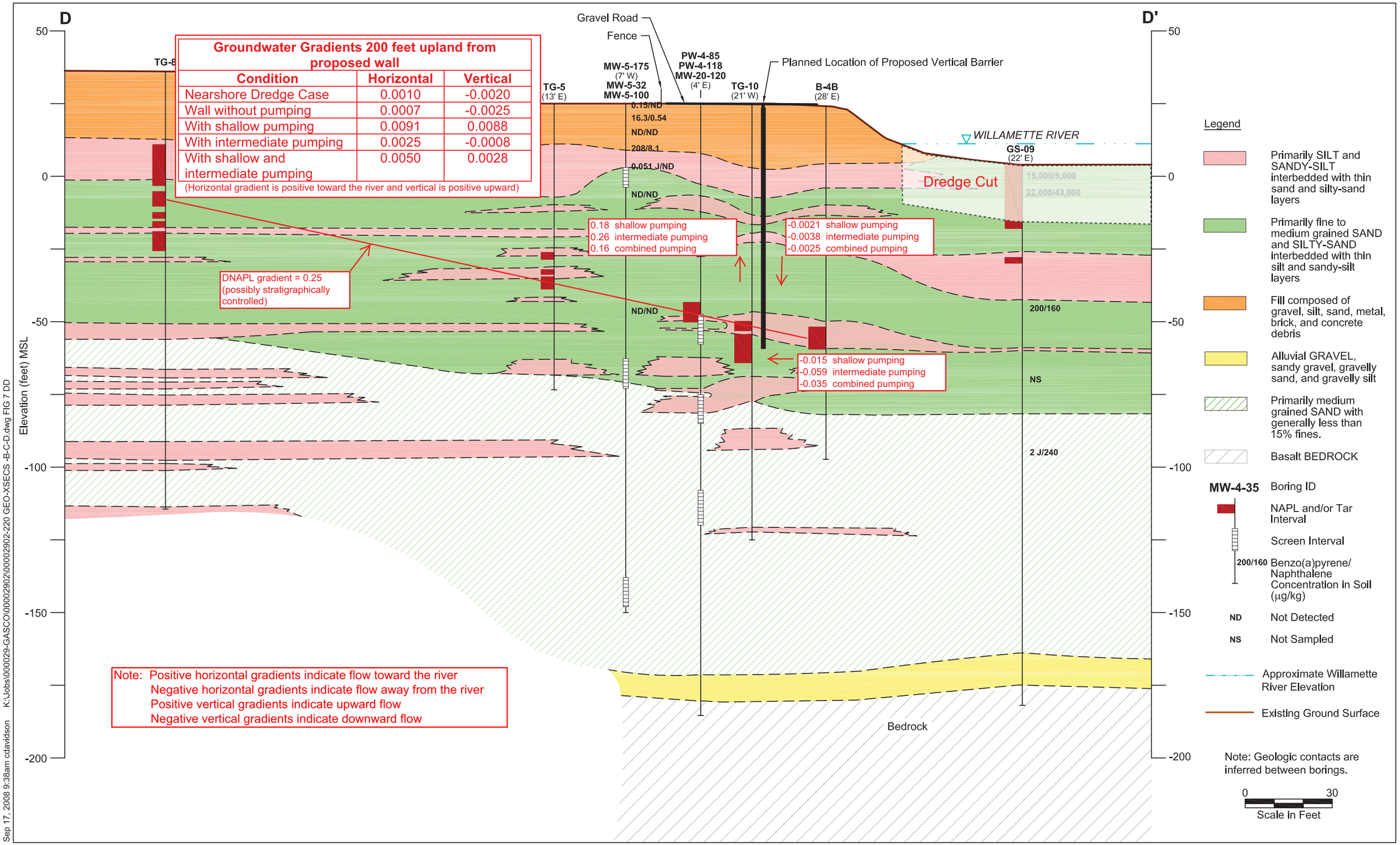
$\Sigma^2\Pi$

Figure 4
Geologic Profile with Gradient Summary, Current Bathymetry Case



Groundwater Gradients 200 feet upland from proposed wall		
Condition	**Horizontal**	**Vertical**
Nearshore Dredge Case	0.0010	-0.0020
Wall without pumping	0.0007	-0.0025
With shallow pumping	0.0091	0.0088
With intermediate pumping	0.0025	-0.0008
With shallow and intermediate pumping	0.0050	0.0028

(Horizontal gradient is positive toward the river and vertical is positive upward)

Note: Positive horizontal gradients indicate flow toward the river
Negative horizontal gradients indicate flow away from the river
Positive vertical gradients indicate upward flow
Negative vertical gradients indicate downward flow

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$\Sigma^2\Pi$

DRAFT

Figure 5
Geologic Profile with Gradient Summary, Nearshore Dredge Bathymetry Case

FIGURE 6
-60 foot Level Vertical Hydraulic Gradients Riverside of Proposed Barrier Wall

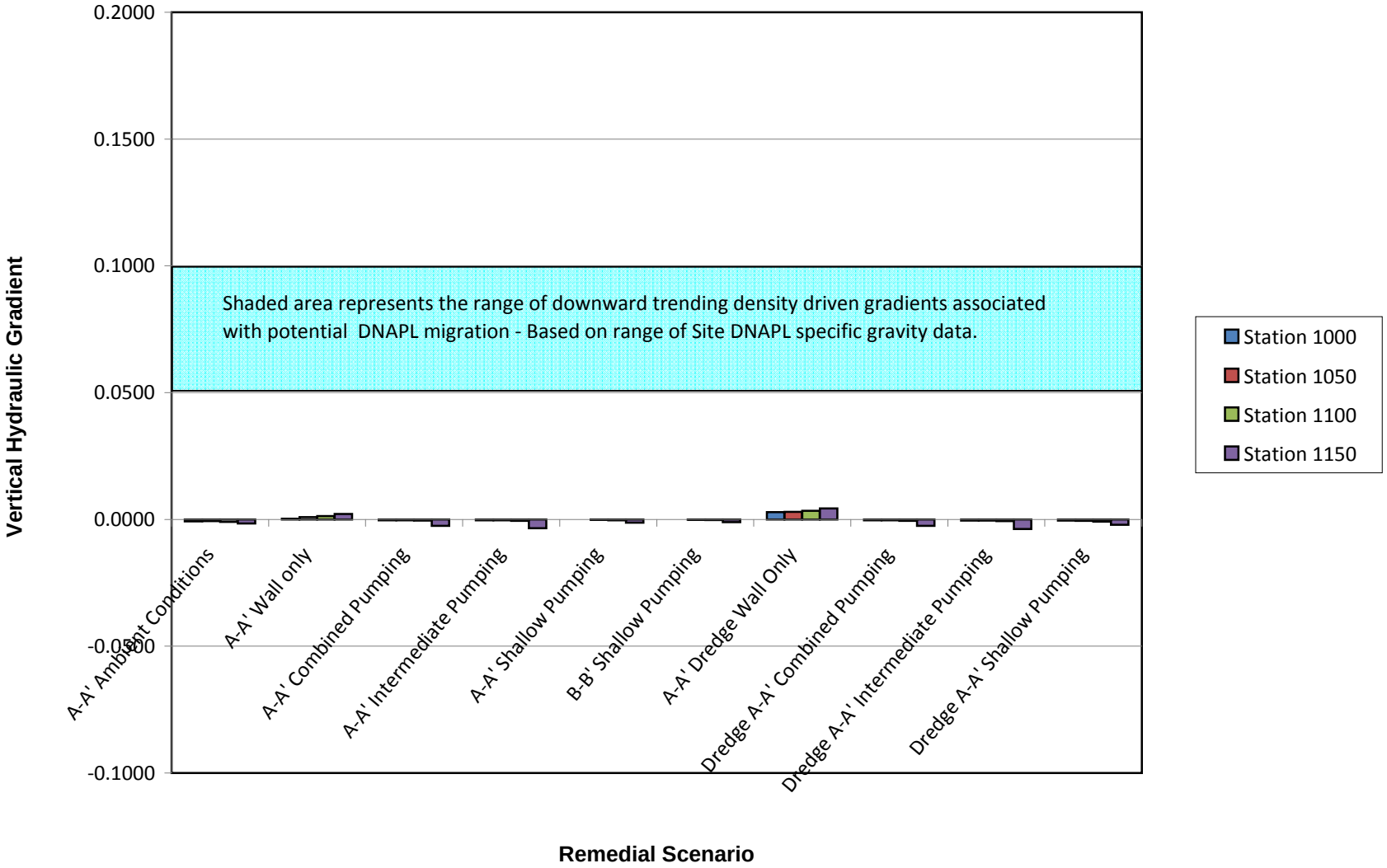

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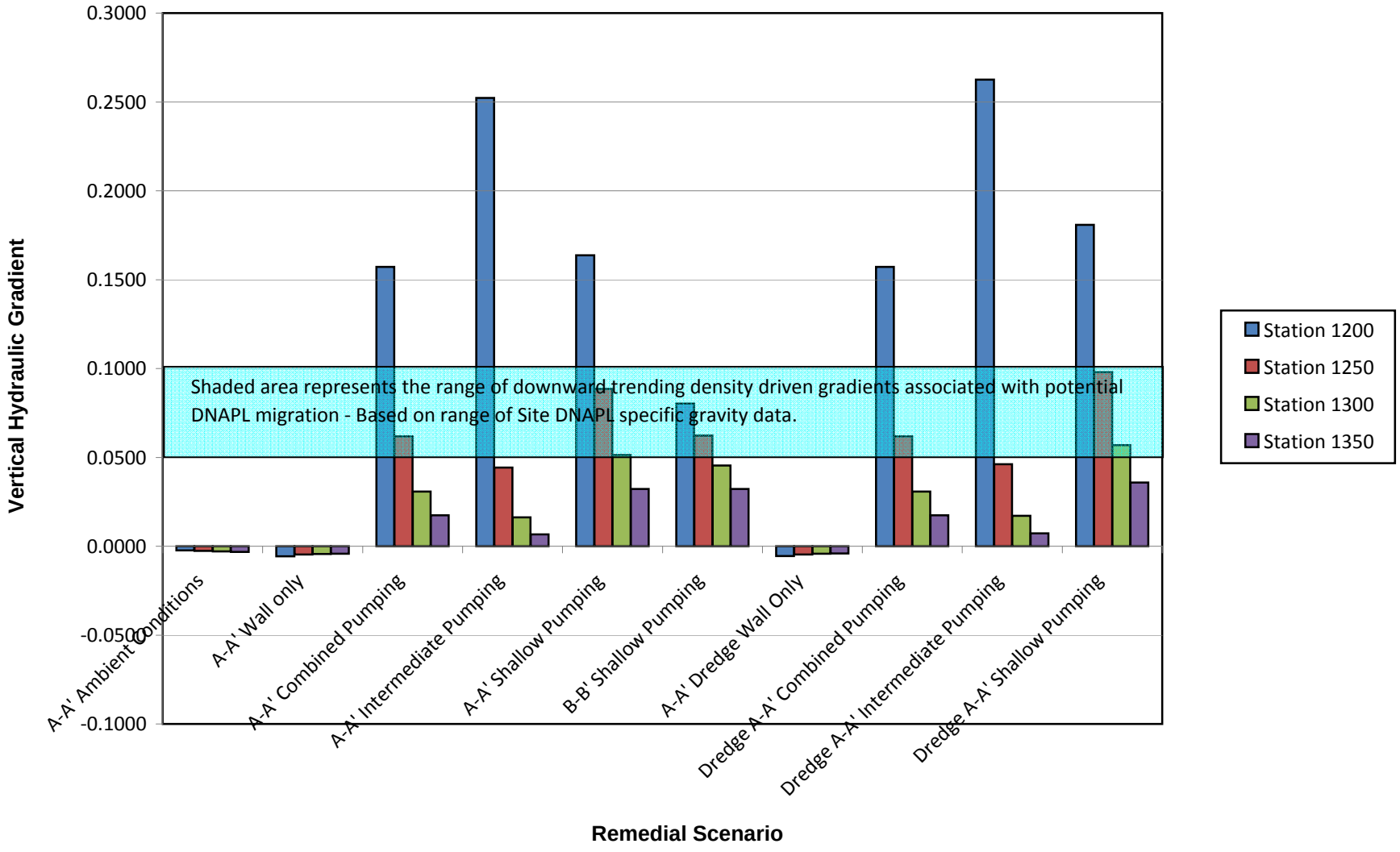
FIGURE 7
-60 foot Level Vertical Hydraulic Gradients Landward of Proposed Barrier Wall



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APPENDIX A
GRADIENT PROFILES A-1 THROUGH A-8

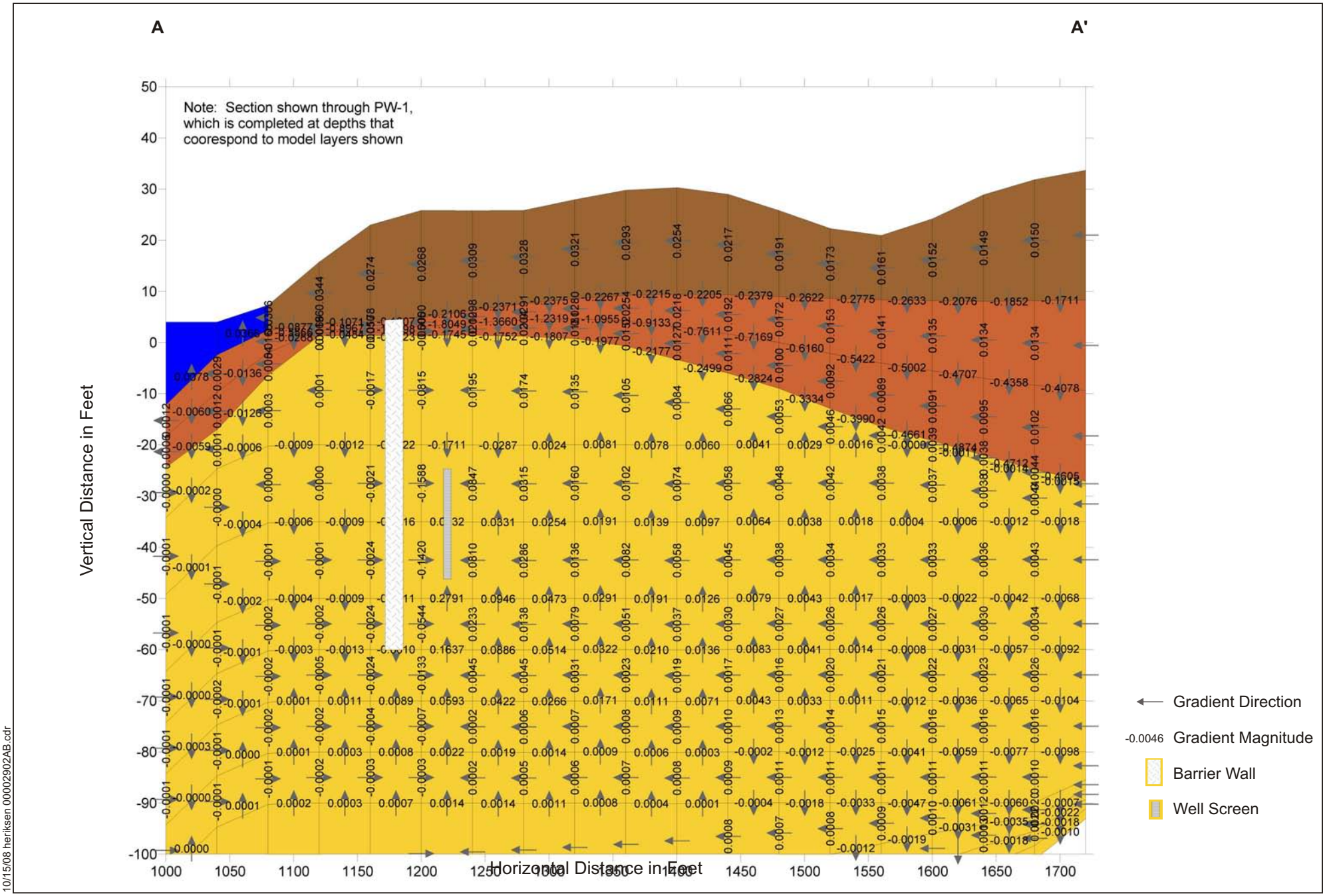

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Figure A-1
Gradient Profile A-A', Current Bathymetry, Shallow Well
NW Natural "Gasco" Site

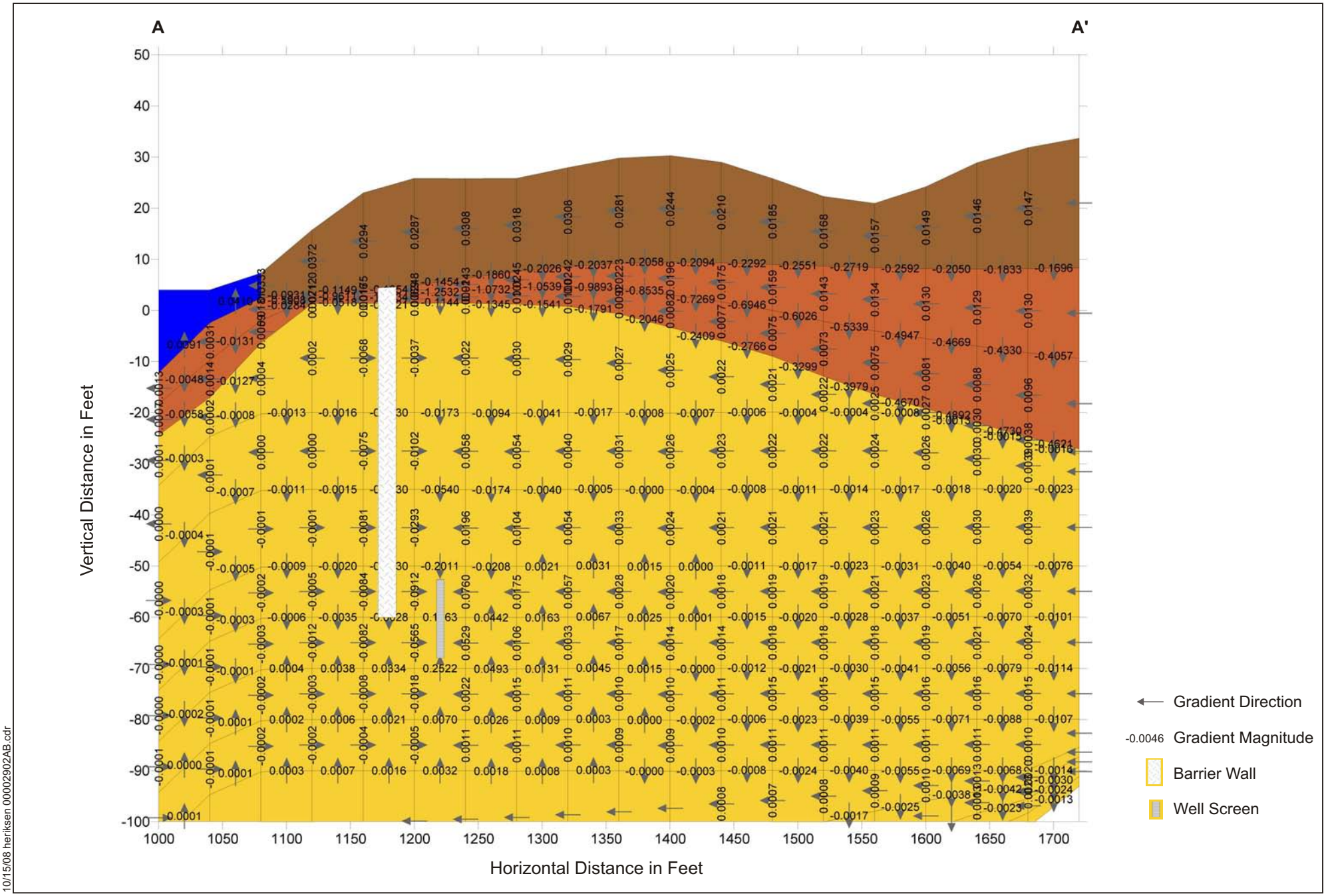

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Figure A-2
Gradient Profile A-A', Current Bathymetry, Intermediate Well
NW Natural "Gasco" Site

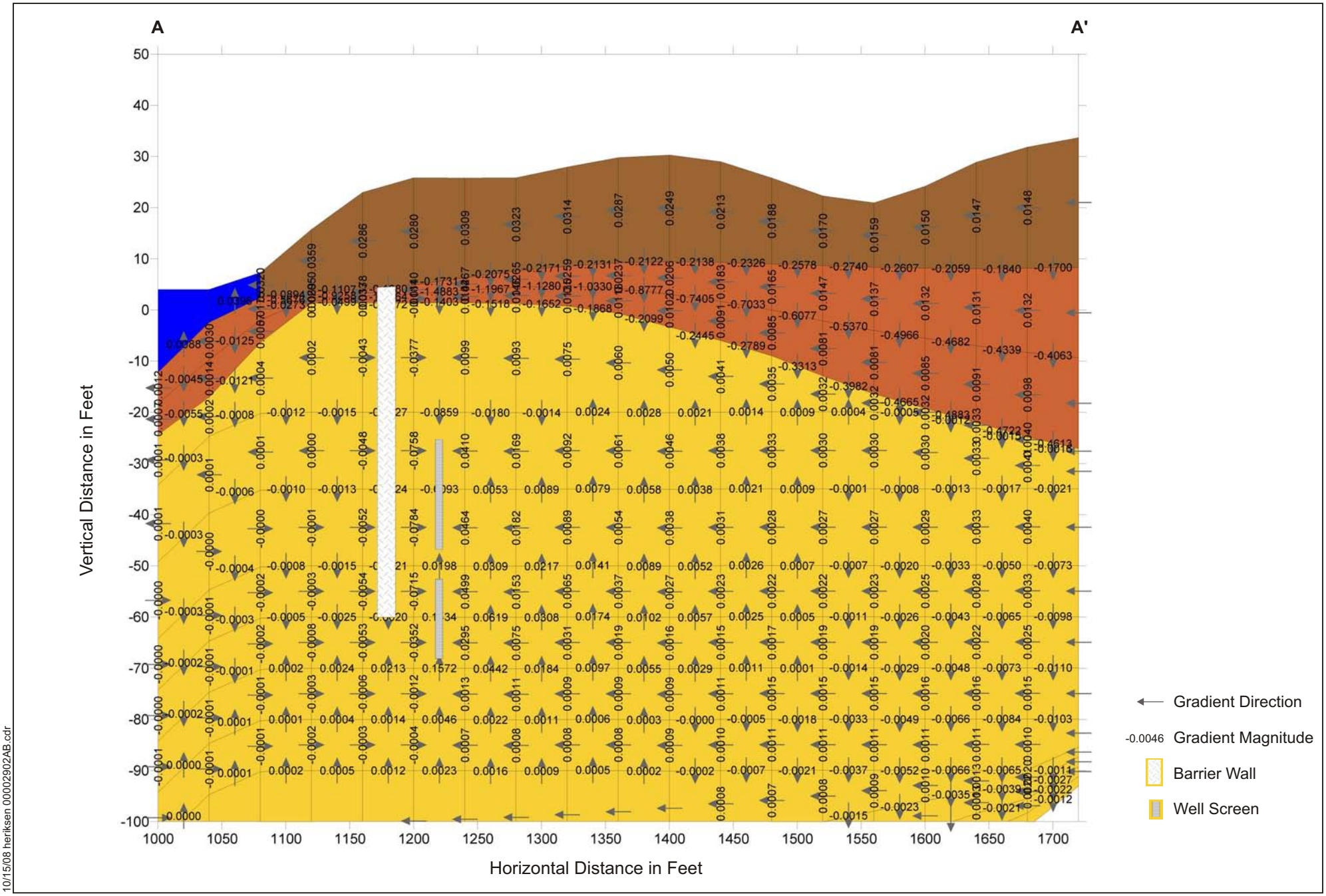

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Figure A-3
Gradient Profile A-A', Current Bathymetry, Shallow and Intermediate Wells
NW Natural "Gasco" Site

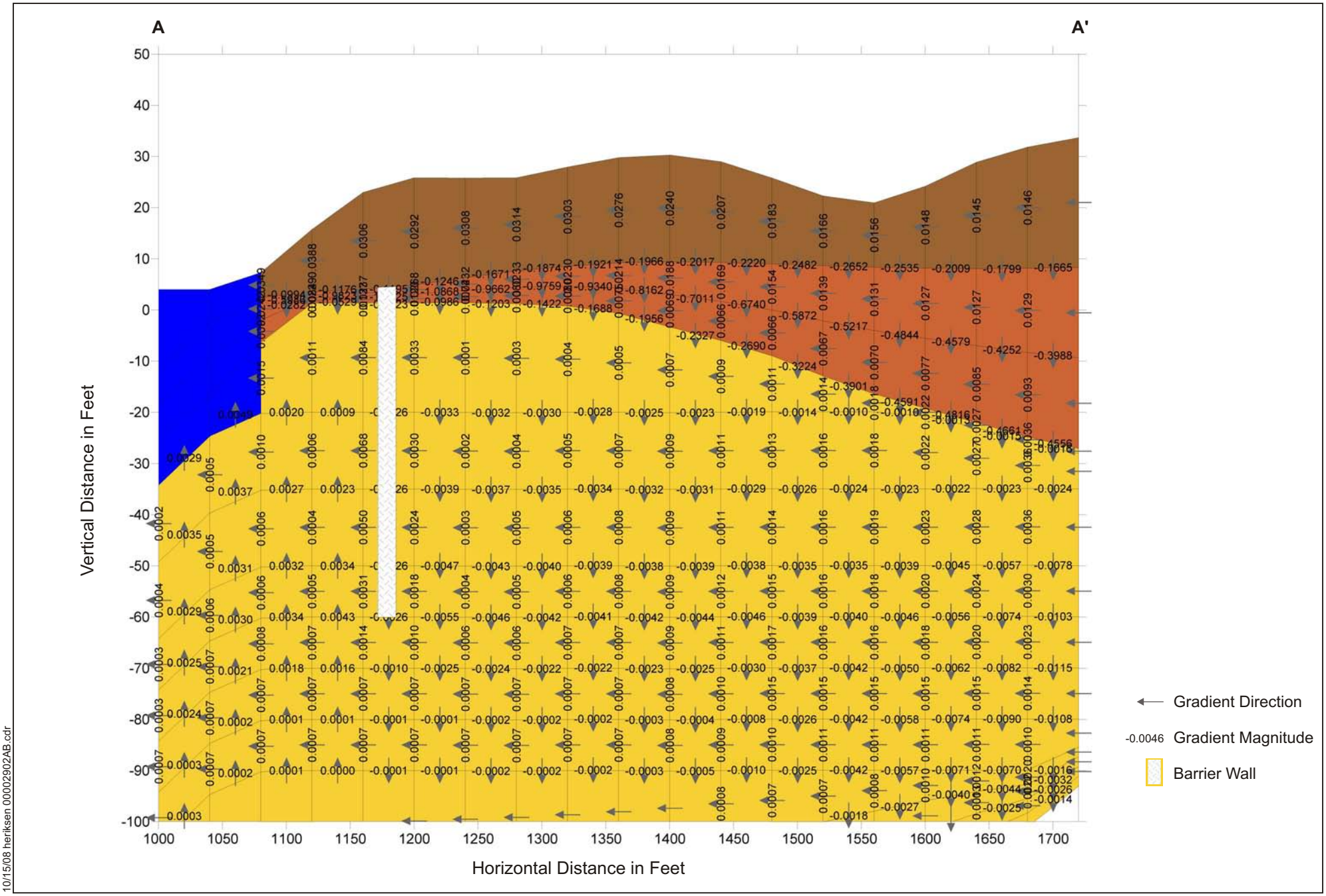

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Figure A-4
Gradient Profile A-A', Dredge Bathymetry, Vertical Barrier, No Pumping
NW Natural "Gasco" Site

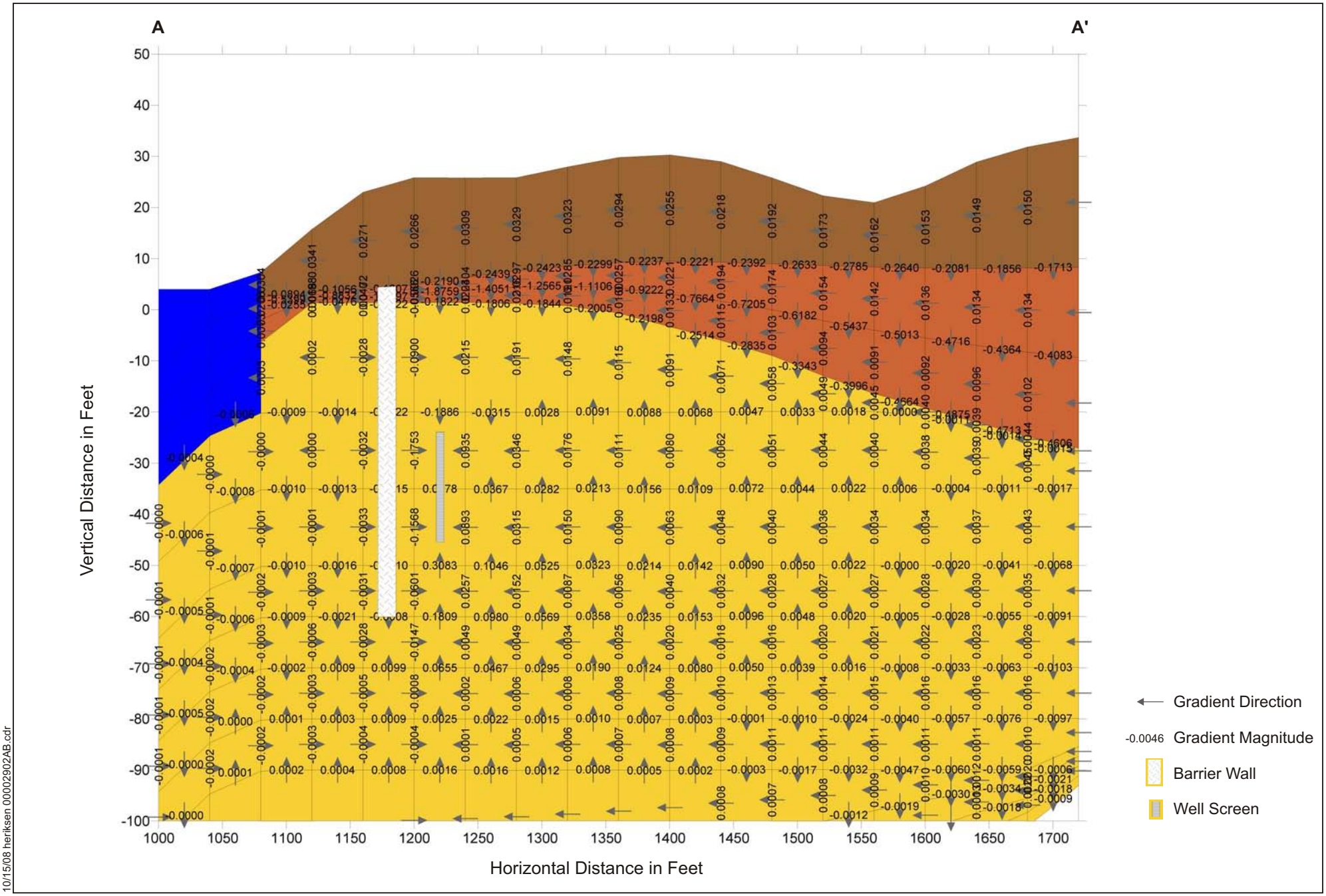

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Figure A-5
Gradient Profile A-A', Dredge Bathymetry, Vertical Barrier, Shallow Well
NW Natural "Gasco" Site

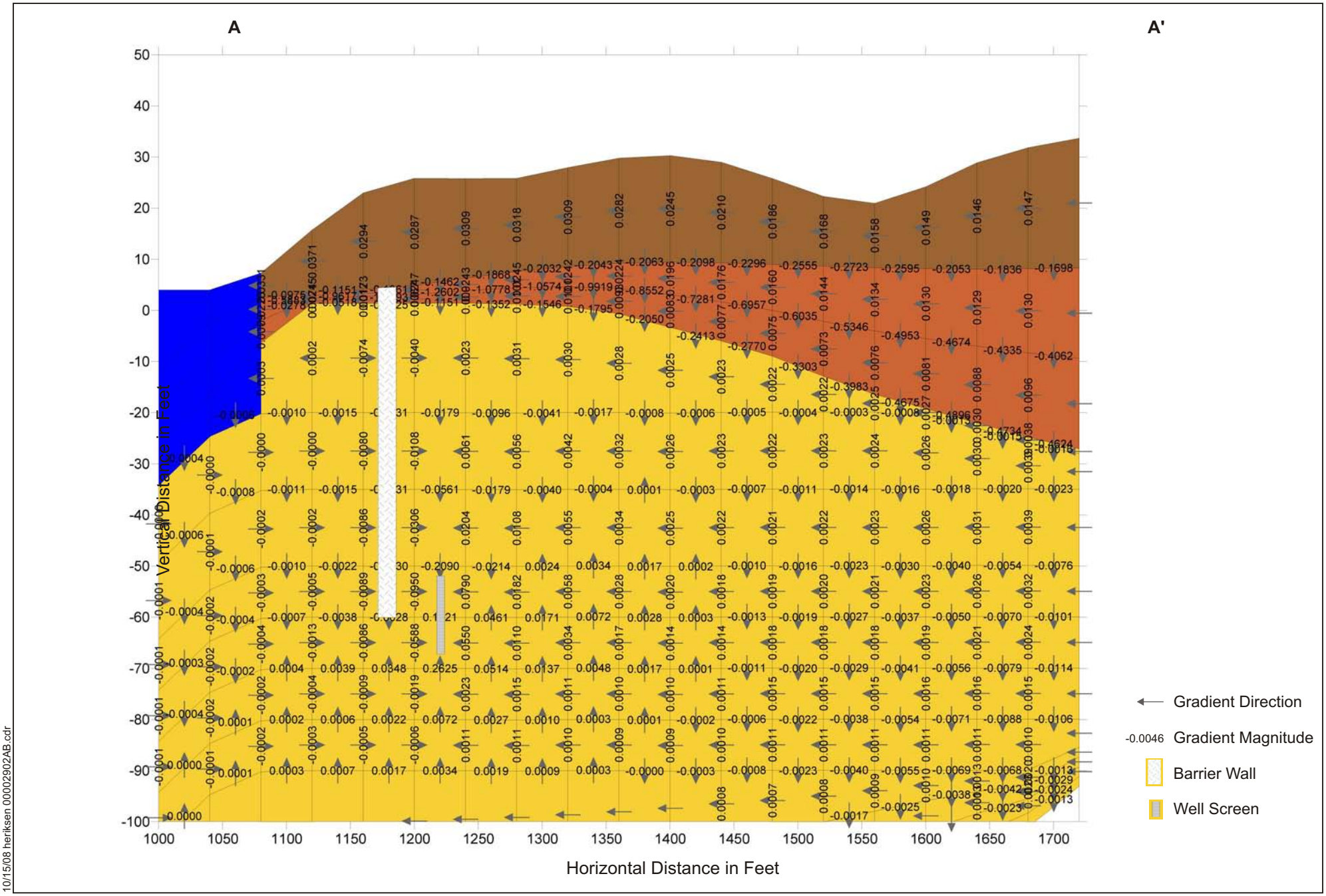

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Figure A-6
Gradient Profile A-A', Dredge Bathymetry, Vertical Barrier, Intermediate Well
NW Natural "Gasco" Site

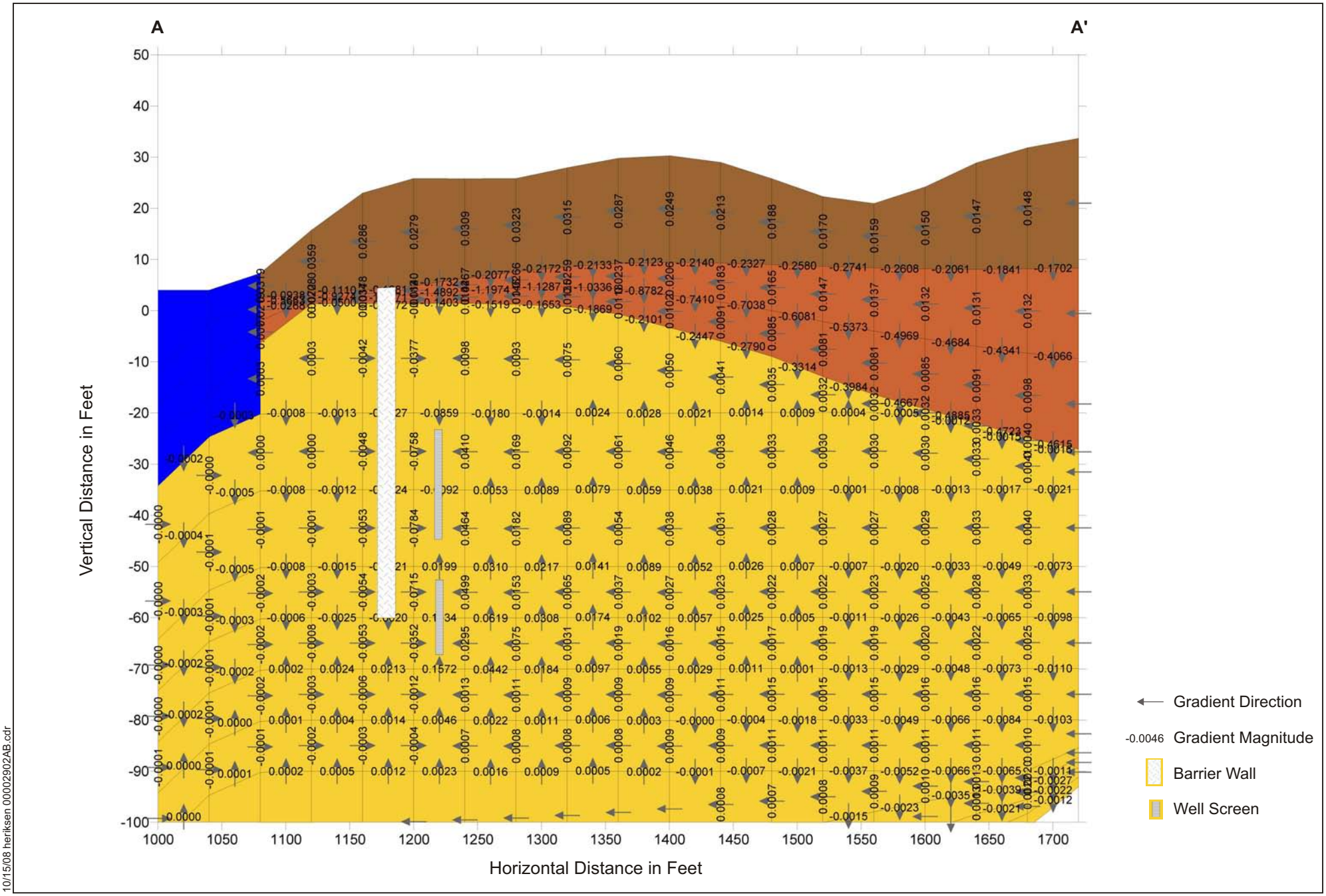

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Figure A-7
Gradient Profile A-A', Dredge Bathymetry, Vertical Barrier, Shallow and Intermediate Wells
NW Natural "Gasco" Site

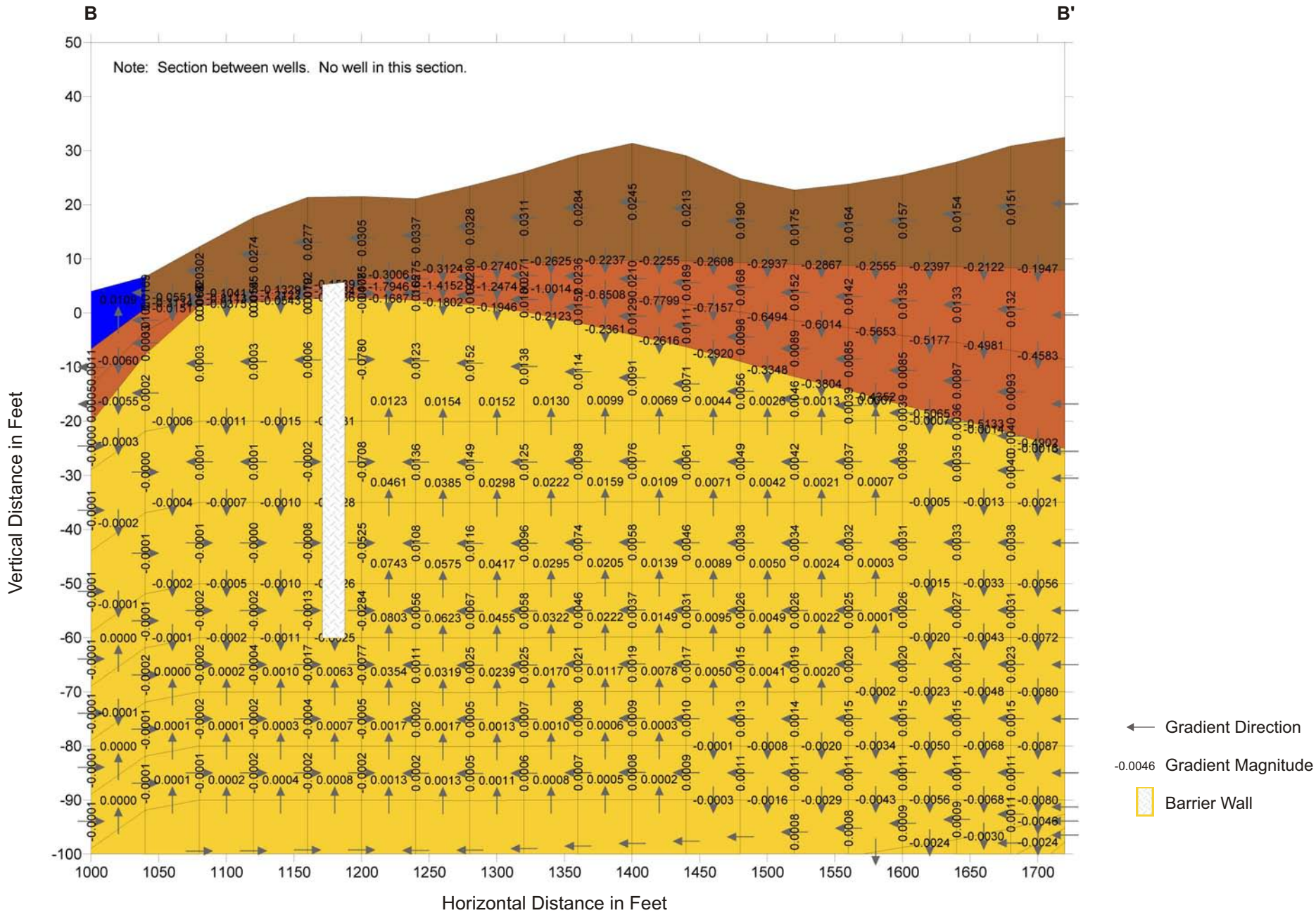

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Figure A-8
Gradient B-B', Current Bathymetry, Veritical Barrier, Shallow Well
NW Natural "Gasco" Site

APPENDIX B
SSPA MEMO ON REASONABLE WORST CASE SCENARIO

S.S. PAPADOPULOS & ASSOCIATES, INC.
ENVIRONMENTAL & WATER-RESOURCE CONSULTANTS

Memorandum

Date: October 15, 2008

From: Michael J. Riley

To: John Edwards, Anchor Environmental

Subject: NW Gasco: Groundwater Modeling, Proposed Reasonable Worst-Case Scenario

The groundwater model analysis for the Gasco shoreline wells was conducted for average water level data and river stage data presented in the site Draft Remedial Investigation Report (RI), June 30, 2006. Average water level data from 8 fill wells and 16 alluvium wells and from on-site river stage measurements were compiled for model calibration. The model was then used to evaluate groundwater extraction rates from shoreline wells to contain site groundwater.

The Oregon Department of Environmental Quality (DEQ) has requested that the groundwater model analysis be conducted for a reasonable worst-case condition rather than just of average conditions to evaluate higher groundwater extraction rates that may be necessary to contain groundwater under higher groundwater flow conditions. The following is an analysis of site groundwater and river stage data and recommendation on conditions to use for a reasonable worst-case evaluation.

Data Analysis

The difference between water level data and river stage data for fill and alluvium wells are presented in Table 1. The highlighted cells in the table indicate when the highest difference between groundwater level and river stage occur for each well.

For fill wells, the highest water level difference occurred at the March 2000 monitoring event at 5 of the 8 wells. The highest occurred at two wells during the September 2005 event and the highest occurred in November 1998 at one well. The highest water level differences exceeded the average values used in the model by approximately 2.5 to 4.5 feet.

For alluvium wells, the highest water level occurrence varied over more dates than for the fill wells. Of the 16 alluvium wells, three wells had the highest difference from the river in August 1999 while December 2004 was the highest in three other wells. Two wells had the highest difference in September 1996. Isolated maximum differences occurred in October 2001 and December 2003 at one well each. The most frequent maximum difference occurred in March 2000 when the maximum difference occurred at six wells.

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The alluvium wells showed a marked difference from well to well depending on proximity to the shoreline. For wells close to the shoreline (MW-2-61, MW-3-56, MW-4-35, MW-4-57, MW-4-101, MW-5-32, MW-5-100, MW-5-175, MW-8-56, and MW-13-61), the maximum water level difference between groundwater and the river varied less than 2 feet with the exception of MW-4-35. In addition, these wells showed negative differences indicating that the river stage was above the water level in the well.

Wells located farther from the shoreline (MW-9-29, MW-10-61, MW-12-36, MW-14-110, MW-15-50, and MW-15-66), showed much higher maximum differences ranging from 7 to 25 feet. In addition, these wells do not show negative values in the difference between water levels and river stage. In all of these wells, even the minimum difference is well above river stage.

Water level differences were compared to monthly precipitation data to aid in understanding differences between river stage and water levels. There was no correlation between precipitation and occurrence of highest water level differences. For instance, November 1998, had 11 inches of rainfall, but only one well showed a maximum water level difference that month. By contrast, 5 fill wells and 6 alluvium wells showed the highest water level data in March 2000, when only 3.2 inches of rainfall occurred. It is likely that the November 1998 rainfall partially went to moisture deficit since previous months were quite dry. However, the winter of 2000 was not particularly wet with 13.4 inches of rainfall from January through March. From 1996 to 2005, the rainfall that occurred in the three months prior to February or March monitoring events was higher in 6 of those years than in 2000. From this, there is no obvious correlation between precipitation and the highest difference between water level data and river stage.

Recommendation

A reasonable worst-case scenario can be based on the March 2000 water level and river stage data. The lack of correlation between precipitation and highest water level differences indicates that there is no value in searching precipitation data for extreme events. The likely reason for the lack of correlation is that higher precipitation generates higher runoff with little change in infiltration, especially if the soil is already saturated.

Water levels in nearshore alluvium wells are strongly correlated with river stage showing limited range between minimum and maximum water level differences. Nearshore wells in both the fill and alluvium often show negative differences between water levels and river stage, which suggests that the difference may be affected by the timing of data collection with respect to tidal fluctuations. Consequently, the differences may not be meaningful with respect to groundwater flow rates over periods of longer than a few hours.

Based on the above, it is recommended that the reasonable worst-case scenario for evaluation of capture at nearshore wells be based on water level data at upland wells and river stage data from the March 27, 2000 monitoring event. The groundwater flow model would be re-calibrated to water level data at fill wells MW-8-29, MW-10-25, MW-11-32, and MW-13-30 and alluvium

wells MW-9-29, MW-10-61, MW-12-36, MW-14-110, MW-15-50, and MW-15-66. The recalibration will likely include changes to both the recharge rate and the upland boundary head.

The reasonable worst-case re-calibration would be used to simulate the hypothetical intermediate and shallow well extraction systems. The pump rates developed for the reasonable worst-case scenarios will be compared to the simulations under average conditions as a means of evaluating possible seasonal fluctuations in pump rates to achieve capture.

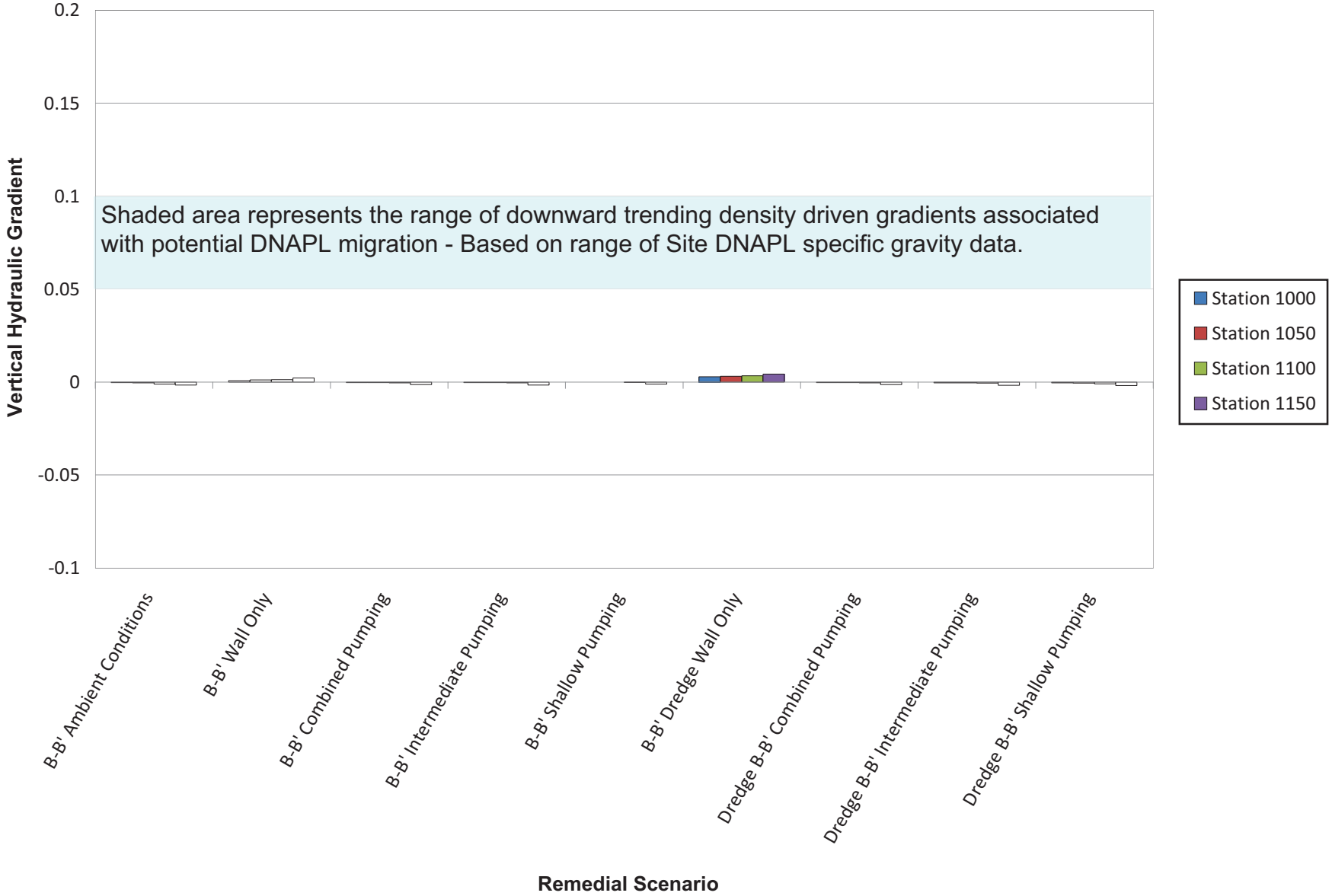
Table 1. Difference between water level and river stage based on data presented in the Draft Remedial Investigation Report

(Highlighted values are dates of maximum difference between water levels and river at each well)

	Nearshore Fill						Upland Fill		Nearshore Alluvium										Upland Alluvium					
Date	**MW-1-22**	**MW-2-32**	**MW-3-26**	**MW-6-32**	**MW-8-29**	**MW-13-30**	**MW-10-25**	**MW-11-32**	**MW-2-61**	**MW-3-56**	**MW-4-35**	**MW-4-57**	**MW-4-101**	**MW-5-32**	**MW-5-100**	**MW-5-175**	**MW-8-56**	**MW-13-61**	**MW-9-29**	**MW-10-61**	**MW-12-36**	**MW-14-110**	**MW-15-50**	**MW-15-66**
05-Dec-95	1.70	0.33	-0.37	-0.10	0.44		5.34	6.80		-0.62	-0.48	-0.76		-0.53			-0.38		12.55	7.01	10.42			
05-Jan-96	7.85	1.99	2.21	8.24	7.65		11.59	13.77		-0.21	-0.36	-0.28		-0.17			-0.04		17.89	10.58	15.44			
12-Feb-96	0.58	-0.58	-0.84	-0.47	-4.33		1.68	3.01		-0.99	-0.98	-1.00		-1.01			-0.86		7.90	3.98	6.99			
18-Mar-96	7.90	2.02	1.83	9.00	9.46		12.86	14.56		0.00	-0.11	-0.09		0.05			0.18		17.11	10.45	15.27			
16-Apr-96	6.57	1.10	1.45	7.56	8.98		12.06	13.74		0.07	-0.25	-0.07		-0.06			0.16		16.19	9.73	14.47			
10-May-96	9.37	3.36	3.50	10.58	11.69		14.61	16.36		0.43	0.33	0.30		0.42			0.57		19.08	11.80	16.82			
17-Jun-96	5.14	1.33	0.98	6.38	7.36		9.98	11.76		0.13	0.20	0.07		0.14			0.25		16.89	9.64	12.98			
21-Aug-96	11.61	6.03	5.24	12.71	13.28		16.01	18.36		0.45	1.14	0.39		0.74			0.57		22.55	13.27	17.53			
17-Sep-96	11.89	6.60	7.70	12.77	13.16		16.62	18.57		0.25	1.59	0.20		0.76			0.70		24.33	14.23	18.03			
30-Sep-96	12.18	6.82	5.39	13.03	13.50		16.93	18.73		1.63	1.68	1.52		1.75			1.28		23.55	14.09	18.32			
15-Nov-96	11.17	5.24	6.15	11.31	11.26		15.60	16.99		0.39	0.49	0.33		0.79			0.56		23.84	13.75	17.64			
24-Feb-97	8.74	2.15	1.90	9.08	7.06		10.77	13.61		-0.01	0.12	-0.09		0.06			0.20		19.70	11.40	15.38			
10-Jun-97	2.03	0.40	0.48	1.87	0.70		3.38	6.06		0.04	0.01	0.14		0.03			0.05		12.98	7.30	10.37			
26-Aug-97	11.47	4.86	3.60	9.08	10.88		14.22	16.19		0.07	0.08	0.79		0.30			0.10		18.04	11.27	16.66			
25-Nov-97	11.61	4.24	6.14	10.50	9.52		14.14	15.79		0.71	0.68	1.01		0.88			0.56		21.08	12.72	18.18			
16-Feb-98	11.94	4.12	5.25	11.01	8.83	9.92	13.41	16.16		0.31	1.08	0.22		0.53			0.42	0.59	22.11	13.23	18.76			
01-Jun-98	2.71	-0.06	-0.05	2.21	1.49	1.62	7.04	7.99		0.01	0.09	-0.02		-0.05			-0.05	0.12	12.85	7.42	11.31			
25-Aug-98	10.73	5.32	4.03	11.38	11.80	10.90	18.50	17.70		-0.12	0.82	-0.23		0.29			0.27	0.16	18.58	11.74	17.32			
16-Nov-98	10.53	4.07	6.11	11.48	12.10	11.28	19.12	18.14	0.25	0.70	1.42	0.63	0.27	1.04	0.32	0.34	1.20	0.87	19.75	12.72	17.97	6.77		
15-Feb-99	12.60	5.26	5.66	12.98	11.25	11.64	16.63	18.18	0.29	0.69	0.42	0.64	0.43	0.90	0.41	0.47	0.98	0.98	22.36	13.81	19.00	6.88		
11-May-99	9.52	3.36	4.44	11.19	11.62	9.92	12.49	16.66	0.51	0.72	0.71	0.63	0.51	0.86	0.53	0.60	0.91	0.96	18.24	11.48	16.67	5.88		
20-Aug-99	11.06	5.98	5.87	9.39	13.12	11.36	17.90	17.82	1.14	1.44	2.24	1.40	1.17	1.78	1.19	1.25	1.77	1.65	19.29	12.55	17.97	7.16	13.78	13.67
25-Oct-99	10.64	4.10	4.08	10.88	12.63	10.71	17.19	17.16	0.01	0.39	0.89	0.41	0.29	0.64	0.32	0.45	0.72	0.52	18.16	11.55	16.55	6.10	12.60	12.45
27-Mar-00	15.05	7.55	8.05	14.64	12.84	13.59	14.70	18.67	0.65	0.98	2.03	0.91	0.63	1.65	0.66	0.73	1.23	1.25	24.58	15.19	20.22	7.48	15.10	14.56
15-Jun-00	8.07	2.86	3.68	9.04	9.14	8.62	14.06	14.61	-0.09	0.09	-0.30	-0.03	-0.16	0.01	-0.18	-0.09	0.29	0.26	17.08	10.36	15.16	4.97	11.41	10.68
04-Oct-00	10.48	5.10	5.87		12.66	11.42	19.01	18.12	-0.63	-0.47	0.40	-0.54	-0.68	-0.22	-0.69	-0.62	-0.45	-0.32	17.86	10.90	15.72	4.98	12.04	11.28
20-Dec-00	9.65	4.61	7.49		12.73	11.04	19.08	18.18	0.16	0.06	1.29	0.14	0.48	0.38	0.56	0.76	-0.11	-0.04	18.31	12.01	16.40	4.24	12.60	11.86
27-Mar-01	11.42	6.10	6.83		13.48	11.63	19.06	18.34	-0.06	0.30	1.11	0.20	-0.16	0.75	-0.16	-0.11	0.64	0.50	19.32	12.06	17.31	5.75	13.15	12.41
28-Jun-01	11.62	5.86	4.86		12.84	11.69	16.84	18.03	0.72	0.85	1.92	0.90	1.00	1.13	0.97	1.11	0.98	0.95	19.23	11.30	17.52	6.42	13.54	12.84
08-Oct-01	11.54	4.33	4.69		13.13	11.48	16.97	17.32	0.59	1.00	1.52	0.88	1.67	1.19	0.74	0.77	1.05	1.03	18.18	11.47	16.27	5.93	12.59	11.90
12-Dec-01	10.34	4.10	5.94		9.83	9.29	15.04	14.71	0.19	0.58	2.74	0.52	0.22	1.14	0.22	0.30	1.02	0.76	20.26	12.65	17.34	6.07	13.24	12.52
02-Apr-02	11.25	5.47	4.98		10.33	10.99	13.93	16.71	0.11	0.22	-0.36	0.17	0.25	0.60	0.23	0.33	0.00	0.41	21.14	12.35	17.69	5.30	12.89	12.12
10-Jul-02	8.61	3.72	3.73		9.70	8.81	14.06	15.43	0.14	0.42	0.46	0.35	0.27	0.59	0.25	0.31	0.44	0.51	17.08	10.45	15.75	5.16	11.10	11.88
23-Sep-02	11.71	4.91	4.78		13.08	11.63			0.37	0.82	1.69	0.66	0.32	1.09	0.30	0.36	1.18	1.03	18.78	11.90	16.67	6.26	13.03	12.35
17-Dec-02	5.59	0.23	4.04		7.48	6.02	13.20	11.27	-0.02	-0.80	1.11	-0.71	-0.52	-0.91	-0.53	-0.62	-1.85	-0.79	14.90	8.71	12.82	3.48	9.95	9.38
17-Mar-03	10.52	4.42	4.99		9.07	9.61	13.49	15.56	0.16	0.39	0.83	0.29	0.12	0.68	0.11	0.19	0.29	0.53	21.45	12.95	11.89	5.86	13.14	12.42
02-Jun-03	6.91	1.77	1.19		6.27	6.48	9.95	12.12	0.11	0.21	0.05	0.11	0.19	0.12	0.14	0.23	0.16	0.31	15.53	9.27	13.80	4.27	10.22	9.67
29-Sep-03	10.63	3.70	3.81		11.99	10.61	17.45	16.12	0.18	1.04	0.63	1.00	1.20	1.13	1.09	1.17	0.64	1.25	17.32	10.88	15.40	5.56	12.08	11.42
29-Dec-03	9.92	3.12	6.39		9.70	8.83	14.41	15.18	0.38	0.80	3.59	0.76	0.62	1.20	0.61	0.67	0.70	0.91	20.96	12.67	17.78	5.76	13.25	12.52
29-Mar-04	11.81	5.60	6.05		11.20	11.32			-0.50	-0.37	0.55	-0.42	-0.50	0.27	-0.49	-0.41	-0.39	-0.28	20.94	12.51	18.32	5.39	13.54	12.70
11-Aug-04	10.81	4.34	3.83		12.08	10.79	17.05	17.12	-0.07	-0.73	0.57	-0.66	-0.79	-0.20	-0.60	-0.43	-0.38	-0.69	18.08	14.16	16.30	4.80	12.66	11.69
20-Dec-04	9.51	3.03	4.88		10.50	9.41	14.96	15.84	1.43	1.24	1.82	1.19	1.21	1.70	1.25	1.36	0.99	1.30	21.07	13.04	17.35	6.17	13.37	12.27
28-Mar-05	9.00	2.50	5.47		8.90	8.15	13.28	14.15	0.76	0.56	1.81	0.55	0.57	0.65	0.55	1.23	0.59	0.78	20.84	12.09	16.42	5.33	12.34	11.67
20-Jun-05	11.43	5.92	5.20		11.55	10.43	15.66	17.25	0.18	0.58	1.34	0.56	0.32	0.94	0.28	0.35	1.08	0.73	21.59	13.48	18.37	6.58	14.07	12.91
16-Sep-05	13.36	5.90	6.04		14.31	13.17	18.37	19.15	0.41	1.04	2.38	0.80	0.29	1.49	0.35	0.39	1.69	1.31	21.39	13.80	18.47	7.25	14.63	13.81
07-Dec-05	10.81	4.52	5.87		10.56	9.79	15.52	16.43	-0.34	-0.19	0.85	-0.30	-0.51	0.53	-0.40	-0.32	-0.03	0.07	21.58	12.94	17.38	5.44	13.19	12.33
Minimum	0.58	-0.58	-0.84	-0.47	0.44	1.62	1.68	3.01	-0.63	-0.99	-0.98	-1.00	-0.79	-1.01	-0.69	-0.62	-1.85	-0.79	7.90	3.98	6.99	3.48	9.95	9.38
Maximum	15.05	7.55	8.05	14.64	14.31	13.59	19.12	19.15	1.43	1.63	3.59	1.52	1.67	1.78	1.25	1.36	1.77	1.65	24.58	15.19	20.22	7.48	15.10	14.56
Calibration Targets	10.51	4.37	5.17	11.99	11.22	10.35	15.85	16.57	0.25	0.45	1.20	0.39	0.31	0.75	0.29	0.38	0.55	0.60	19.47	12.12	16.73	5.76	12.59	11.94
Difference from Calibration Targets	4.54	3.18	2.88	2.65	3.09	3.24	3.27	2.58	1.18	1.18	2.39	1.13	1.36	1.03	0.96	0.98	1.22	1.05	5.11	3.07	3.49	1.72	2.51	2.62

SUPPLEMENTAL FIGURES

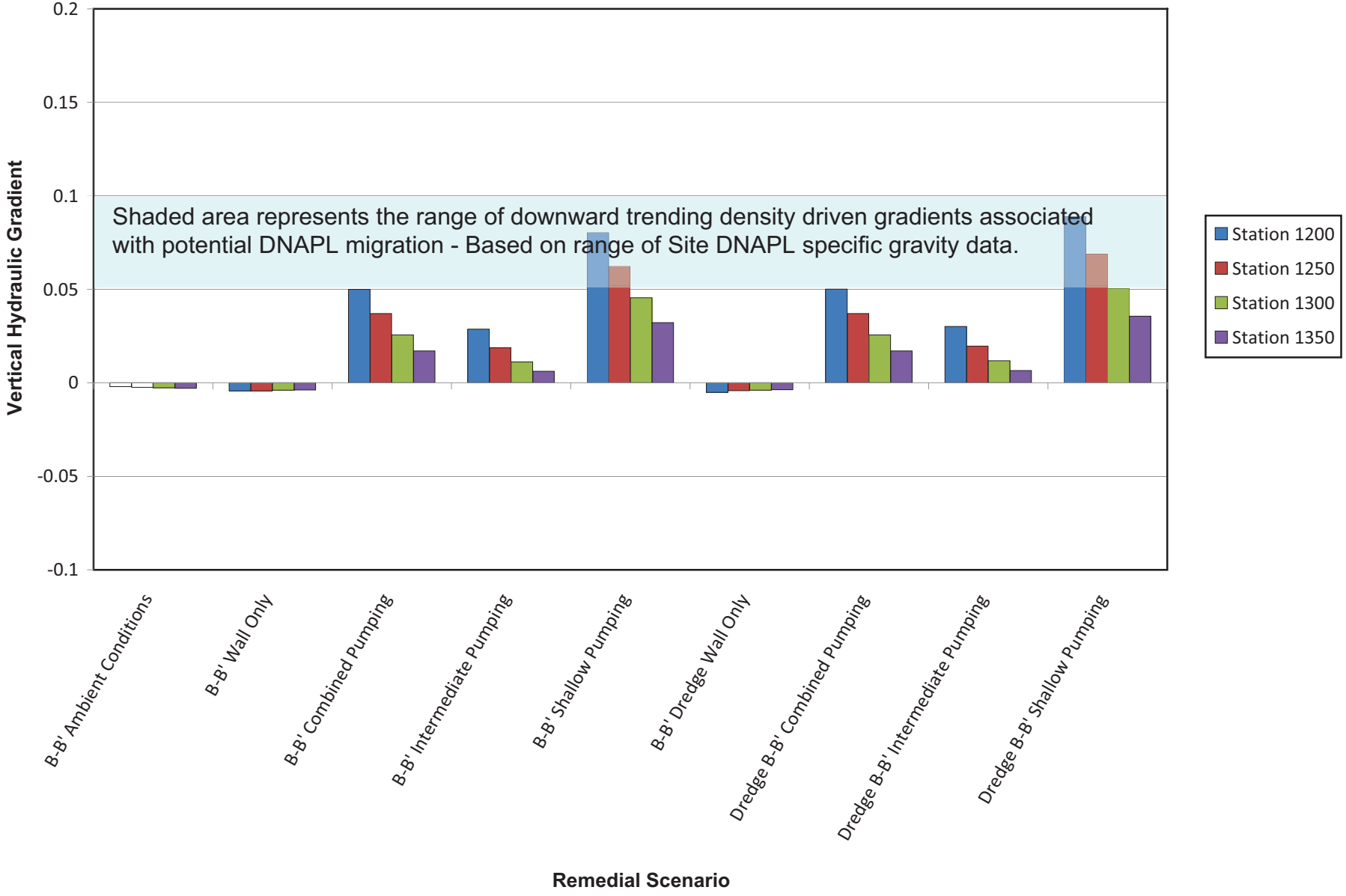
Figure 8
-60 foot Level Vertical Hydraulic Gradients Riverside of Proposed Barrier Wall



ANCHOR ENVIRONMENTAL, L.L.C.

Figure 9

-60 foot Level Vertical Hydraulic Gradients Landward of Proposed Barrier Wall



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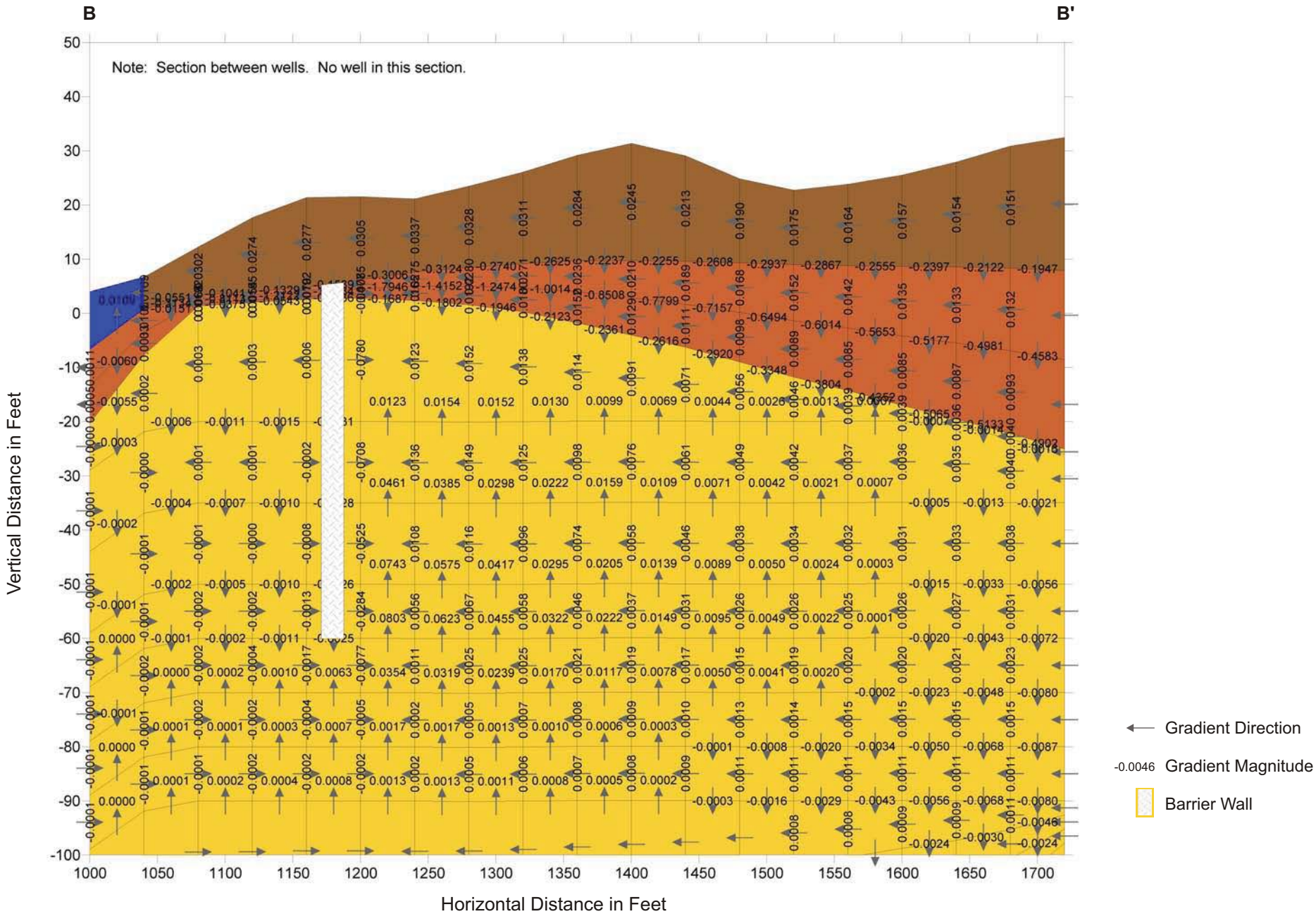

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Figure A-8
Gradient Profile B-B', Current Bathymetry, Shallow Wells
NW Natural "Gasco" Site

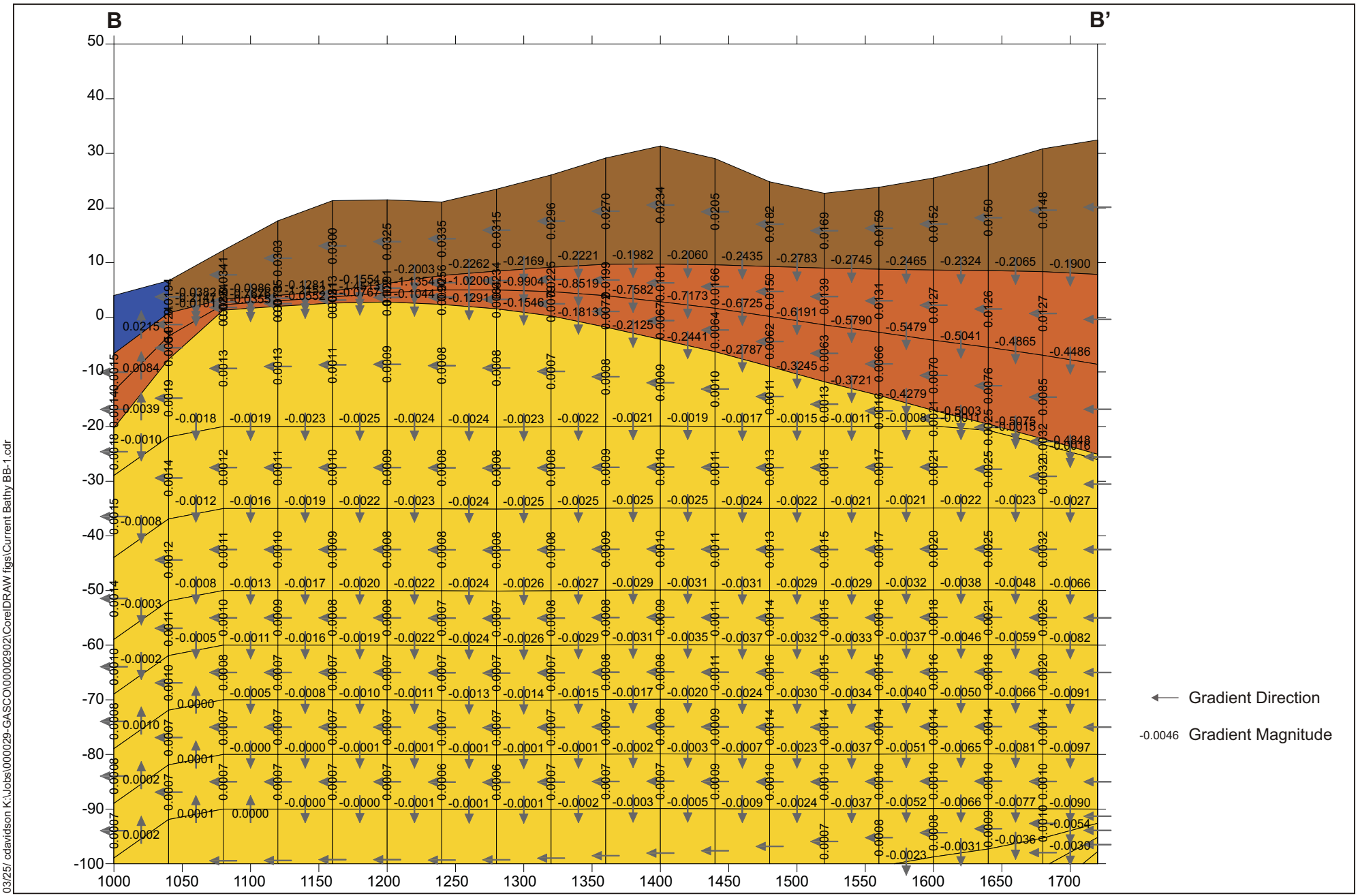

Figure A-9

Gradient Profile B-B', Current Bathymetry, No Vertical Barrier, No Pumping
NW Natural "Gasco" Site

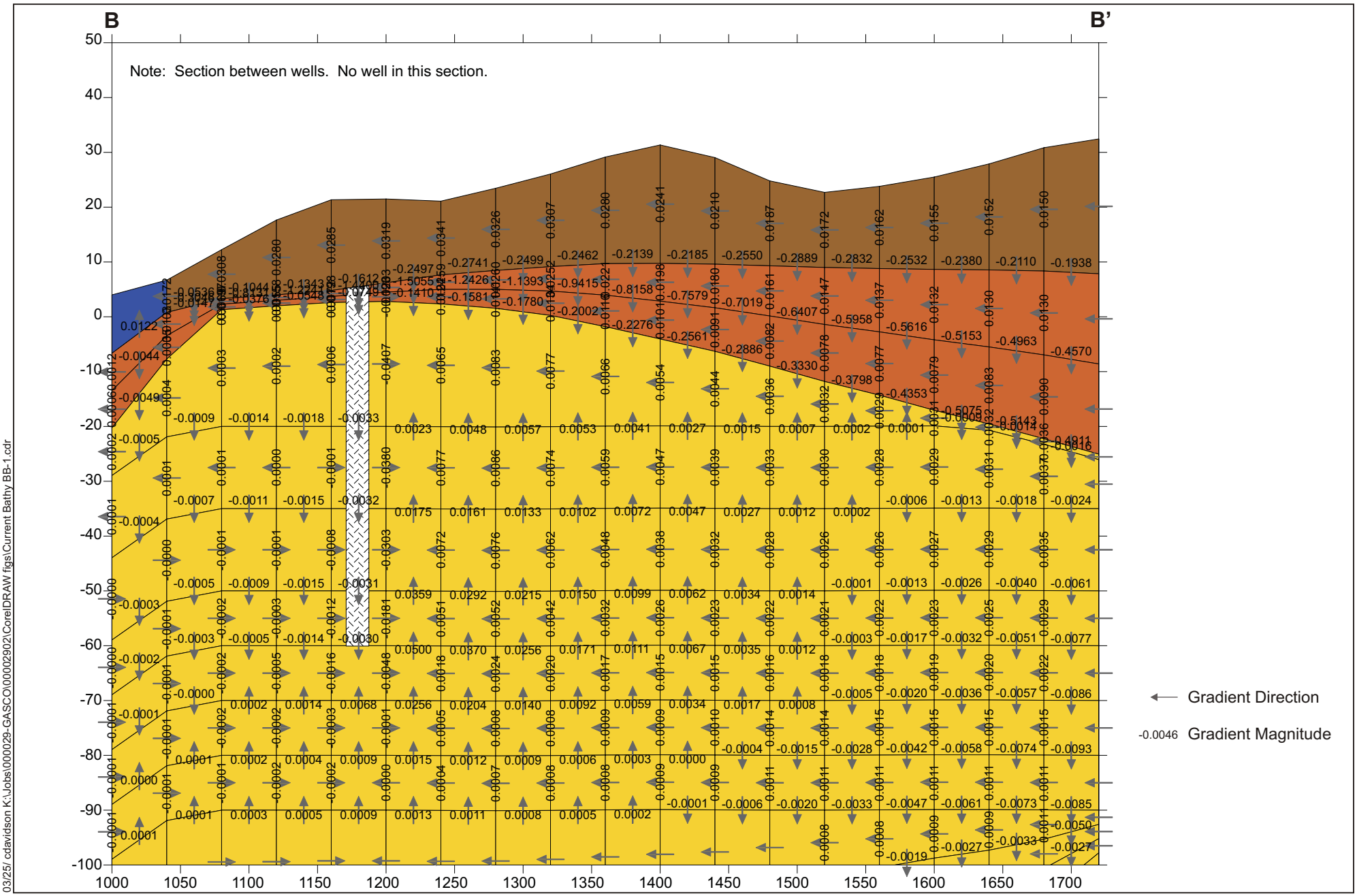

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Figure A-10

Gradient Profile B-B', Current Bathymetry, Vertical Barrier, Shallow and Intermediate Wells
NW Natural "Gasco" Site

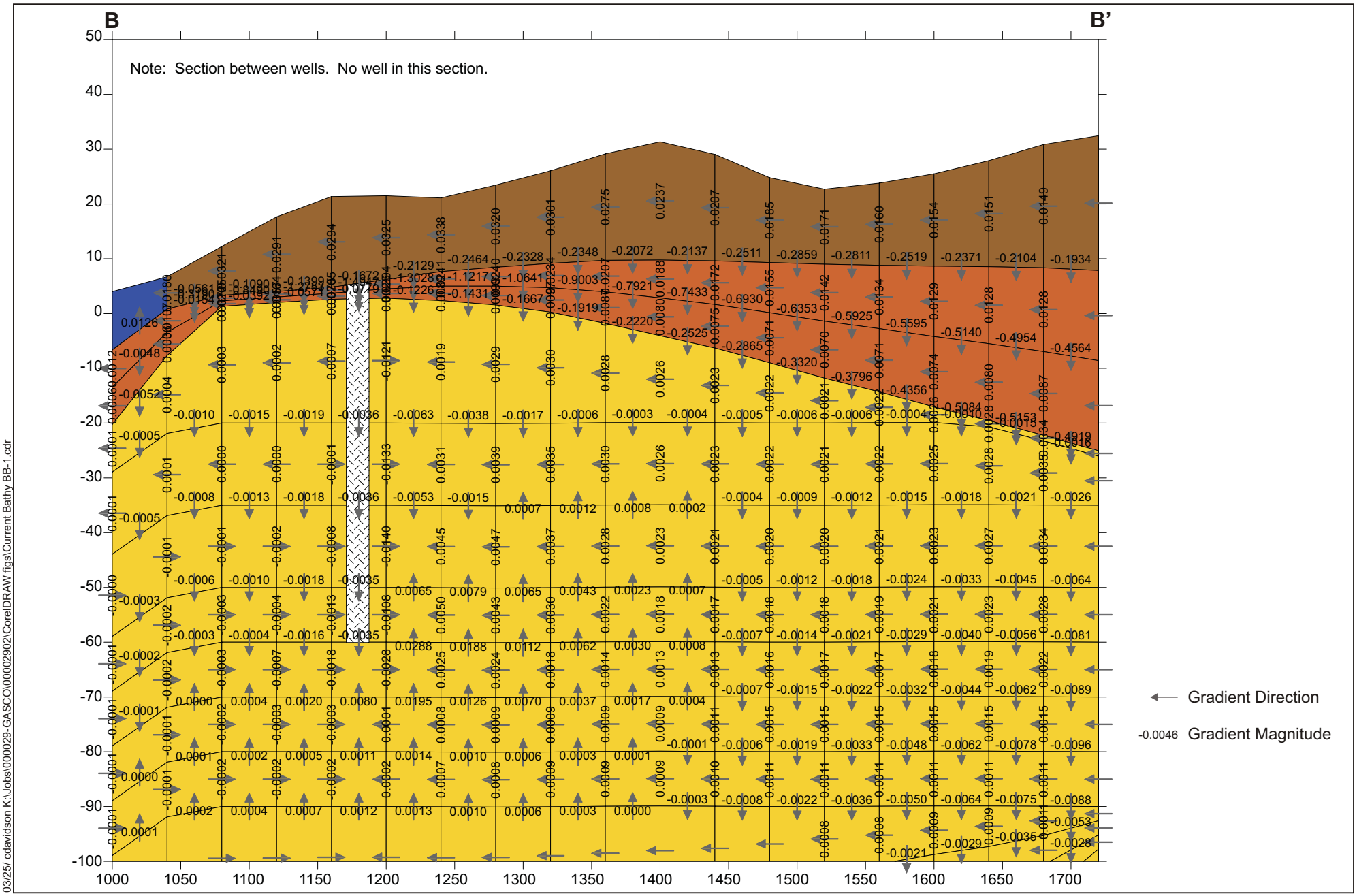

Figure A-11

Gradient Profile B-B', Current Bathymetry, Vertical Barrier, Intermediate Wells
NW Natural "Gasco" Site

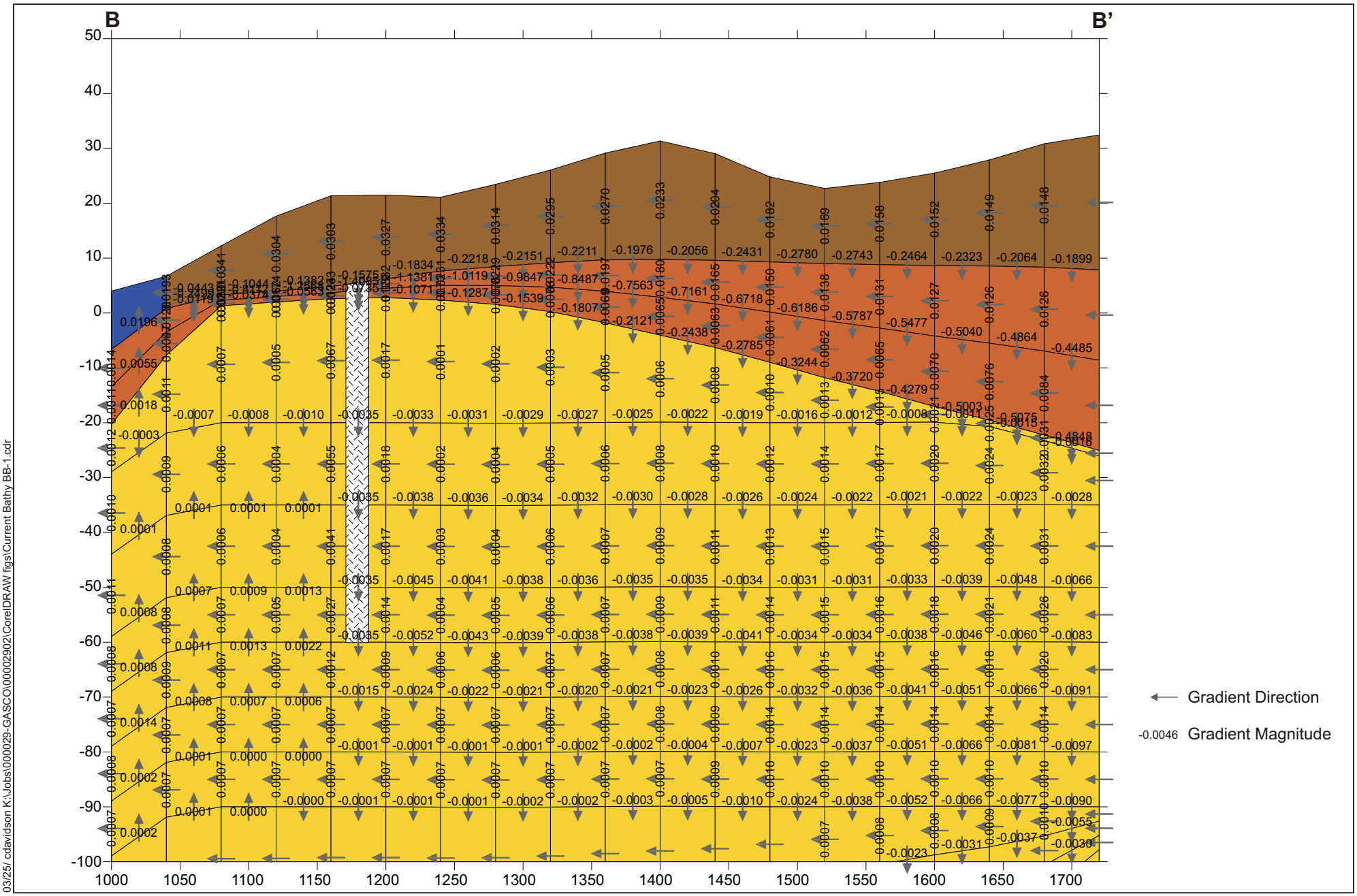

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Figure A-12
Gradient Profile B-B', Current Bathymetry, Vertical Barrier, No Pumping
NW Natural "Gasco" Site

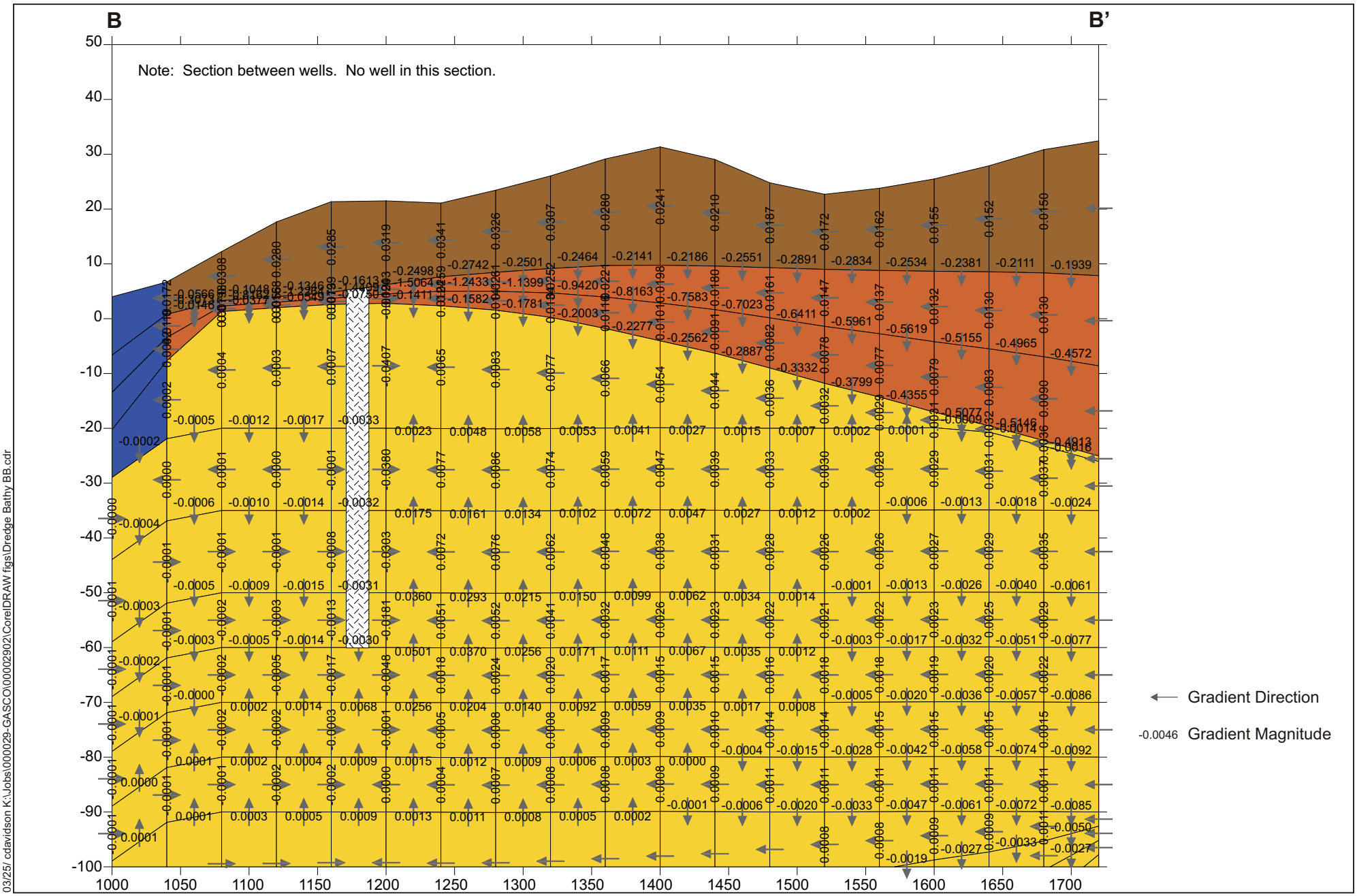

Figure A-13

Gradient Profile B-B', Dredge Bathymetry, Vertical Barrier, Shallow and Intermediate Wells
NW Natural "Gasco" Site

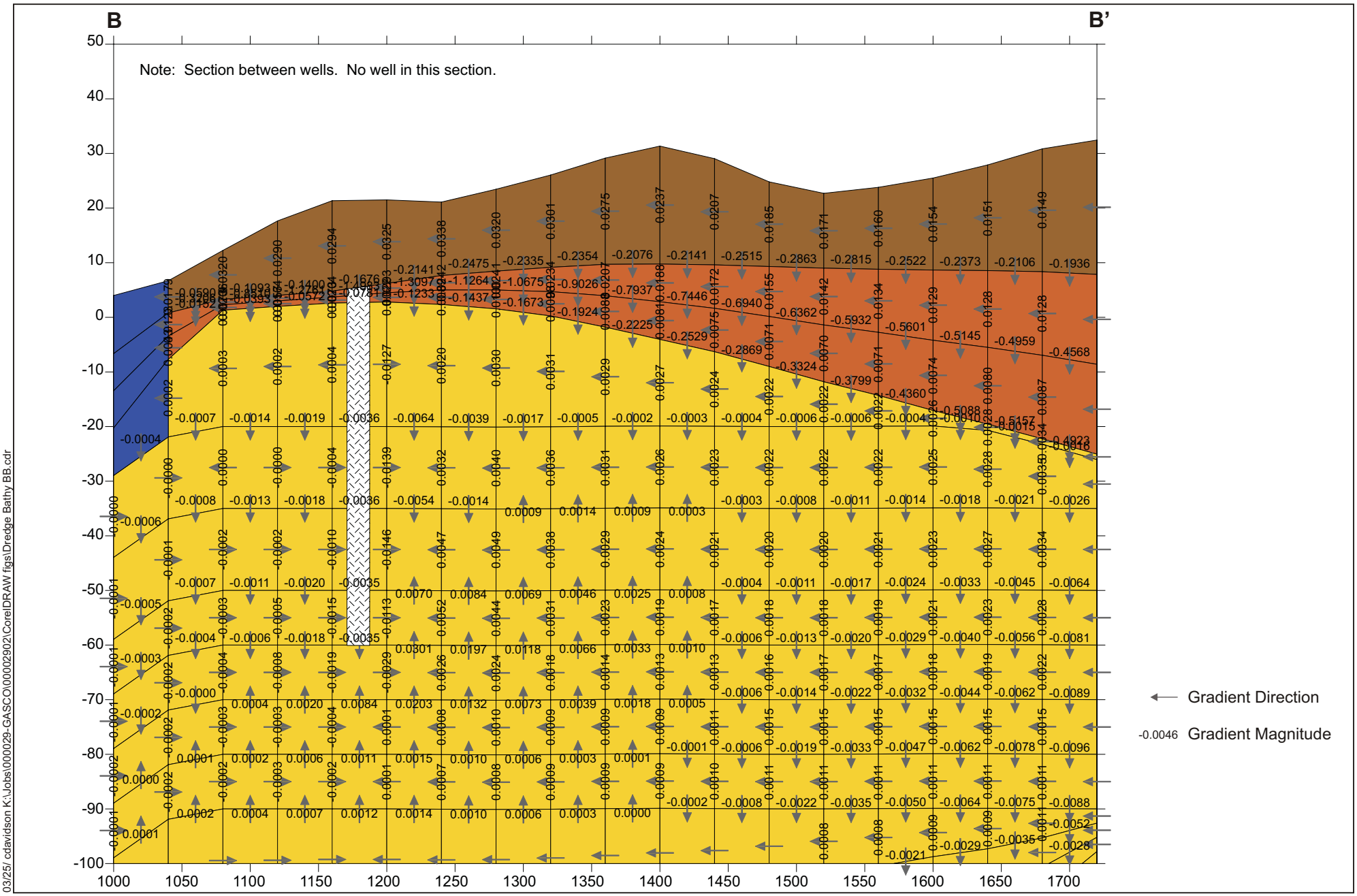

Figure A-14

Gradient Profile B-B', Dredge Bathymetry, Vertical Barrier, Intermediate Wells
NW Natural "Gasco" Site

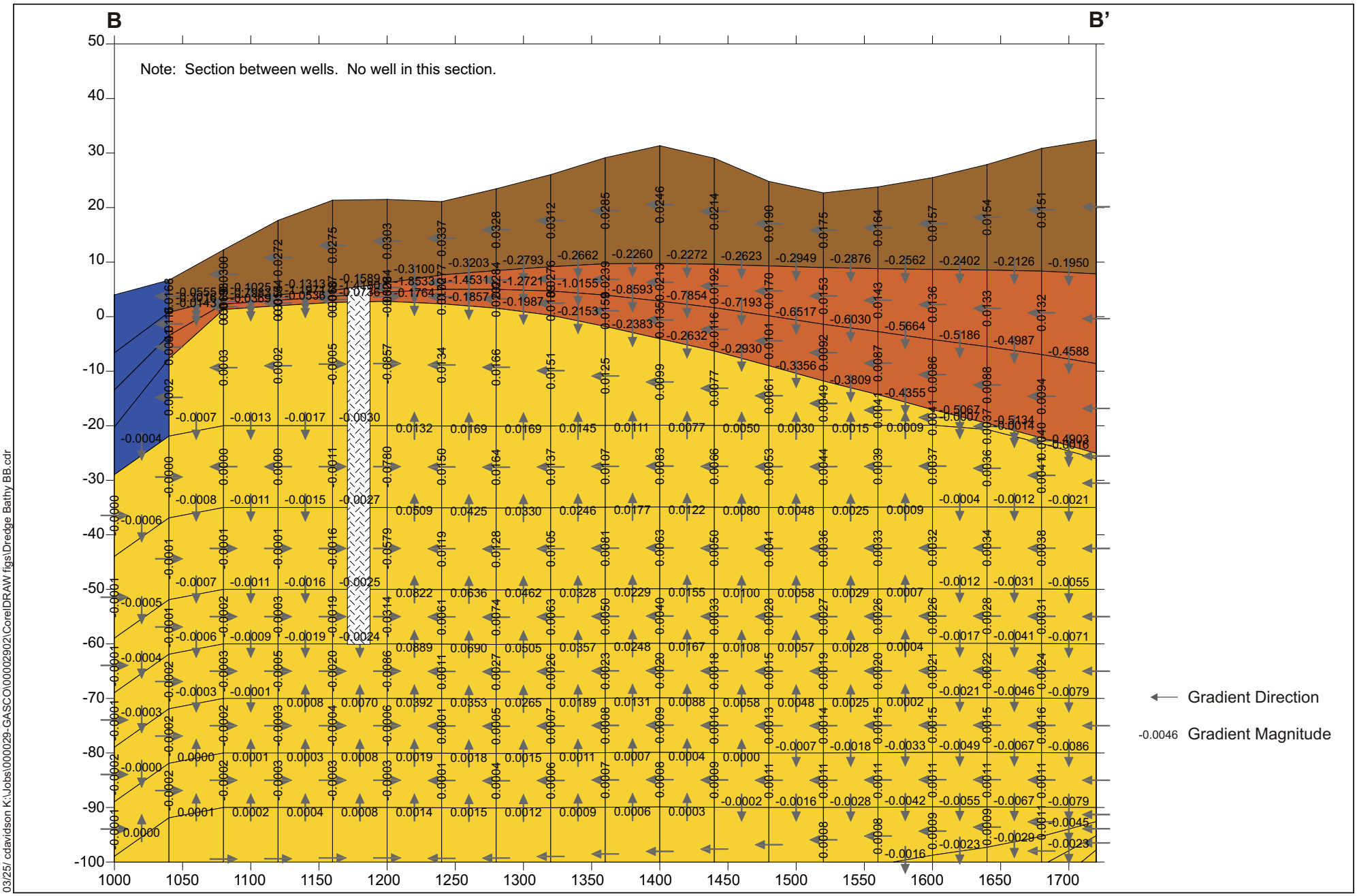

Figure A-15

Gradient Profile B-B', Dredge Bathymetry, Vertical Barrier, Shallow Wells
NW Natural "Gasco" Site

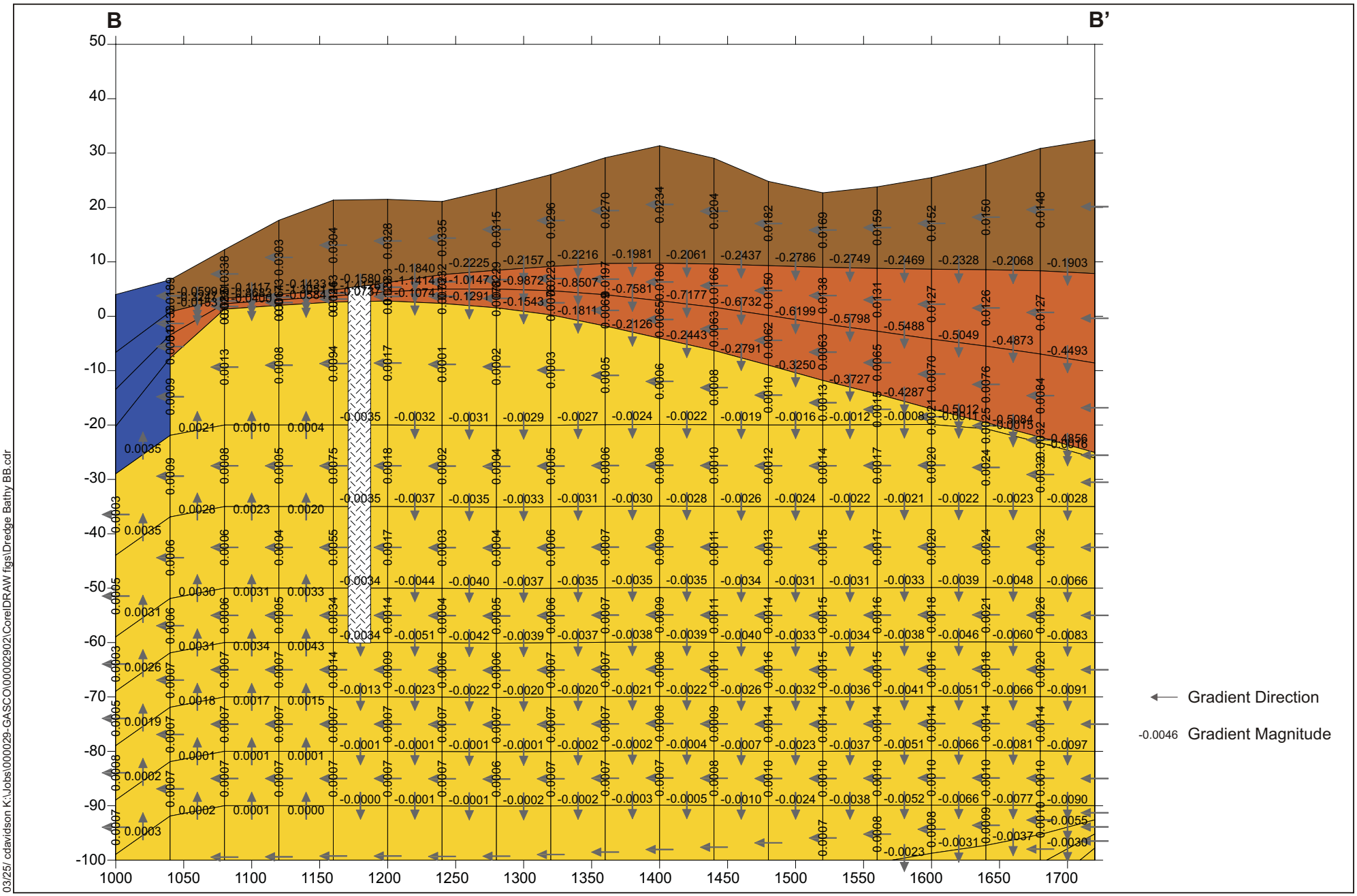

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Figure A-16
Gradient Profile B-B', Dredge Bathymetry, Vertical Barrier, No Pumping
NW Natural "Gasco" Site

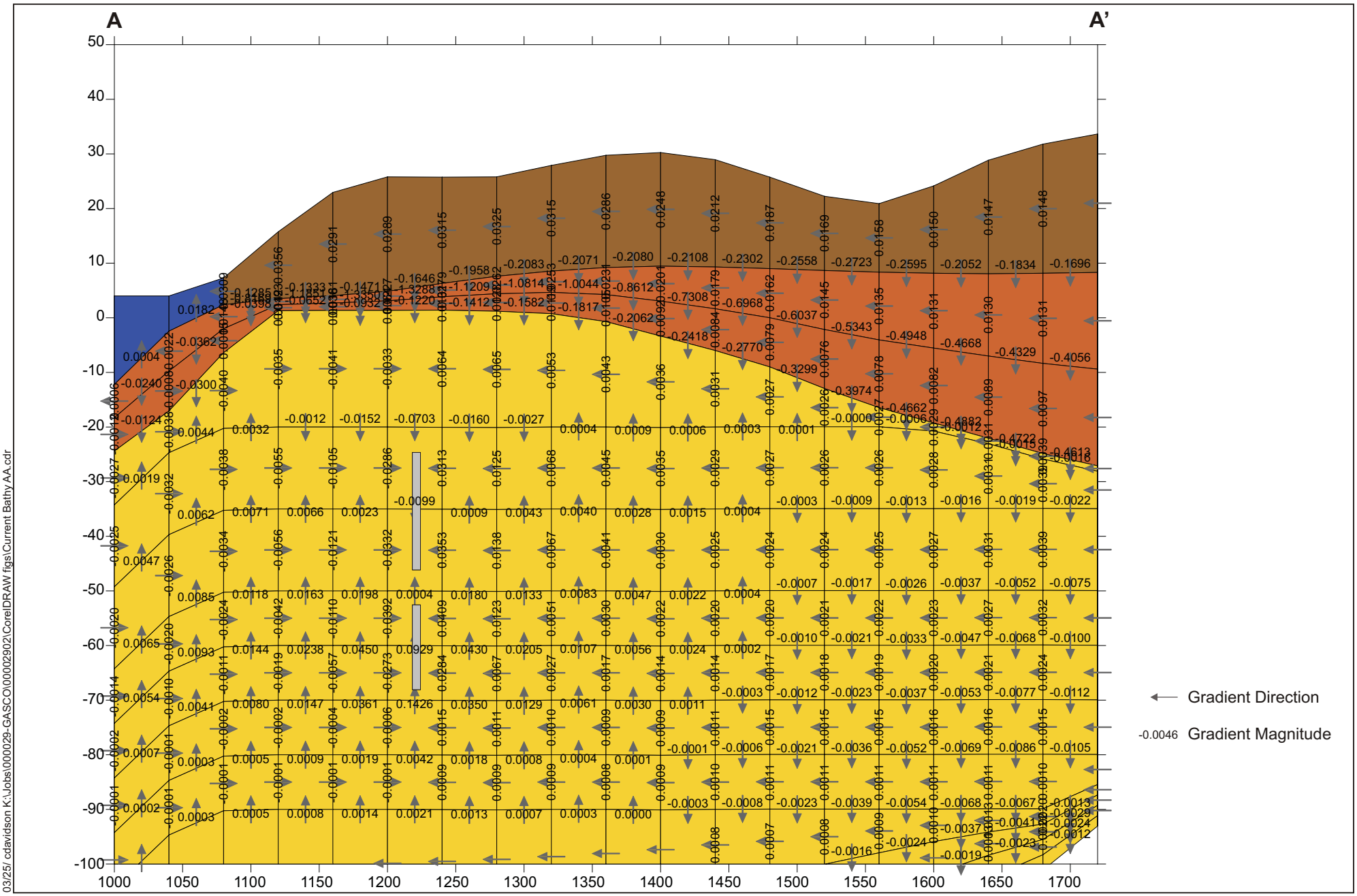

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Figure A-17

Gradient Profile A-A', Current Bathymetry, No Vertical Barrier, Shallow and Intermediate Wells
NW Natural "Gasco" Site

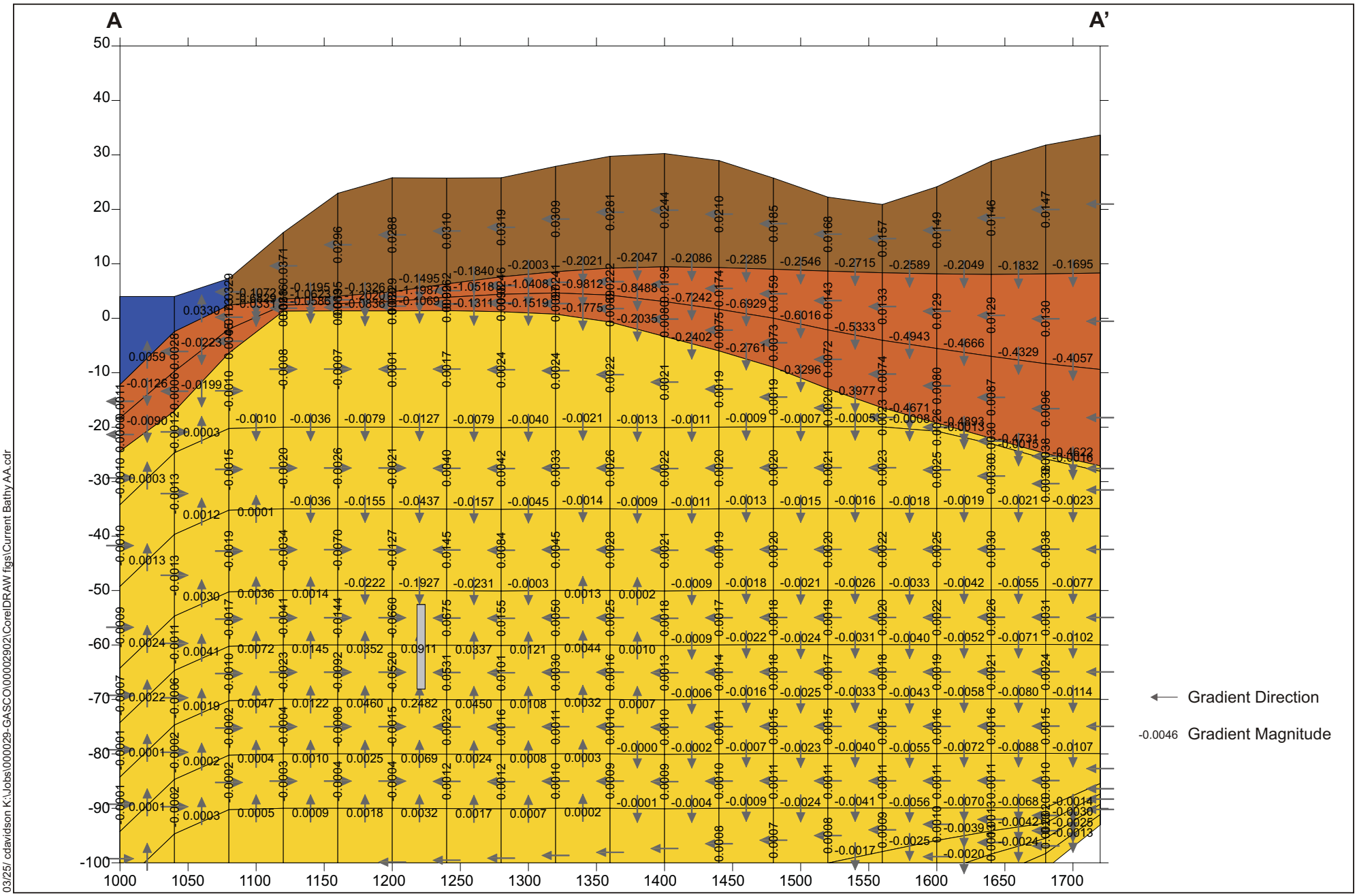

Figure A-18

Gradient Profile A-A', Current Bathymetry, No Vertical Barrier, Intermediate Wells
NW Natural "Gasco" Site

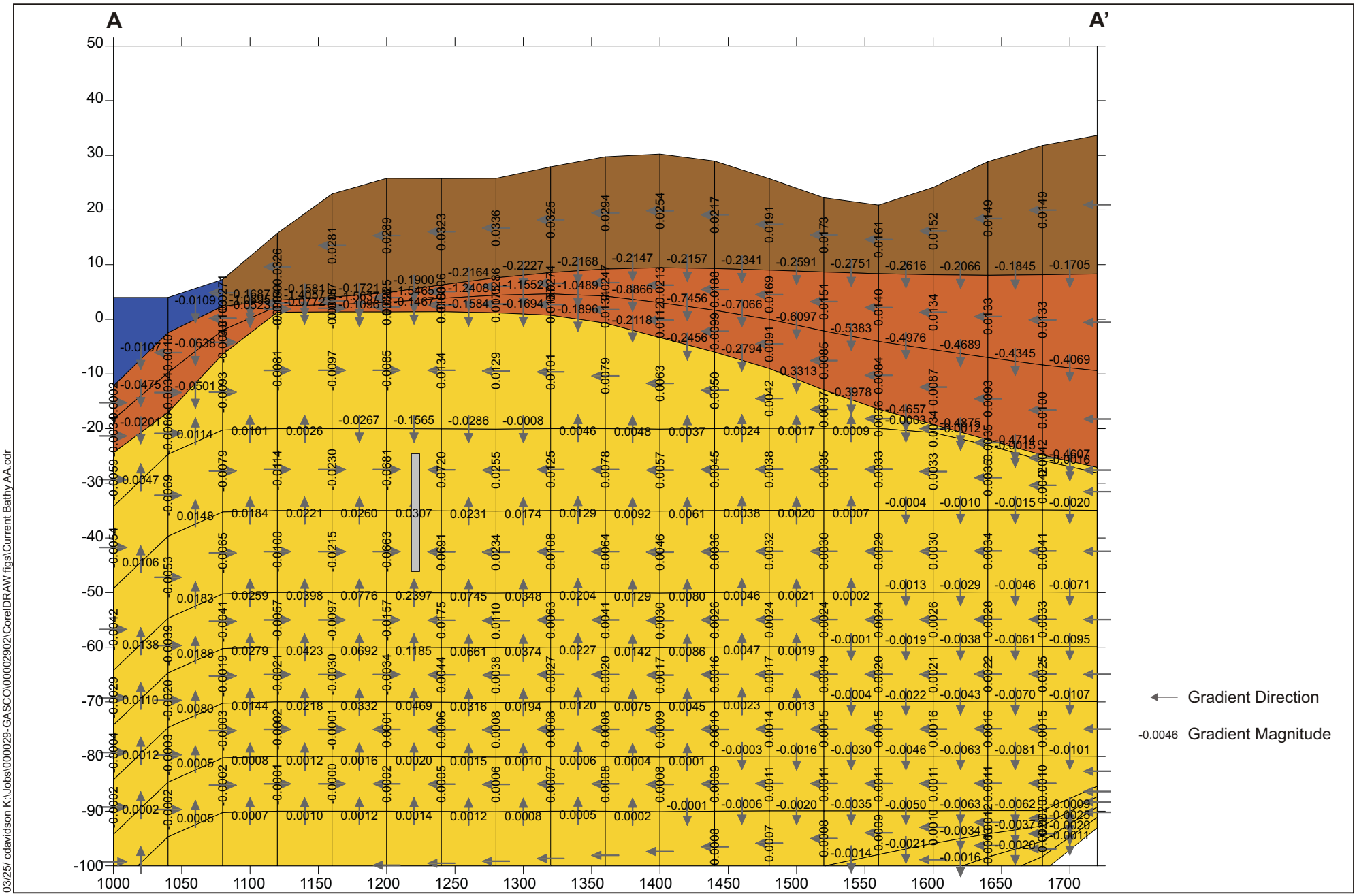

Figure A-19

Gradient Profile A-A', Current Bathymetry, No Vertical Barrier, Shallow Wells
NW Natural "Gasco" Site

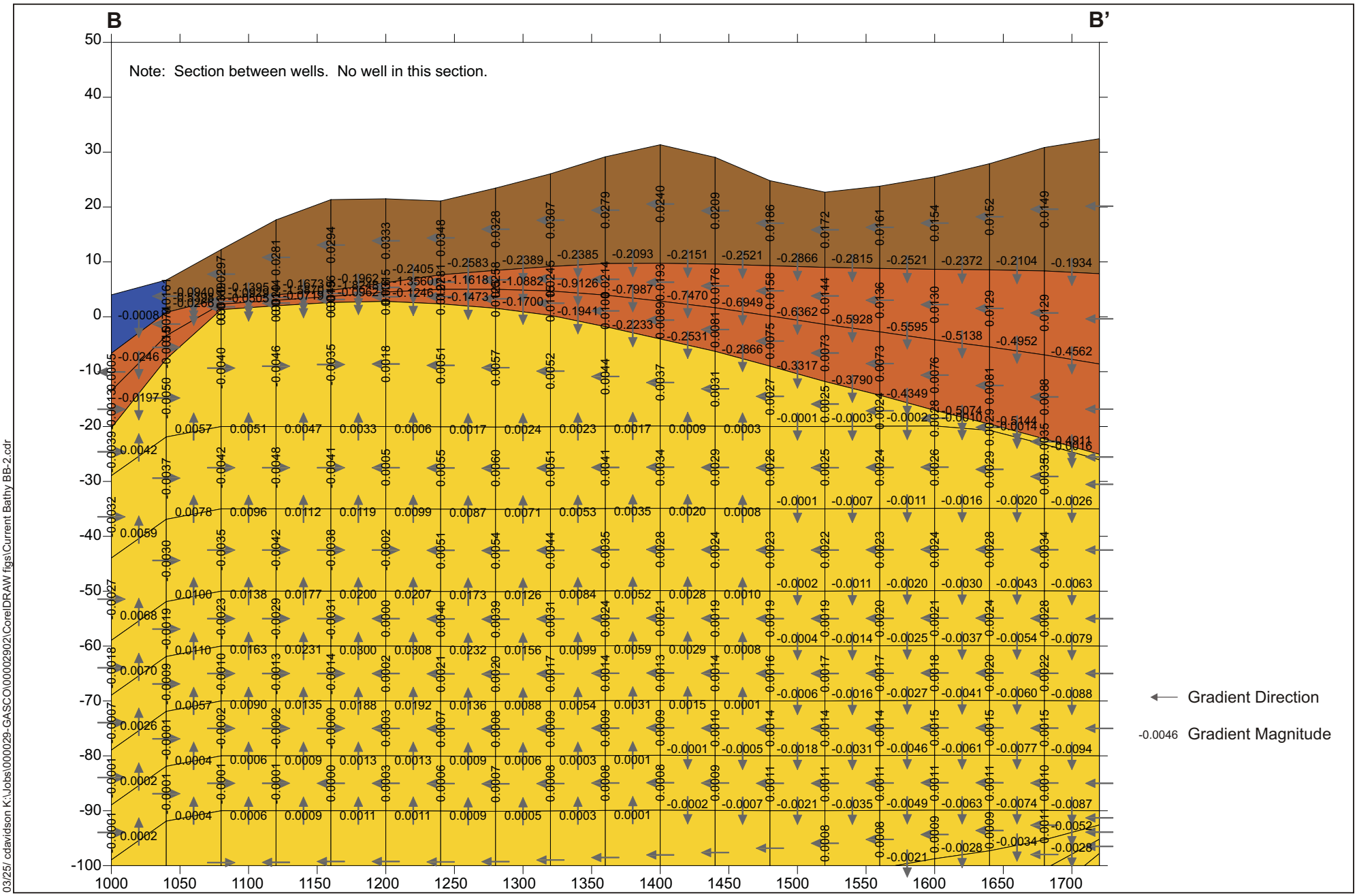

Figure A-20

Gradient Profile B-B', Current Bathymetry, No Vertical Barrier, Shallow and Intermediate Wells
NW Natural "Gasco" Site

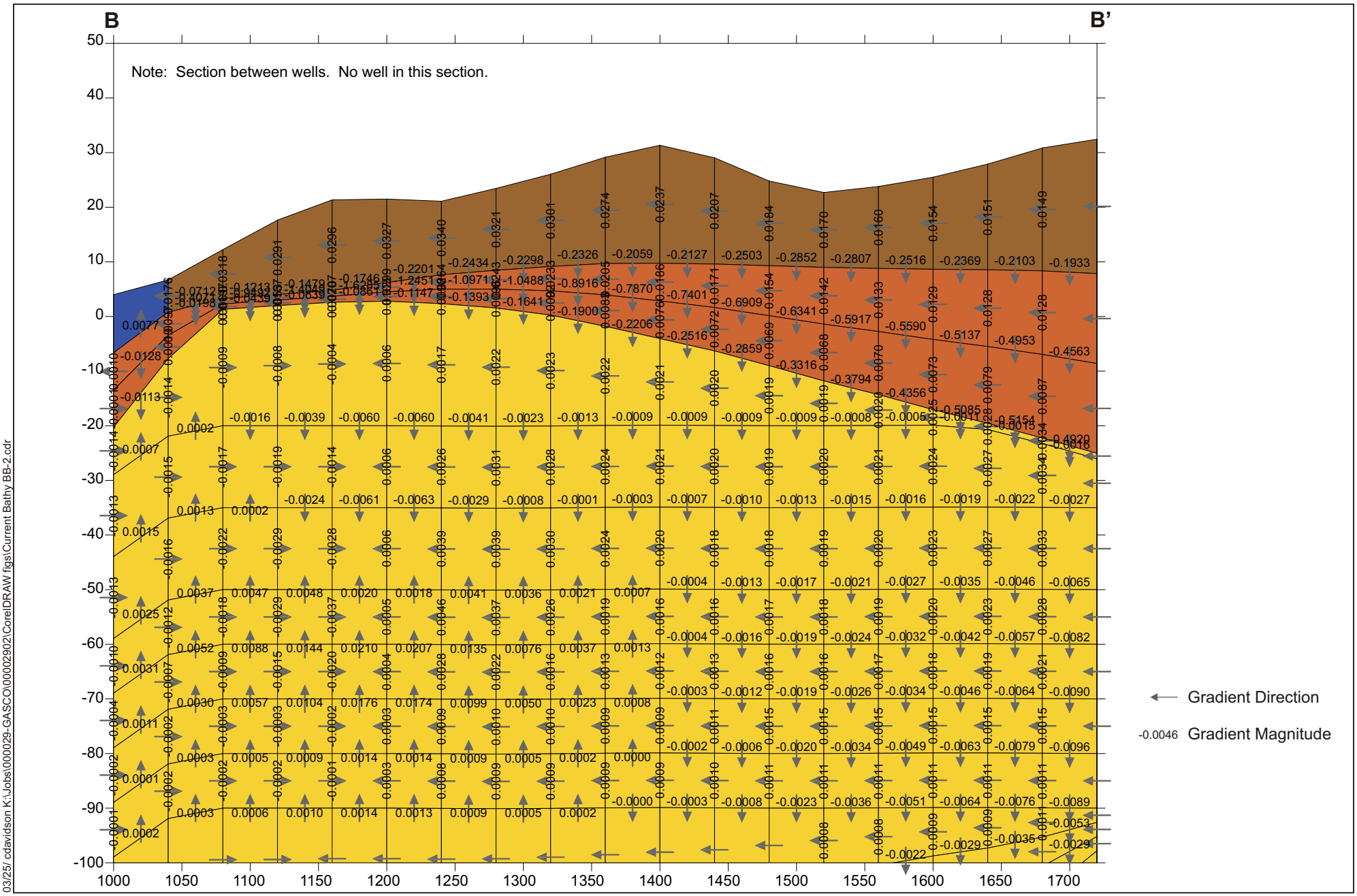

Figure A-21

Gradient Profile B-B', Current Bathymetry, No Vertical Barrier, Intermediate Wells
NW Natural "Gasco" Site

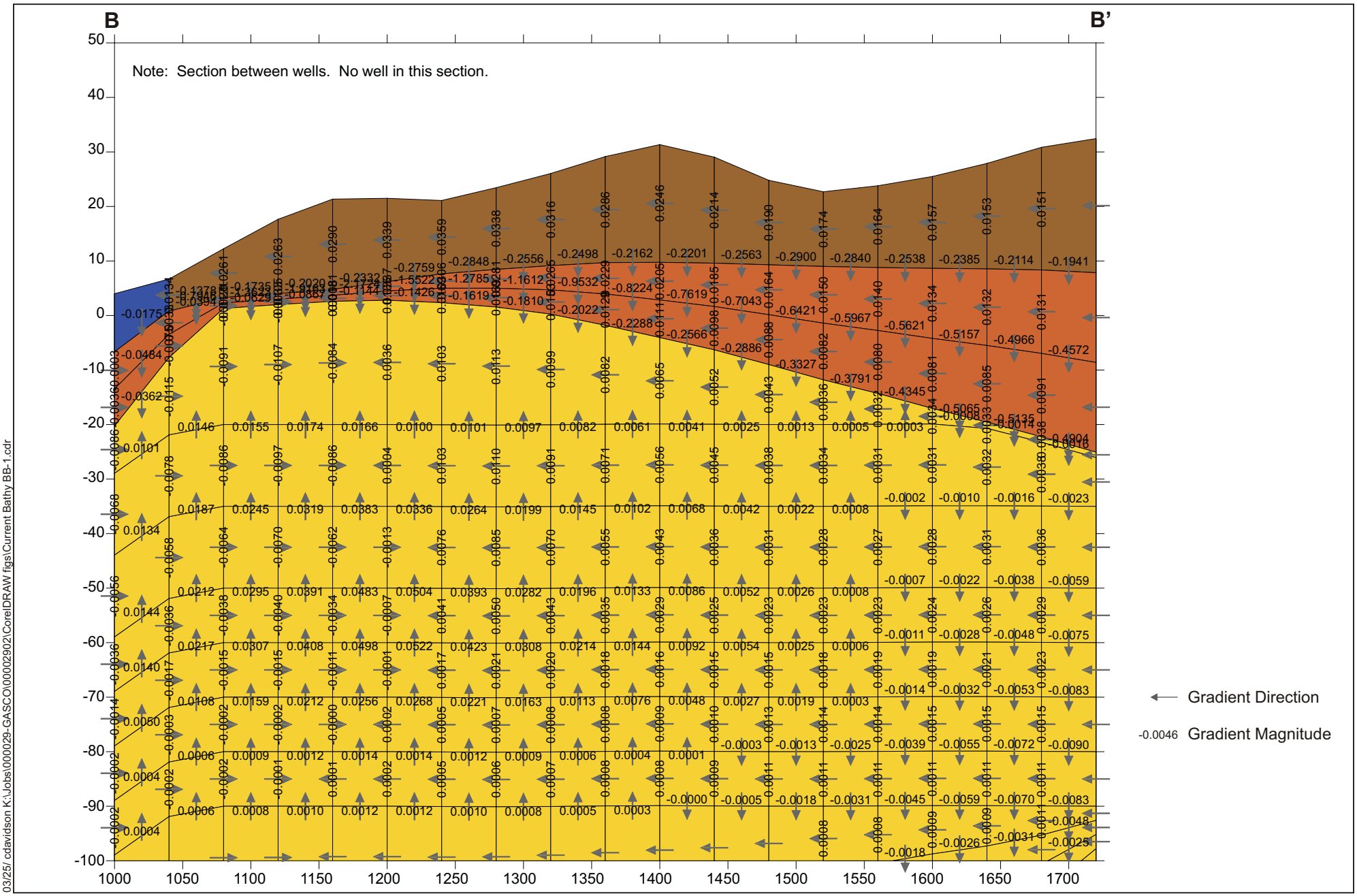

Figure A-22

Gradient Profile B-B', Current Bathymetry, No Vertical Barrier, Shallow Wells
NW Natural "Gasco" Site

APPENDIX J
TECHNICAL MEMORANDUM, MARCH 18, 2009 EVALUATION OF DNAPL MOBILIZATION

ANCHOR QEA

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MEMORANDUM

To:	Bob Wyatt, NW Natural	**Date:**	March 18, 2009
From:	David Keith, Mike Riley, and John Edwards, Anchor QEA	**Project:**	000029-02
Cc:			
Re:	Evaluation of Potential DNAPL Mobilization in Former Effluent Pond Area by Shoreline Source Control Extraction Wells, Gasco Site, Portland, Oregon		

INTRODUCTION

This memorandum provides an evaluation of the potential for the mobilization of dense non-aqueous phase liquids (DNAPL) in the former effluent pond area as a result of groundwater pumping at the Gasco Site in Portland, Oregon. The evaluation is in response to an Oregon Department of Environmental Quality (DEQ) request that NW Natural assess the potential migration of DNAPL in the former effluent pond area under the pumping influence of shoreline source control wells.

The sources and distribution of DNAPL at the site are described in detail in the Remedial Investigation Report (RI) (HAI 2007). The RI Report describes root macropores in the former effluent pond area that provide a very limited method for migration of DNAPL through the silt in this area. The RI report also concludes that mobile DNAPL is now largely absent in the fill in the former effluent pond area. DNAPL recovery efforts conducted to date at Gasco and the findings from manufactured gas plant (MGP) sites around the United States have shown that mobile DNAPL oil migrates very slowly (Gerhard 2007), while the solid tar does not migrate at all. The results from TarGost borings completed in 2008 showed that the RI did a good job of defining the extent of DNAPL in the former effluent pond area.

Although DEQ has stated in recent documents that they believe DNAPL is currently migrating in lenses toward the shoreline, evidence of current movement has not been found. The extensive offshore investigations completed in 2007 (Anchor 2007) indicated that the only DNAPL present in shoreline sediments is very shallow and is the result of historic direct

discharge of effluent into the river, not the result of subsurface migration of DNAPL from the former effluent pond area into river sediments. This was conclusively demonstrated in near shoreline borings GS-01 through GS-12, where DNAPL was absent in deep sediments, thereby showing that DNAPL detected in upland nearshore alluvium has not migrated into nearshore sediments. Therefore, subsurface DNAPL has not migrated from upland site areas into river sediment after nearly 100 years since the former effluent ponds began operation.

In summary, these extensive investigations have shown that any migration of DNAPL that may exist occurs so slowly as to be insignificant. However, at DEQ's request we have prepared this technical memorandum to further evaluate the potential for DNAPL migration to be influenced during proposed source control activities.

The next section provides a conceptual model for DNAPL flow in the subsurface based on literature descriptions. The subsequent sections focus on development and interpretation of various analytical solutions specific to mobilization of subsurface DNAPL occurrences in saturated porous groundwater systems.

DNAPL CONCEPTUAL SITE MODEL

Subsurface DNAPL is acted upon by three distinct forces in a groundwater environment (Yan et al. 1994) including:

1. Gravity
2. Capillary pressure
3. Hydrodynamic force

After release, DNAPLs will generally migrate vertically downward because they are denser than groundwater and gravitational forces are dominant compared to hydraulic forces in most groundwater systems. The rate of flow of a DNAPL through a geologic medium depends on: 1) the density and viscosity of the DNAPL; 2) the pressure driving the DNAPL migration; 3) the intrinsic permeability of the geologic medium; and 4) the degree of DNAPL saturation of the pore space in the medium. More permeable media and higher DNAPL saturations will permit higher rates of DNAPL flow. Higher-density and lower-viscosity fluids, such as chlorinated solvents, are subject to higher flow rates than lower-density and higher-viscosity fluids such as MGP wastes like those at Gasco (Pankow and Cherry 1996).

Nearly all movement of subsurface DNAPL occurs within zones of continuous (i.e., connected) DNAPL. In such zones, the DNAPL in different pore openings forms an immiscible-phase continuum through the intervening pore throats. Once the release of DNAPL into the subsurface ceases, the forces driving DNAPL movement eventually dissipate and the DNAPL in the pore openings become disconnected to form zones of residual DNAPL. DNAPLs distribute themselves in the subsurface in the form of disconnected blobs and ganglia of organic liquid referred to as residual occurrences, and in higher saturation configurations along bedding discontinuities referred to as pools (Gerhard et al. 2007). Very high hydraulic gradients are required in groundwater to induce movement of residual DNAPL occurrences (Pankow and Cherry 1996), which is one of the reasons remediation/recovery of DNAPL is so difficult. Wilson and Conrad estimated that a gradient of 0.1 foot/foot is necessary to start some blobs or ganglia of DNAPL moving in a fine gravel (approximately 10 cm/sec permeability). This is a steep, but not unreasonable, gradient. However, typical hydraulic gradients at Gasco are two orders of magnitude lower than 0.1 foot/foot, and there are no gravel zones associated with DNAPL at the Site. In a medium sand (approximately 10^{-3} cm/sec permeability), the gradient necessary for residual DNAPL movement is on the order of 10 feet/foot.

For most DNAPLs, which are non-wetting on the mineral grains of an aquifer with respect to water, water will coat the soil grains and occupy the smaller pores and pore throats; therefore, the DNAPL is restricted to the larger pore openings. When the DNAPL is non-wetting, like the DNAPL at Gasco, capillary forces oppose the entry of the DNAPL into wet geologic media. The forces driving subsurface DNAPL movement are a function of the DNAPL density and the pressures resulting from its release into the subsurface. For DNAPL movement to occur in wet media, these driving forces must overcome the capillary resistance. The DNAPL in the larger pore openings must deform to pass through smaller pore throats to reach other pore openings. The pressure required for this deformational movement is the entry pressure. The value of the entry pressure is proportional to the interfacial tension between the DNAPL and the water, and inversely proportional to the size of the pore throats. Therefore, the entry of a DNAPL into a fine-grained porous medium or into a fractured medium having small apertures requires high driving forces to overcome high entry pressures.

Consequently, low permeability strata (permeabilities of 10^{-5} cm/sec or less) can be barriers to DNAPL migration (Pankow and Cherry 1996). Vertical permeability tests were run on six

shelby tube samples obtained during geotechnical soil borings completed along the proposed vertical barrier alignment in 2007. This work was done at the request of DEQ. The samples were obtained at depths ranging from 61 to 96 feet below top of the shoreline bank. Following are the measured vertical permeabilities in cm/sec:

Silt	4.42E-07
Clayey silt	9.60E-08
Clayey silt	1.67E-07
Clayey silt w/fine sand	3.19E-07
Clayey silt w/fine sand	2.68E-07
Fine sand	6.14E-05

Subsurface investigations have shown that the upper alluvium contains a higher percentage of fine-grained layers than the lower alluvium. This explains why DNAPL is not found below the upper alluvium in most of the former effluent pond area.

The Gasco Site is underlain by a heterogeneous granular aquifer. In these environments, small horizontal zones of residual or free-phase DNAPL are not solely caused by particularly low permeability zones such as silt or clay. A minor contrast in grain size distribution and permeability, as from a coarse sand layer to a finer sand, causes variation in DNAPL entry pressure. A DNAPL moving downwards through a coarse-grained material will encounter a higher entry pressure when a finer-grained layer is contacted. This will cause lateral spreading of the DNAPL. The DNAPL will accumulate on the finer-grained layer while spreading laterally until it reaches the edge of the layer, or until the height of free product accumulation on the layer exceeds the entry pressure for the layer. In the latter case, the DNAPL will pass through the layer and continue its downward movement towards the bottom of the aquifer (Pankow and Cherry 1996). Pools of DNAPL generally form at stratigraphic discontinuities, where finer-grained and lower permeability materials prevent vertical DNAPL migration because intergranular surface tension and capillary forces prevent further penetration. It should be noted that DNAPL pools that form on stratigraphic discontinuities will generally flow in the direction of stratigraphic dip because of gravitational forces, and this direction may be different than the dominant direction of groundwater flow defined by the hydraulic gradient.

DNAPL MOBILIZATION AT GASCO

Based on the conceptual models for the distribution of DNAPL in groundwater environments described above, and site observations of the occurrence of DNAPL at Gasco, there are two cases for potential mobilization of DNAPL as a result of pumping, including:

- Mobilization of a DNAPL pool
- Mobilization of residual ganglia or blobs of DNAPL

Case 1. Mobilization of a DNAPL Pool

McWhorter (1992) provided an equation that describes the movement of a DNAPL pool along a stratigraphic discontinuity at a slope (a) to horizontal as follows:

$$q_{nwi} = \frac{-kk_{rnw}}{\mu_{nw}} p_w g \frac{d}{dx_i}\left[h + \frac{Pc}{p_w g} + \frac{\Delta p}{p_w} z\right] \tag{1}$$

Where:

q_{nwi}	=	DNAPL mass flux
k	=	the intrinsic permeability
k_{rnw}	=	the relative permeability to DNAPL
μ_{nw}	=	the viscosity of the DNAPL
p_w	=	the water density
g	=	the gravitational acceleration
h	=	the hydraulic head in the aqueous phase
Pc	=	the capillary pressure
Δp	=	the density difference between the DNAPL and water
z	=	the vertical coordinate
x_i	=	the coordinate direction (defined as the direction of slope)

At equilibrium, the flux of DNAPL is 0 and Equation 1 becomes:

$$\frac{d}{dx_i}\left[h + \frac{Pc}{p_w g} + \frac{\Delta p}{p_w} z\right] = 0 \tag{2}$$

Integrating Equation 2 from 0 to L (the length of a DNAPL pool) yields the following equation:

$$p_w \frac{dh}{dx_i} L\cos\alpha + \frac{Pc}{g} + \Delta p L \sin\alpha = 0 \qquad (3)$$

Where

α = the slope angle as defined in Figure 1

Physically, the first term in Equation 3 represents the hydraulic force acting on a unit area of DNAPL, the sign of which can be positive or negative, depending on whether water flow is upslope or downslope compared to the dip of the host stratigraphy. The second term represents the capillary force that is resisting the flow of DNAPL. This force is always opposite to that of the resultant of the hydraulic flow and gravity forces. The third term is the gravity or buoyancy force of DNAPL at equilibrium in the direction of the stratigraphic dip (Yan et al. 1994).

Geologic three point problems were solved on the top of two continuous apparent bedding layers from cross sections at Gasco to determine the slope of bedding at the Site. Figure 2 is a map showing the locations of the TarGost borings used to assess the slope of bedding at the Site. The base of fill/top of silt and the top of the lower sand layer were used for the calculations. The calculated angles for those bedding layers were less than 0.5 degrees and indicate that the bedding that DNAPL would tend to pool on at Gasco is essentially horizontal. Table 1 shows the slope of the bedding layers. This information was developed from the TarGost borings provided on the left side of the table.

Table 1
Summary of Bedding Strike and Dip Calculations for the Base of Fill/Silt and Top of Medium Sand Contacts

Borings			Base of Fill/ Silt contact			Top of Medium Grained Sand		
			Gradient (ft/ft)	Direction (degrees)	ATAN of Gradient (Alpha - degrees)	Gradient (ft/ft)	Direction (degrees)	ATAN of Gradient (Alpha - degrees)
TG-3	TG-5	TG-11	0.037	21	0.037	0.10	39	0.10
TG-3	TG-5	TG-8	0.065	26	0.065	0.11	39	0.11
TG-1	TG-7	TG-3	0.019	335	0.019	0.15	229	0.15
TG-1	TG-1S	TG-13	0.033	28	0.033	0.32	48	0.31

Because Sinα ≈ 0 and Cos α ≈ 1 under these conditions, Equation 3 reduces to:

$$pw\frac{dh}{dx_i}L + \frac{Pc}{g} = 0 \qquad (4)$$

Groundwater model output for the Site previously presented to the Oregon DEQ (Anchor and SSPA 2008) included predicted groundwater gradients under ambient and pumping conditions, and these results were used to evaluate potential DNAPL movement due to hydraulic stress (Anchor and SSPA 2008). These results were combined to look at the change in groundwater gradient between ambient and pumping conditions. A review of the model output shows the shallow well configuration imposes the largest increase in groundwater gradients and the intermediate well configuration has the least effect. The subsurface profiles on Figures 3a, 3b, and 3c show the predicted gradients using shallow, intermediate depth, and paired extraction wells. Figure 3d shows the map location of the subsurface profiles. Groundwater gradients in the former effluent pond area under the shallow extraction well configuration increase by 0.01 to 0.02 while groundwater gradients increased by only 0.001 to 0.002 with intermediate depth extraction wells.

The maximum effect of these changes in gradient can be computed from Equation 1 by making the following assumptions:

- Capillary forces = 0
- Stratigraphic slope (α) = 0, which has been shown to be negligible at the Site
- Relative permeability = 1, which is the maximum value
- Intrinsic permeability computed for the Site = 6e-8 cm2
- Porosity = 0.3

These assumptions provide the maximum DNAPL velocity that can be expected due to pumping, and travel distance derived for different time periods can be computed. The results are shown in the Table 2 for changes in gradient in the former effluent pond area due to shallow and intermediate depth extraction wells.

Table 2
Predicted Horizontal DNAPL Travel Distance due to Increased Gradient from Nearshore Groundwater Pumping

Extraction Well Configuration	Groundwater Gradient Increase in Former Effluent Pond Area	Velocity (ft/day)	Distance traveled (ft) over the following time periods			
			0.5 years	1 year	2 years	3 years
Shallow Depth Extraction Wells	0.01	0.0047	0.9	1.7	3.5	5.2
	0.02	0.0095	1.7	3.5	6.9	10.4
Intermediate Depth Extraction Wells	0.001	0.00047	0.1	0.2	0.3	0.5
	0.002	0.00095	0.2	0.3	0.7	1.0

From this analysis, enhanced groundwater movement in the former effluent pond area due to shoreline extraction wells is minimal and would not substantially change DNAPL distribution over time, especially if the capillary term were factored into the calculation. The analysis also shows that pumping from the intermediate wells produces significantly smaller potential distances of travel. Therefore, it is unlikely that that shallow extraction wells will be selected for design of the shoreline extraction system.

Case 2. Mobilization of Residual Ganglia or Blobs of DNAPL

Residual DNAPL in the form of ganglia or blobs can also be mobilized by increasing hydraulic gradients, such as what may occur during pumping. In this case, the capillary number, (σ), the ratio of capillary to viscous forces, provides a measure of the propensity of DNAPL trapping and mobilization (Cohen and Mercer 1993). It is defined as:

$$Nc = \frac{kpwgJ}{\sigma} \tag{5}$$

Where:

σ = the interfacial tension between the DNAPL and water

J = the hydraulic gradient

Other terms are defined in Equation 1

The critical value (N_c) of the capillary number is defined as the value at which motion of some of the DNAPL blob is initiated. Based on experimental data, Wilson and Conrad (1984)

noted a strong correlation between displacement of residual DNAPL and the capillary number. Conrad and Wilson found that initial movement occurred when the gradient produced N_c values greater than 2e-5. The hydraulic gradient necessary to initiate ganglia mobilization for various permeabilities and interfacial tensions is shown in Figure 4.

Figure 4 shows that in very permeable media (e.g., gravel and coarse sand) it is theoretically possible to obtain sufficient hydraulic gradients to mobilize DNAPL blobs. In soils with medium permeability (e.g., fine to medium sands), some of the residual DNAPL can be hydraulically mobilized. In less permeable materials, mobilization is not possible unless surfactants are used to drastically reduce interfacial tensions (Cohen and Mercer 1993). This is another example of why DNAPLs are difficult to recover from groundwater environments.

At Gasco, measured interfacial tensions between DNAPL and water were 14.2 and 15.8 dynes/cm and most of the soil where DNAPL occurs would be classified as silty sands or finer (HAI 2007). The intrinsic permeability was calculated from the hydraulic conductivity of the shallow alluvium used in the Site MODFLOW model of 15 feet/day, which gives an intrinsic permeability of 6e-8 cm^2. Based on Figure 4, the hydraulic gradient that would be required to mobilize residual DNAPL under these conditions would be near 1 foot/foot or greater, which is much higher than any gradient that could be induced in the former effluent pond area under non-pumping or pumping conditions at the Site.

SUMMARY DISCUSSION AND CONCLUSIONS

The lack of stratigraphic gradient and the presence of silt interbeds in the upper alluvium at the Gasco Site indicates that the most likely mechanism for potential lateral DNAPL movement is by pooling on silt lenses and flowing along stratigraphic interfaces to the edge of the silt lens. Upon reaching coarser and more permeable media at the edges of silt lenses, DNAPL would tend to flow downward under the influence of gravity until reaching another lower permeability stratigraphic discontinuity.

The maximum effect of changes in hydraulic gradient was computed from Equation 1 by making the following assumptions:

- Capillary forces = 0
- Stratigraphic slope (α) = 0, which has been shown to be negligible at the Site
- Relative permeability = 1, which is the maximum value

- Intrinsic permeability computed for the Site = 6e-8 cm^2
- Porosity = 0.3

These assumptions, which neglect the capillary forces that would resist DNAPL flow, provide the maximum DNAPL velocity that can be expected due to pumping, and travel distance derived for different time periods can be computed. The results, summarized in Table 2 above, show that changes in gradient in the former effluent pond area due to shallow and intermediate depth extraction well pumping would cause maximum distances traveled over a 3 year period to range between approximately 5.2 to 10.4 feet using shallow extraction wells, and 0.5 to 1.0 feet for intermediate depth extraction wells.

From this analysis, enhanced groundwater movement in the former effluent pond area due to shoreline extraction wells is minimal and would not substantially change DNAPL distribution over time. These calculations are conservative approximations of the potential distances that DNAPL could travel and the true estimate would be less if the capillary term were factored into the calculation. The analysis also shows that pumping from the intermediate wells produces significantly smaller potential distances of travel. Therefore it is unlikely that that shallow extraction wells will be selected for design of the shoreline extraction system.

Finally, as shown in Case 2, mobilization of residual DNAPL (as opposed to pools) is not expected to occur at Gasco in the former effluent pond area because groundwater gradients that result from pumping, and the material properties of the aquifer matrix and of the DNAPL produce a capillary number that is well below the critical value (Figure 4).

REFERENCES

Anchor Environmental, LLC, 2007. Phase 1 Report and Phase 2 Field Sampling Approach. Gasco Siltronic Groundwater Source Control Evaluation. Prepared for NW Natural. Portland, Oregon. May 2007.

Anchor Environmental, LLC and S.S. Papadopulos, Inc (SSPI). 2008. Groundwater Flow Model and DNAPL Evaluation Supplemental Report, NW Natural, Gasco Site, prepared for NW Natural, October, 2008.

Cohen, R.M., and J.W. Mercer. 1993. *DNAPL Site Evaluation.* EPA/600/R-93/022, United States Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma [also published as *DNAPL Site Evaluation*, C.K. Smoley].

Gerhard, J.I., T Pang, and B.H. Kueper, 2007. *Time Scales of DNAPL Migration in Sandy Aquifers Examined via Numerical Simulation.* Ground Water, Vol. 45, No. 2, pp. 147 – 157.

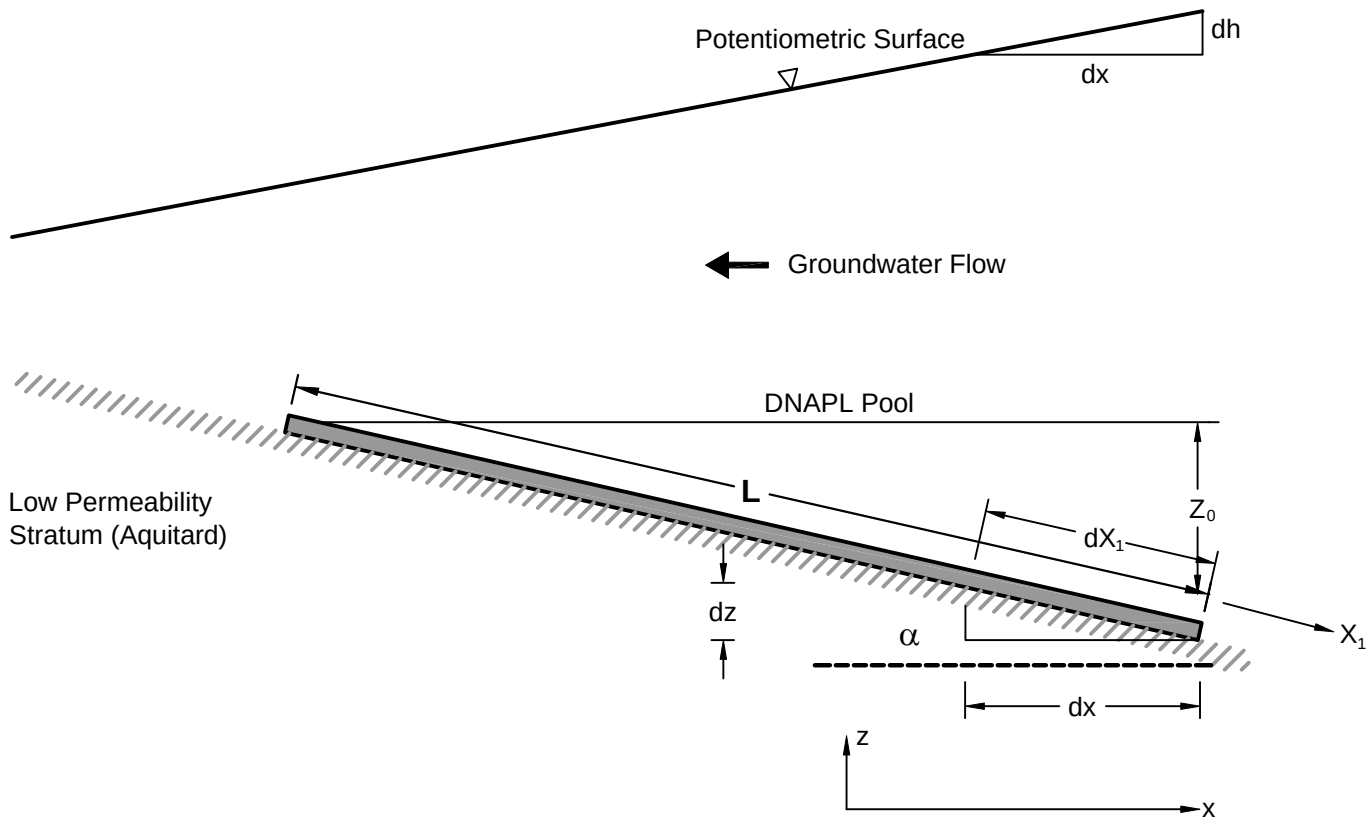
Hahn and Associates, Inc. 2007. Remedial Investigation Report, NW Natural Gasco Facility. Prepared for NW Natural. Portland, Oregon.

McWhorter, D.B. 1992. *Site characterization and remediation of dense non-aqueous phase liquid concentrations (DNAPLs) in porous and fracture media-water flooding.* DNAPL Short Course, Chicago, IL, Nov. 25, 1992.

Pankow, J.F. and J.A. Cherry. 1996. *Dense Chlorinated Solvents and other DNAPLs in Groundwater: History, Behavior, and Remediation.* Waterloo Press.

Wilson, J. L., and S. H. Conrad. 1984. *Is physical displacement of residual hydrocarbons a realistic possibility in aquifer restoration?* Proceedings of the NWWA/API Conference on Petroleum Hydrocarbons and Organic Chemicals in Ground Water, Houston, Texas. National Water Well Association, Worthington, OH. Nov. 5-7. 1984.

Yan, S., G.R. Lnady and T. Tate. 1994. *A Computer Model for DNAPL Potential Migration Study.* Ground Water, Vol. 32, No 6, pp. 1029 – 1034.



Source: Yan, S., G.R. Landry and T. Tate, 1994.

Feb 03, 2009 10:59am cdavidson K:\Jobs\000029-GASCO\00002902\00002902-RP-018.dwg FIG 1

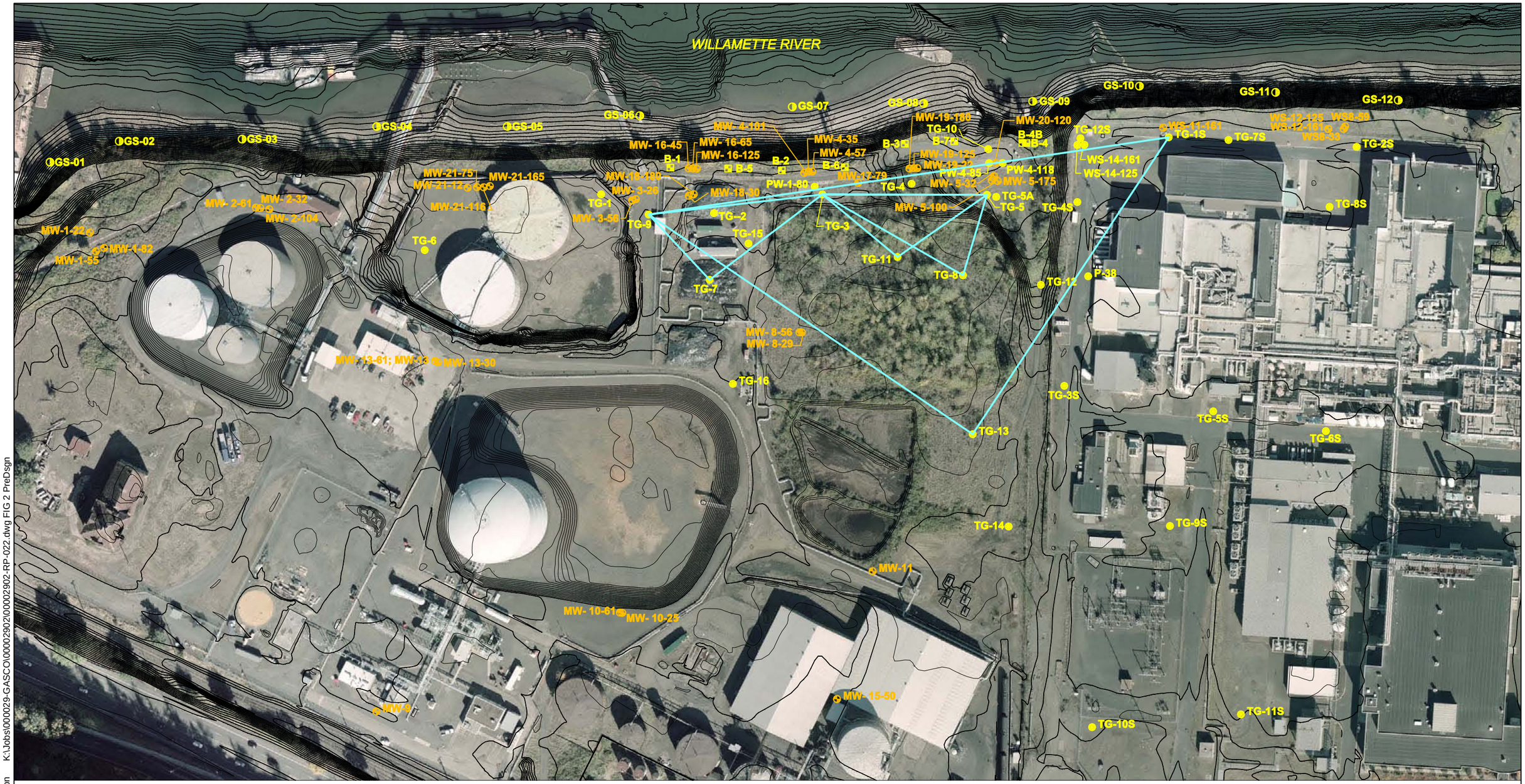
ANCHOR QEA

Figure 1

Diagram of DNAPL Pool held in Aquifer on a Low Permeability Sloping Bed

Gasco/Siltronic

Portland, Oregon



Legend

TG-9	Boring Location and Number
MW-2-12	Existing Monitoring Well Location and Number
GS-01	Gasco Phase 1 Offshore Boring Location and Number
B-1	Geotechnical Boring Location and Number

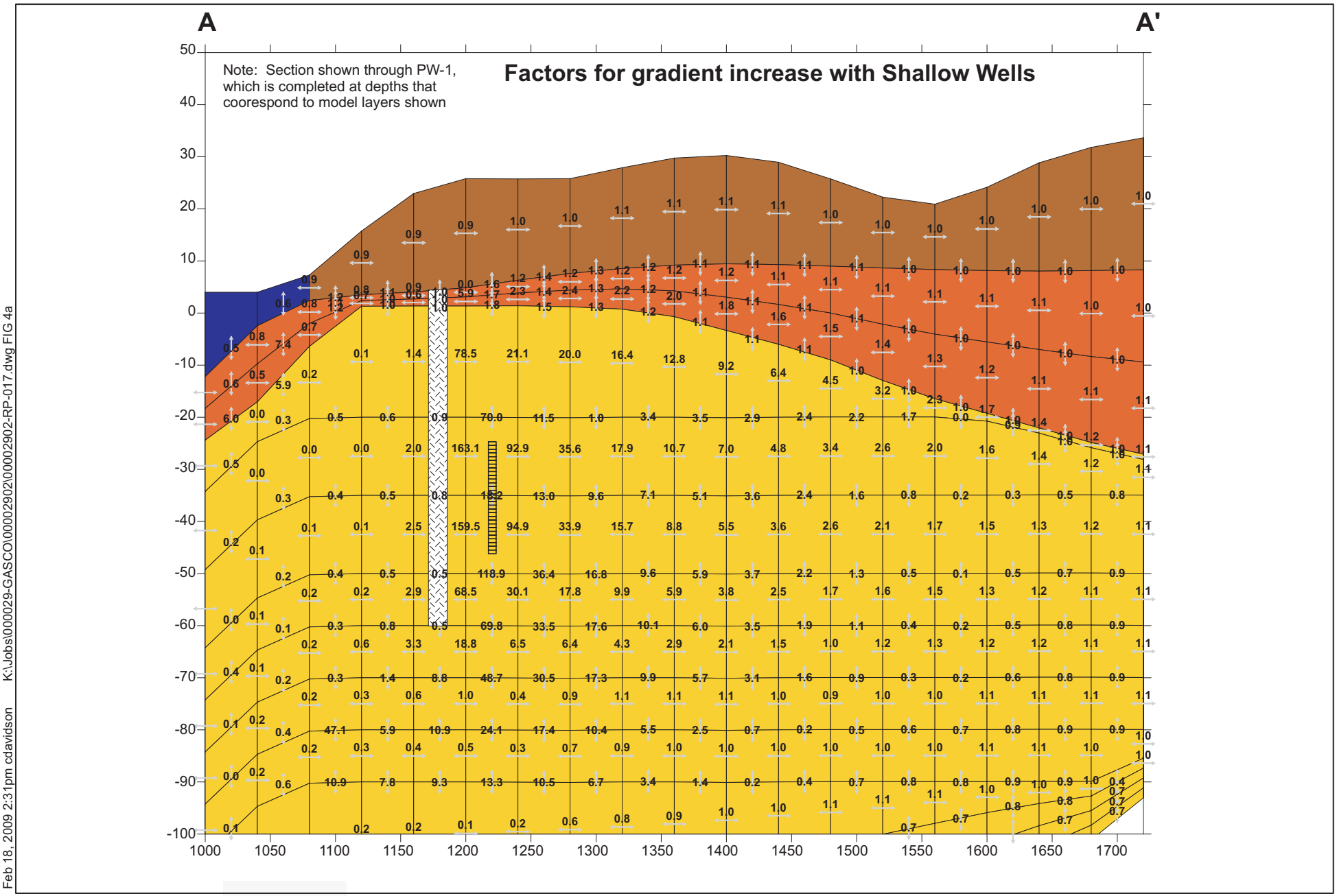
Area used to Calculate Bedding Slope

0 150
Scale in Feet

Feb 17, 2009 2:22pm cdavidson K:\Jobs\000029-GASCO\00002902\00002902-RP-022.dwg FIG 2 PreDsgn

ANCHOR ENVIRONMENTAL, L.L.C.

Figure 2
Location of Bedding Slope Calculations
Gasco, Portland, Oregon



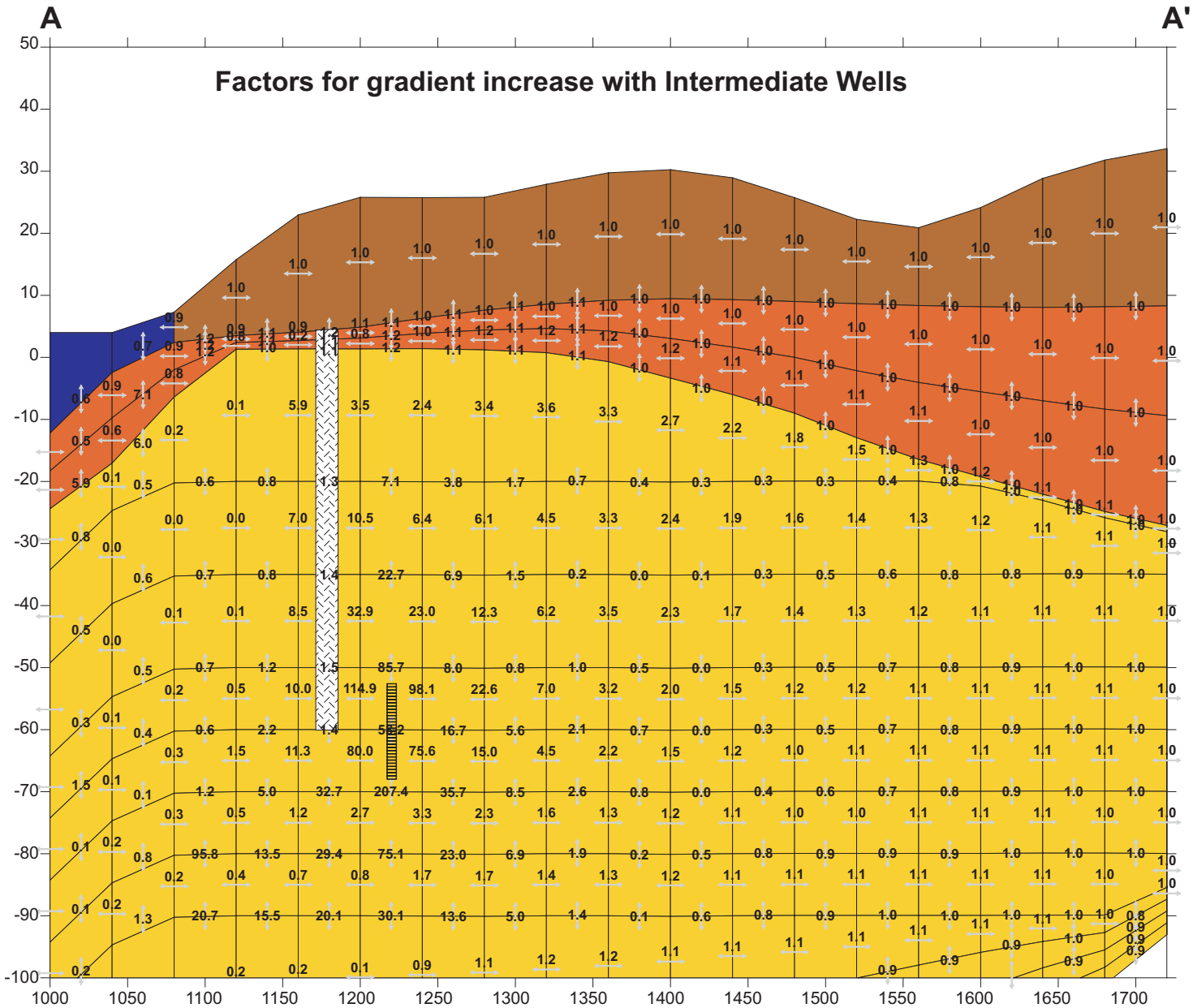
Feb 18, 2009 2:31pm cdavidson K:\Jobs\000029-GASCO\00002902\00002902-RP-017.dwg FIG 4a

ANCHOR QEA

$\Sigma^2\Pi$

Figure 3a

Predicted Factors for Hydraulic Gradient Increases Under Pumping Conditions for Shallow Wells
Gasco/Siltronic
Portland, Oregon



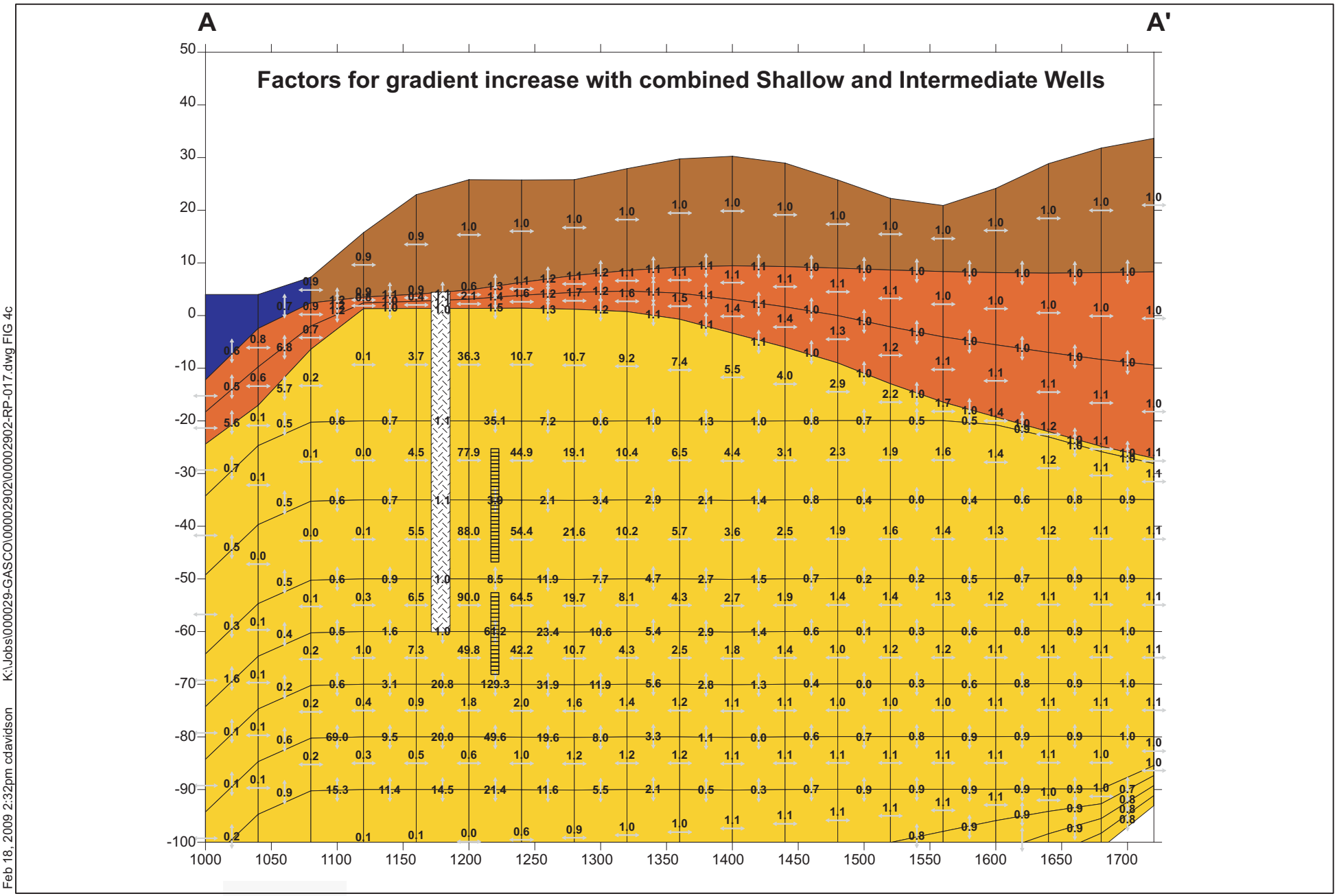
Feb 18, 2009 2:32pm cdavidson K:\Jobs\000029-GASCO\00002902\00002902-RP-017.dwg FIG 4b

ANCHOR QEA

$\Sigma^2\Pi$

Figure 3b

Predicted Factors for Hydraulic Gradient Increases Under Pumping Conditions for Intermediate Wells
Gasco/Siltronic
Portland, Oregon



Feb 18, 2009 2:32pm cdavidson K:\Jobs\000029-GASCO\00002902\00002902-RP-017.dwg FIG 4c

ANCHOR QEA

$\Sigma^2\Pi$

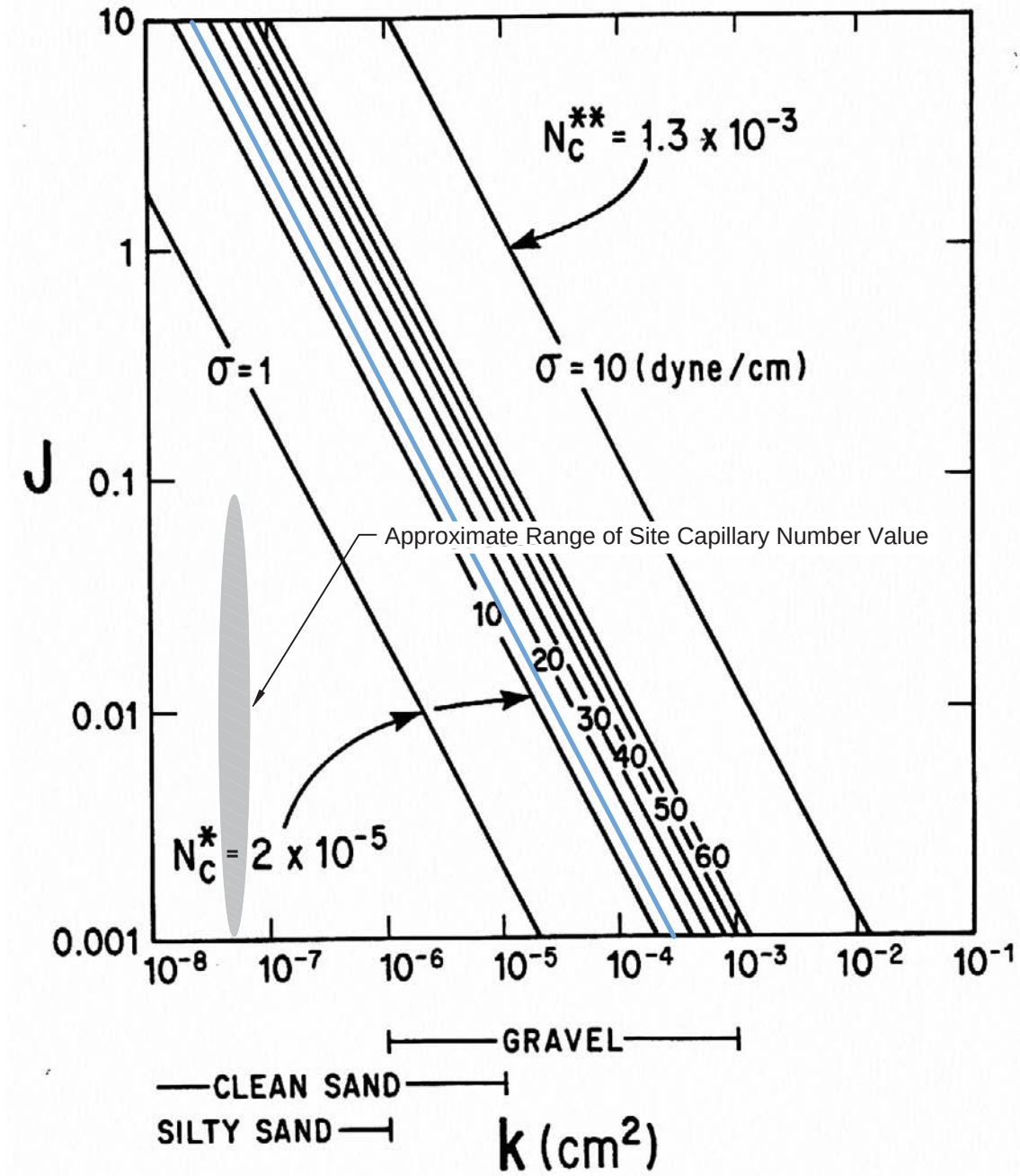
Figure 3c

Predicted Factors for Hydraulic Gradient Increases
Under Pumping Conditions for combined Shallow and Intermediate Wells
Gasco/Siltronic
Portland, Oregon

ANCHOR ENVIRONMENTAL, L.L.C.

0 150
Scale in Feet
1 inch = 150 feet

Figure 3d
Approximate Location of Cross Sections Showing Predicted Changes in Hydraulic Gradients Under Pumping Conditions at the Gasco Site
Gasco/Siltronic
Portland, Oregon



Line of Critical Capillary Values for σ of 15 dynes/cm

Source: Mercer and Cohen, 1993.

Feb 19, 2009 10:28am cdavidson K:\Jobs\000029-GASCO\00002902\00002902-RP-017.dwg FIG 5

ANCHOR QEA

Figure 4
Hydraulic Gradient Necessary to Initiate DNAPL Blob Mobilization in Soils of Various Permeabilities
Gasco/Siltronic
Portland, Oregon

APPENDIX K
AQUAGARD WELL TREATMENT INFORMATION

AQUA GARD®

well maintenance technology

The AQUA GARD® permanent in-well device significantly improves well maintenance

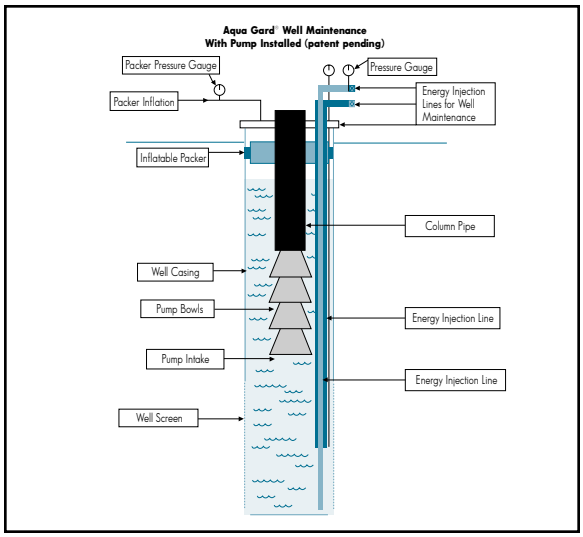
by applying increased energy to more completely remove deposits from wells. The AQUA GARD® system utilizes the permanent placement of energy injection equipment in the well, to efficiently clean well surfaces without pulling the pump.

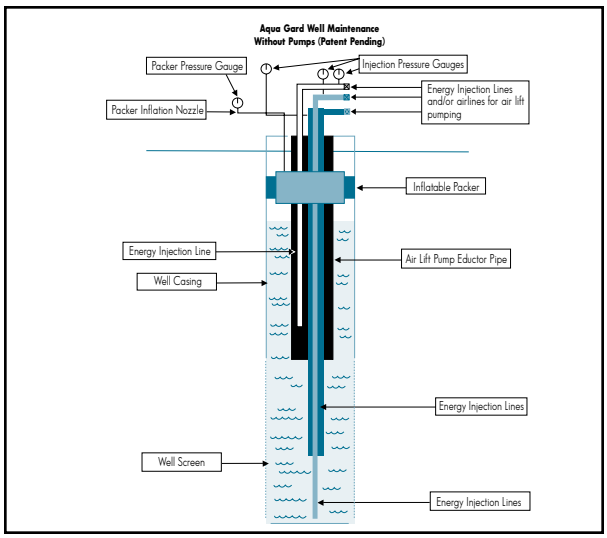
Many wells experience loss of production and water quality problems as a normal process of aging.

The causes of lost capacity and water quality problems are normally categorized into physical, mineral and biological. Often the causes of problems within wells is a combination of bacteria growing in biofilms and filtering minerals from the water as it passes over the surface. Within this biologically accumulated material, fines from the formation (clay, silt, and fine sand) can also become trapped.

Delayed or insufficient rehabilitation treatment can cause build-up or incomplete cleaning of wells.

The amount of deposited material can be very extensive and complete removal of the deposits will most likely be difficult if well treatment is





delayed. Some well rehabilitation treatments are often performed with the pumps in place to reduce the cost, although removing a well's pumping equipment during rehabilitation will allow more energy into the well and the surrounding aquifer. Consequently, the lower portion of many wells is not effectively cleaned due to insufficient velocity achieved to "flush" deposits from the well.

In order to remove deposits from surfaces, we need to deliver more effective energy into the well and aquifer.

This required energy consists of energy of disruption, energy of detachment, energy of dissolution, energy of mobilization and energy of fluidization. Shock chlorination of wells has been used widely in the past in an attempt to maintain a well's performance. However, chlorine as an oxidizing agent does not have the capability of dissolving minerals that are most often associated with biological slime.

Carbon Dioxide possesses the energy to more completely remove deposits from surfaces in the well and further into the surrounding formation.

AQUA GARD® cleans wells more economically and effectively.

The permanent placement of energy injection equipment in the well allows the energy necessary

to remove deposits from the surfaces to be introduced and mobilized in the well without the cost of pulling the pump. The AQUA GARD® system is patent pending and utilizes gaseous and liquid carbon dioxide, providing one of the best methods to deliver energy into every part of the well and the surrounding formation. With a packer and injection lines already in place, Aqua Gard performs the cleaning process without having to pull the pump.

Periodic cleaning can be performed on a scheduled interval to keep the well surfaces clean. The cost of this periodic cleaning can be significantly reduced with the injection equipment already in place. The cleaning is often performed using only carbon dioxide, offering the advantage of not having to neutralize or dispose of chemicals. The use of chemical energy can be added if necessary to remove severe biomass and associated minerals.

Barrier wells and injection wells not equipped with pumps can also benefit from an AquaGard® installation.

There are many barrier wells or injection wells that currently are operated in an injection mode. They do not have internal pumps to backflush their surfaces. Periodically pumping an injection well will extend the time between cleanings, by removing some of the deposited material from surfaces.

Once the material has been detached from the surfaces it must be removed from the bottom part of the well and the surrounding formation. This can best be achieved with the simultaneous pumping and occasional fluidization of the sediments and deposits. This cleans the surfaces more completely and can maintain the original pore volume that exists around wells more effectively. Maintaining the pore volume and keeping surfaces clean increases the timeframe between rehabilitations.

THE BENEFITS OF AQUA GARD®

- Improved Well Performance
- Lower Cost for Well Maintenance
- No need to pull the pump
- Keeping the surfaces clean
- Less “unsafe” bacterial results
- Minimizes the effects of “Iron Related Bacteria”
- Increases the life of a well
- Maintains the Pore Volume of the Well and Aquifer
- Maintains Well Production
- Provides for scheduled preventative well maintenance
- Can be completely automated

If you are experiencing any or all of the following problems, Aqua Gard® may be your long-term solution

- Well experiences lost capacity quickly and/or frequently
- Well has water quality problems
- New wells in areas where deposition of material is known to occur
- Well has periodic “unsafe” bacterial results

AQUA GARD® APPLICATIONS

- Water Supply Wells
- Horizontal Wells
- Collector Wells
- Barrier Injection Wells
- Remediation Wells

SUBSURFACE TECHNOLOGIES INCORPORATED

40 Stone Castle Road • Rock Tavern, NY 12575 • 845.567.0187 • FAX: 845.567.1035

1828 Walnut Street, Suite 819 • Kansas City, MO 64105 • 816.221.7770 • FAX: 816.221.7997
http://www.subsurfacetech.com

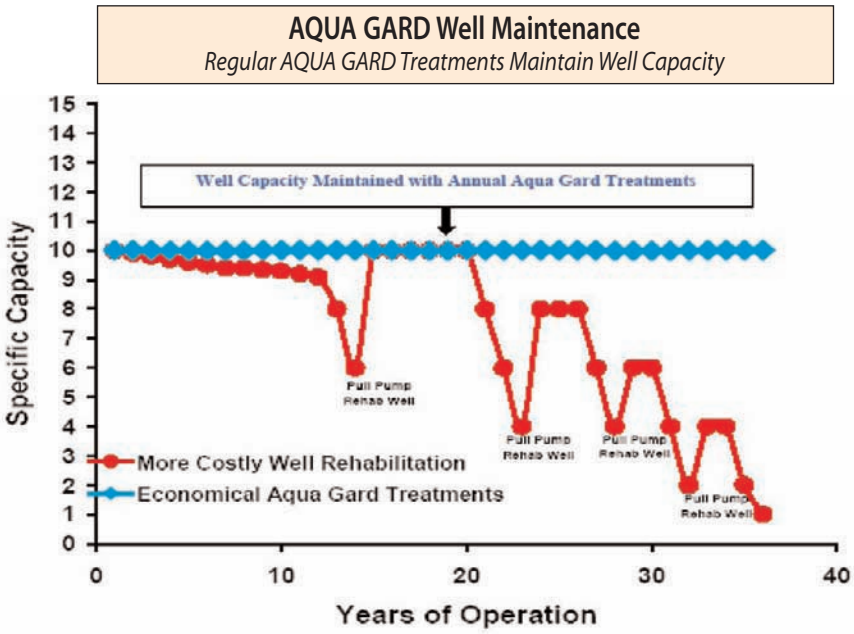
Well Maintenance Technology (patented)

The AQUA GARD® permanent in-well device significantly improves well maintenance

AQUA GARD® Well Maintenance Systems include the permanent placement of energy injection equipment into the well to allow the well to be cleaned effectively, maintaining quantity and quality, without having to remove the pumping or injection equipment. AQUA GARD provides a "proactive rather than reactive cleaning, and has proved to be more effective and much more economical for the client.

Many wells experience loss of production and water quality problems as a normal process of aging.

When your well is equipped with an AQUA GARD system, energy can be delivered into the well for removal of mineral and biological deposits, before they become hardened making them much easier to remove. Subsurface Technologies use of carbon dioxide applied on many thousands of wells over decades has proven to be the most effective method of injecting energy and rehabilitating wells and continues to be the energy of choice, because of its effectiveness and environmental friendliness. The scheduled periodic cleaning service is performed usually in one to two days, reducing down time and cost while ensuring that the well surfaces are kept clean for improved water quality and increased flow capacity.



AQUA GARD®

Well Maintenance Technology (patented)

The Benefits of AQUA GARD®

- ✓ Improved Well Performance
- ✓ Lower Cost for Well Maintenance
- ✓ No need to pull the pump
- ✓ Keeping the surfaces clean
- ✓ Less "unsafe" bacterial results
- ✓ Minimizes the effects of "Iron Related Bacteria"
- ✓ Increases the life of a well
- ✓ Maintains the Pore Volume of the Well and Aquifer
- ✓ Maintains Well Production
- ✓ Provides for scheduled preventative well maintenance
- ✓ Can be completely automated

If you are experiencing any or all of the following problems, AQUA GARD may be your long-term solution

Well experiences lost capacity quickly and/or frequently

Well has water quality problems

New wells in areas where deposition of material is known to occur

Well has periodic "unsafe" bacterial results

AQUA GARD Applications

Water Supply Wells

Horizontal Wells

Collector Wells

Barrier Injection Wells

Remediation Wells

CASE STUDIES

Study 1— Taconic Farms, Germantown, NY

A 9 well industrial site in the northeast, required rehabilitation every 6 months to restore lost capacity due to very high levels of biological activity, producing extremely poor water quality and rendering the wells un-potable. In 2001 AQUA GARD was installed on 5 of the 9 wells and serviced quarterly, producing increased yield, along with sustained higher pumping levels & efficiencies. Plant demand was then fully met by the 5 wells that were equipped with AQUA GARD, with greatly reduced maintenance and energy costs during the following 3 year period as shown in the cost benefit analysis below.

Taconic Farms	36 Month Period pre AQUA GARD	36 Month period post AQUA GARD	
Item	**10/98 to 10/01**	**10/01 to 10/04**	**Savings**
Well Rehabilitation		$ 9,200.00	
Aqua Gard Installation	$ 2,595.00		
Per Well Cleaning Cost	$ 2,520.00	$ 6,000.00	
Water Treatment Cost During Cycle	$ 65,600.00	$ 13,600.00	
Energy Cost During 3 Year Term			
Supplemental Water			
36 Month Per Well Total	$ 68,120.00	$ 31,395.00	$ 36,725.00
36 Month Site total	$ 613,080.00	$ 156,975.00	$ 456,105.00

Study 2— Aqua America, Forest, PA

In November of 2004, AQUA GARD was installed on 1 of a 5 well potable water supply system. The well was completed to 540' and produced 160 GPM with a pumping level of 259'. Almost immediately well yield and efficiency began a steady decline. Within 6 months the well had lost 35% of its yield and 37% of its efficiency. The well was cleaned and AQUA GARD installed. Based on the historical performance the well would have required cleaning at 6 month intervals to minimize lost yield and reduced efficiency. The following represents the cost benefit to the installation of an AQUA GARD preventative maintenance system.

Forest, PA (5) well site	Without Aqua Gard	With Aqua Gard	Savings
Well Rehabilitation	$ 19,000.00	$ 19,000.00	
Aqua Gard Installation		$ 7,000.00	
Service Events During 3 Year Cycle	5.00	11.00	
Cost per service	$ 19,000.00	$ 3,400.00	
Energy cost			
Supplemental water cost			
Total per well cost for 36 months	$ 114,000.00	$ 63,400.00	$ 50,600.00
Cost per site during 3 year term	$ 570,000.00	$ 317,000.00	$ 253,000.00

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APPENDIX L
GROUNDWATER TREATMENT SYSTEM PILOT TEST PLAN

NW Natural Gas Company

Revised Wastewater Pilot Plant Testing Plan

(Second Revision in Response to DEQ June 23, 2009 Comments)

June 2009

Sevenson Environmental Services, Inc.

NW Natural
Wastewater Pilot Plant Testing Plan
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June 2009

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Pilot Plant Process Design—NW Natural Site

The proposed treatment process is largely designed to remove iron and manganese, cyanide, heavy metals, VOCs and SVOCs. The pilot plant will be situated inside a secondary containment area containing crushed stone over a 40-mil liner, with berms around the entire pilot site to contain wastewater, residual, or chemical spills. The facility will be operated under a site-specific Health and Safety Plan (HASP), submitted under separate cover. The site-specific HASP will address spill prevention and countermeasures to be taken and emergency contacts in the event of a spill.

The NW Natural pilot plant is designed to operate at an average daily flow rate of 50 gpm (18,000 gals/day), 6 hours per day, allowing one hour for startup and one hour for shutdown each day over a 5-day week. Treated effluent from the Siltronic pilot plant (15 gpm) will be blended into the NW Natural pilot plant for discharge to the current POTW.

All backwash water will be recirculated to the influent equalization tanks for re-treatment. All plant residuals (bag filters, sedimentation tank solids, and spent carbon) will be properly disposed of to a permitted facility.

Sevenson has included its wastewater treatment pilot plant design and materials balance in Appendix A. This mass balance will be expanded upon completion of the pilot plant with data taken during the runs. The expanded mass balance will be incorporated into the final design data. The proposed process flow diagram for the pilot plant is included in Appendix B.

Influent Wells Location

The NW Natural pilot plant will draw from two or more wells on the NW Natural Site: MW-1-55 and PW-1-80 as shown on Figure 1. It is anticipated that the well pumps will operate constantly to replenish the influent equalization tanks of the pilot plant. Figures 2 and 3 show the expected flow from MW-1-55 and PW-1-80, respectively. The pumping capacity of well MW-1-55 will be measured before the pilot test. If the yield from well MW-1-55 is inadequate to supply sufficient water for the pilot test, an additional well or

wells in the northern area of the Site will be identified before the pilot test begins. Each well pump will pump into a separate 21,000-gallon equalization tank. The well pump flows, which are continuous, have been sized to allow for continuous pilot plant operation during the operating week.

Influent Equalization Tanks

Waters from both wells will be pumped into two 21,000-gallon frac tanks. Besides well water, the equalization tanks will also receive spent backwash water from the downstream GAC vessels. The tanks will be air-tight, with a vapor-phase carbon system on top of one of the tanks to handle off-gases (volatile organic compounds and air) that may be released from the tanks.

The tanks are designed to permit settling of solids and flotation of light solids and oil. Periodically, the operator will employ a “sludge judge” in each tank to monitor the buildup of DNAPL in the bottom of the equalization tanks. The “sludge judge” is a clear plastic tube approximately 8 feet with a foot valve on the bottom to allow the operator to determine the sludge buildup, if any, in each tank. Accumulated solids and floatables in the tanks will be periodically removed as required using a trash pump.

In the full-scale design, it is planned to utilize a dedicated DNAPL tank which will receive DNAPL directly from the process wells, thus greatly reducing the DNAPL accumulating in the equalization tanks in the full-scale system.

Clarifier Feed Pumps

Two 100-gpm clarifier feed pumps will be provided, one per equalization tank. The pumps are oversized to provide the capability to “loop” the flow through an in-line aerator to facilitate iron removal prior to sedimentation. The pumps also have variable-frequency drives to allow for pumping different flow ratios from each well to the pilot plant.

Sodium Hydroxide Feed Pumps

Two sodium hydroxide feed pumps, pH meters and controllers will be installed on the influent equalization tanks to increase the influent pH to approximately 8.5. The rates of iron and manganese oxidation are both greatly accelerated at higher pH.

Figure 1: Location of NW Natural Wells for Pilot Plant

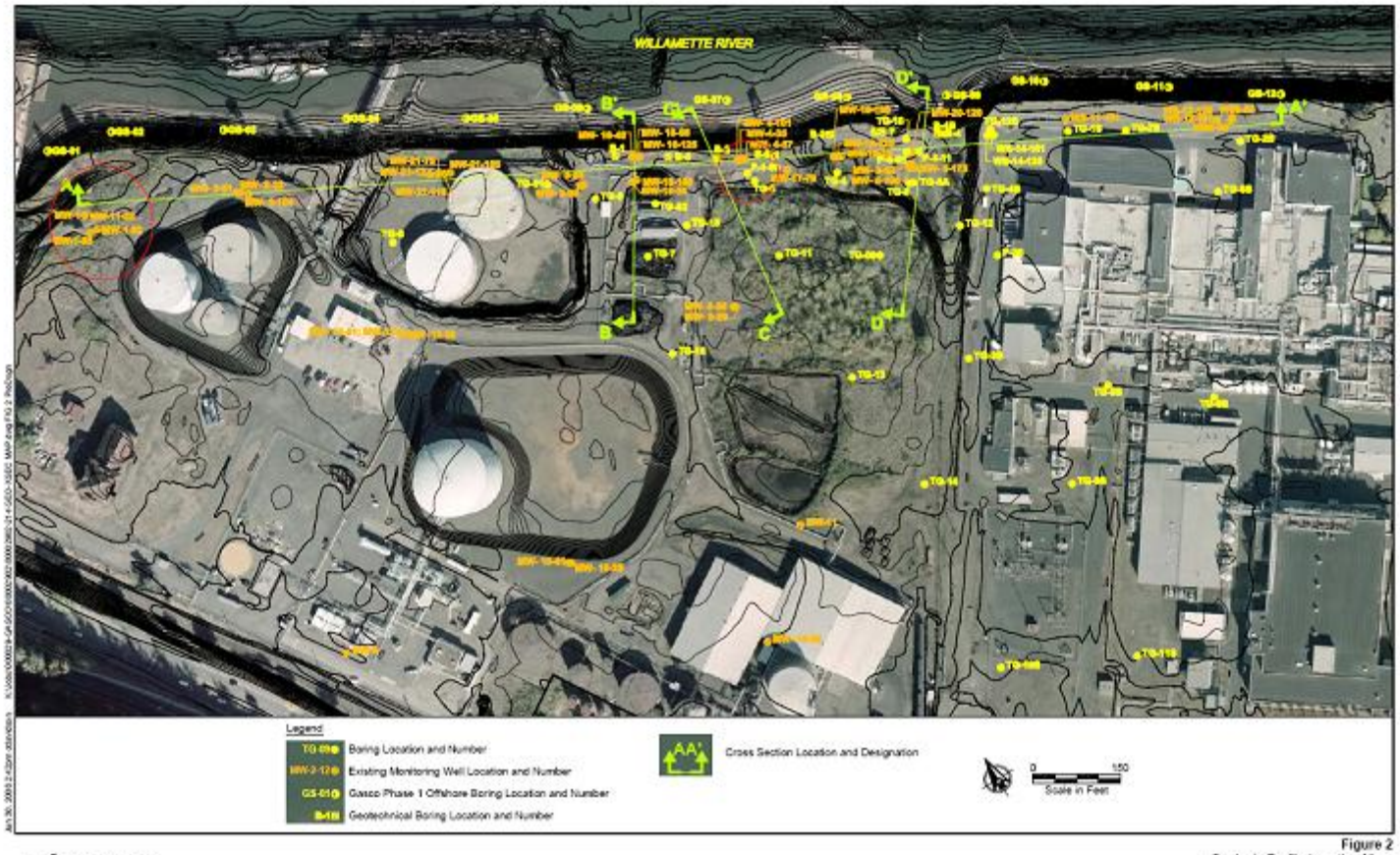


Figure 2: Well Flow Calculations and Equalization Volume for NW Natural MW-1-55

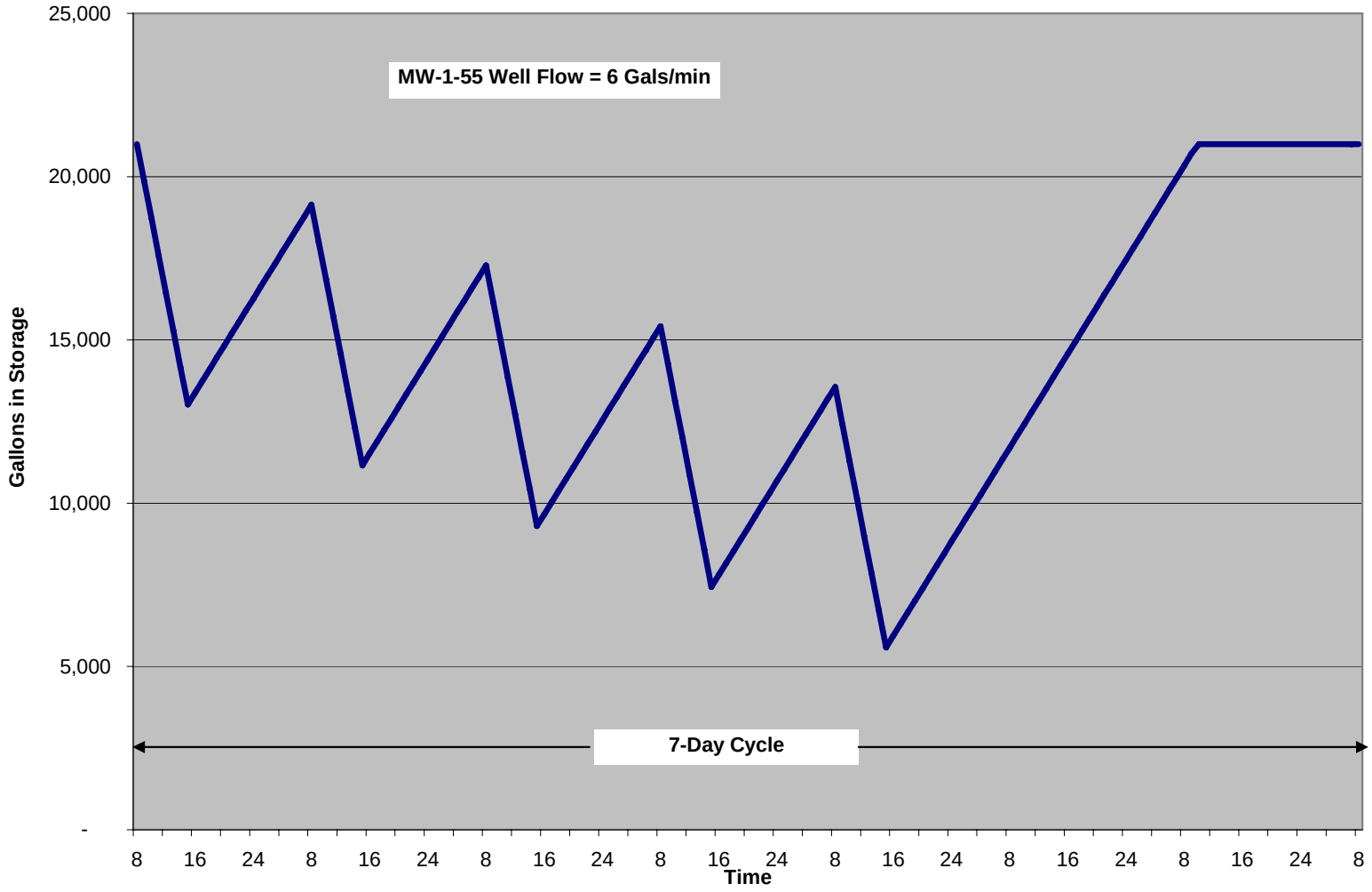
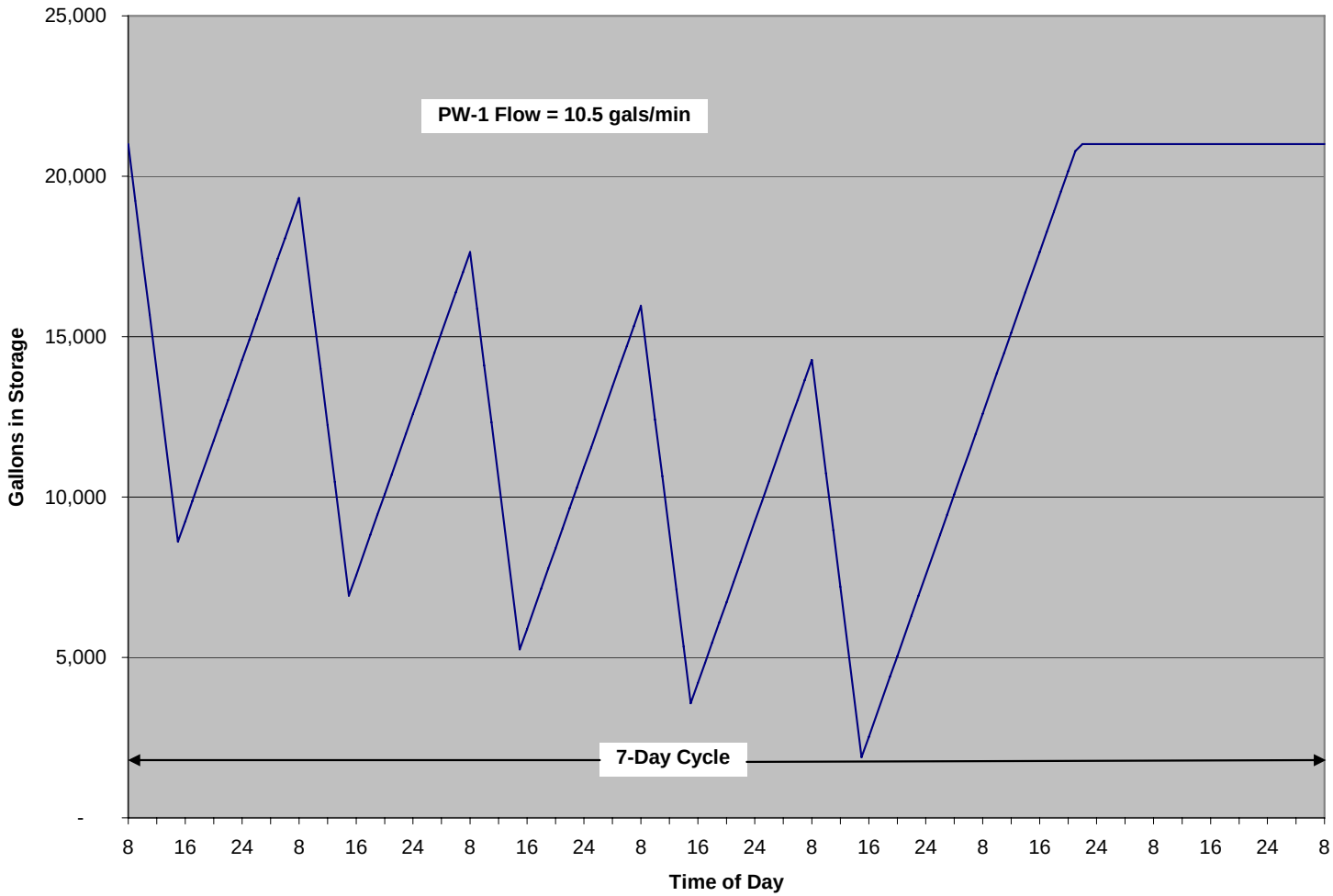


Figure 3: Well Flow Calculation and Equalization Volume for NW Natural PW-1



Recirculation Loop and In- Line Aeration

Two in-line aerators (eductors) will be installed on the recirculation lines from the clarifier feed pumps to the Influent Equalization Tanks. The eductors will draw air into the recirculation lines to assist in iron and manganese oxidation.

Polymer Addition

A polymer addition system will be installed to feed polymer to the wastewater prior to introduction into the downstream inclined-plate clarifier to facilitate settling. The polymer will be mixed in line with a 2-inch static mixer, and paced off the flow meters.

Inclined-Plate Clarifier (IPC)

An inclined-plate clarifier (IPC) will receive the flow from the equalization tanks and remove the oxidized iron and manganese. In addition, heavy metals will be removed via iron co-precipitation in the clarifier. Settled sludge will be removed and stored for dewatering that will be conducted in a filter press as necessary during the pilot operation. The resulting filter cake will be stored in a proper container within the containment area and properly disposed of prior to pilot plant demobilization.

IPC Effluent Tank

A 2,500-gallon effluent tank will be positioned at the outlet of the IPC to receive the flow by gravity. This tank will serve as the pump tank for the filter feed pump. The tank will also receive the treated flow from the Siltronic Pilot Plant.

Filter Feed Pump

Following the IPC will be a single 75-gpm electric centrifugal pump. This pump will be manually controlled, using the level in the IPC Effluent Tank. The flow rate will be adjusted with the use of a variable-frequency drive.

The Filter Feed Pump will pump the combined flows through the cyanide destruct tank, the bag filters, and the granular activated carbon (GAC) vessels, before discharging into the effluent /backwash storage tanks.

Hydrogen Peroxide Feed System

A hydrogen peroxide feed pump, oxidation-reduction potential (ORP) indicator and controller will deliver 50% hydrogen peroxide solution to an in-line static mixer to thoroughly mix the wastewater and hydrogen peroxide. The feed pump will take suction from a chemical tote, containing approximately 260 gallons. The peroxide dosage will be paced off the ORP set point.

Sodium Hydroxide Feed System

A sodium hydroxide feed pump, pH meter and controller will be installed on the cyanide destruct tank to increase the wastewater pH to approximately 10.0. The feed pump will take suction from a chemical tote, containing approximately 260 gallons. The rates of cyanide oxidation and any iron and manganese are greatly accelerated at higher pH.

Cyanide Destruct Reactor

A separate reactor tank will be used for cyanide destruction. The tank will be sized for a minimum detention time of 120 minutes, based upon the results in the treatability tests.

Sulfuric Acid Feed System

A sulfuric acid feed pump, pH meter and controller will be installed on the pipe from the cyanide destruct tank to reduce the wastewater pH to approximately 8.5. The feed pump will take suction from a drum, containing approximately 20 gallons. The acid will be injected upstream of a 2-inch in-line static mixer.

Primary Bag Filters

Two pressure bag filters will be provided to remove remaining particulates from the wastewater prior to the GAC units. The bag filters will be set up to operate in series to filter iron and other solids prior to introduction into the GAC vessels. Each bag filter has a capacity of 100 gpm.

The upstream and downstream filters will be fitted with 10-micron and 5-micron bags, respectively. The vessels are fitted with inlet and outlet pressure gauges. The bags will be changed at an appropriate pressure differential.

Granular Activated Carbon Vessels

The waste stream then flows through two, 6-foot diameter Granular Activated Carbon (GAC) vessels, piped in series, with differential pressure measured across each vessel. The GAC units will remove volatile organics and semi-volatile organics in the effluent from the filter units. Seventeen hundred pounds of carbon will be loaded into each vessel.

The sizing of the system is intended to produce breakthrough on the lead carbon vessel within the pilot plant study period to better determine carbon life in the full-scale system. The sizing has also been designed to remove all organics in the lag vessel after breakthrough in the lead vessel. Breakthrough will be determined by daily sampling of total organic carbon between the columns. After breakthrough, total organic carbon will be monitored from the lag column. No pilot work will continue if the lag vessel becomes exhausted.

The GAC filters will be provided with backwashing capability to allow continuous operation. The amount of carbon in each vessel has been calculated to give the process water the correct amount of contact time at a maximum flow rate of 65 gallons per minute.

Effluent/Backwash Storage Tank

After the GAC vessels, the treated wastewater will be discharged into two 21,000-gallon effluent/backwash storage tanks. These tanks will serve as “batch holding tanks” during the start up phase of the operation, and will be utilized as clean water holding tanks for backwash water.

Effluent/Backwash Pumps

Two electric centrifugal pumps will be provided, each with a capacity of 350 gpm, to allow for a suitable backwash rate for the GAC vessels, and to discharge to the approved discharge point.

Flow Meter Rate/Totalizer

All treated wastewater discharged from the plant will pass through a 2-inch flow meter and totalizer.

In addition, a backwash flow meter will be installed on the backwash line.

Effluent Bag Filters

A final filtration step will be accomplished using two bag filters arranged in parallel. The filters are intended to remove any carbon fines and adsorbed organics escaping the GAC vessels.

The bag filters will be equipped with 0.5-micron bags. The vessels are fitted with inlet and outlet pressure gauges. The bags will be changed at an appropriate pressure differential.

Residual Disposal

All residuals from the pilot treatment plant: settled solids, GAC media, and spent bag filters will be properly disposed of.

Hoses

Two-inch hose will be used for the conveyance of the process water between the process tankage in the pilot plant. Hose is used instead of hard piping because they provide a degree of flexibility and shock absorption that is critical in the field. The proposed hose is a hard rubber 150-psi suction type hose with a spiral wound steel reinforcement running through its length.

Pilot Plant Process Design—Siltronic Site

The proposed treatment process is largely designed to remove iron and manganese, cyanide, heavy metals, and chlorinated solvents including vinyl chloride. The pilot plant will be situated inside a secondary containment area containing crushed stone over a 40-mil liner, with berms around the entire pilot site to contain wastewater, residual, or chemical spills. The facility will be operated under a site-specific Health and Safety Plan (HASP), submitted under separate cover. The site-specific HASP will address spill prevention and countermeasures to be taken and emergency contacts in the event of a spill.

The Siltronic pilot plant is designed to operate at an average daily flow rate of 15 gpm (5,400 gals/day), 6 hours per day, allowing one hour for startup and one hour for shutdown each day over a 5-day week. Treated effluent from the Siltronic pilot plant will be blended into the NW Natural pilot plant at the Clarifier Effluent Tank, for further treatment and discharge to the current POTW.

All plant residuals (disposable bag filters containing solids and sedimentation tank solids) will be treated as a listed F002 waste and will be properly disposed of to a permitted facility. Prior to disposal, the residuals will be stored in a closed container located within the containment zone.

Sevenson has included its wastewater treatment pilot plant design and materials balance for the Siltronic site in Appendix A. This mass balance will be expanded upon completion of the pilot plant with data taken during the runs. The expanded mass balance will be incorporated into the final design data. The proposed process flow diagram for the pilot plant is included in Appendix B.

Influent Well(s) Location

The pilot plant will draw from selected well(s) on the Siltronic site. It is anticipated that the well pump(s) will operate constantly to replenish the influent equalization tank of the

pilot plant. Figure 4 shows the total expected flow from the Siltronic site. Each well pump will pump into a 21,000-gallon equalization tank.

The well pump flows, which are continuous, have been sized to allow for continuous pilot plant operation during the operating week.

Influent Equalization Tank

Waters from the Siltronic well(s) will be pumped into a single 21,000-gallon frac tank. The tank will be air-tight, with a vapor-phase carbon system on top of the tank to handle off-gases (volatile organic compounds and air) that may be released from the tank.

The tank is designed to permit settling of solids and flotation of light solids and oil. The accumulated solids and floatables in the tanks will be periodically removed as required using a trash pump. Plant influent characteristics will be sampled from this tank.

Clarifier Feed Pump

One 30-gpm clarifier feed pump will be provided. The pump is oversized to provide the capability to "loop" the flow through an in-line aerator to facilitate iron removal prior to sedimentation. The pump will also have a variable-frequency drive to allow for pumping different flows to the pilot plant.

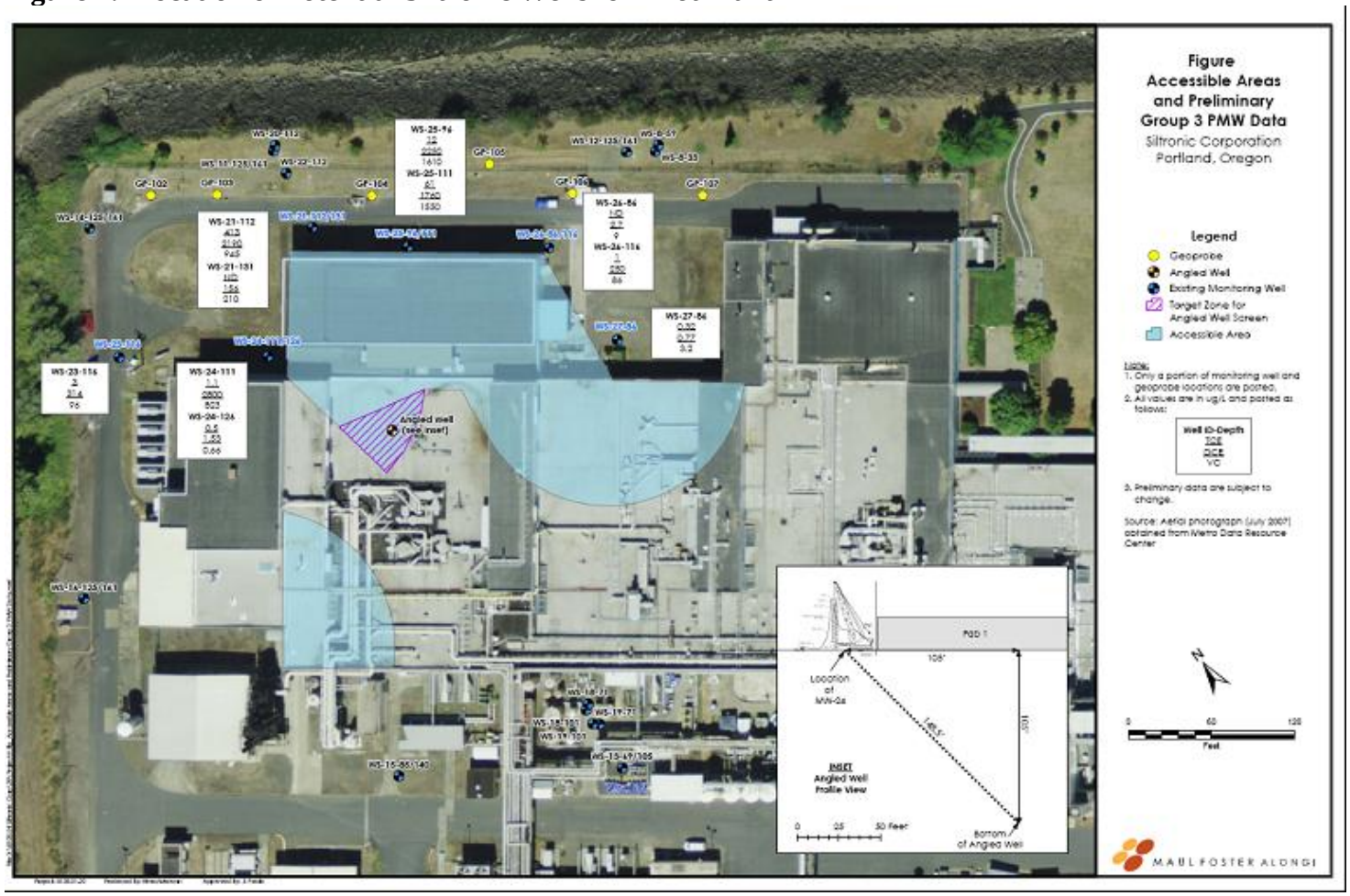
Flow Meter Rate/Totalizer

All treated wastewater discharged from the plant will pass through a 1-inch flow meter and totalizer.

Sodium Hydroxide Feed Pumps

A sodium hydroxide feed pump, pH meter and controller will be installed on the influent equalization tank to increase the influent pH to approximately 8.5. The rates of iron and manganese oxidation are both greatly accelerated at higher pH.

Figure 4: Location of Potential Siltronic Wells for Pilot Plant



Recirculation Loop and In- Line Aeration

An in-line aerator will be installed on the recirculation lines from the clarifier feed pumps to the Influent Equalization Tanks. The aerator will draw air into the recirculation line to assist in iron and manganese oxidation.

Polymer Addition

A polymer addition system will be installed to feed polymer to the wastewater prior to introduction into the downstream inclined-plate clarifier to facilitate settling. The polymer will be mixed in line with a 1-inch static mixer, and paced off the flow meter.

Inclined-Plate Clarifier (IPC)

An inclined-plate clarifier (IPC) will receive the flow from the equalization tanks and remove the oxidized iron and manganese. In addition, heavy metals will be removed via iron co-precipitation in the clarifier. Settled sludge will be removed and stored for dewatering once the full-scale plant is constructed.

IPC Effluent Tank

A 750-gallon effluent tank will be positioned at the outlet of the IPC to receive the flow by gravity. This tank will serve as the pump tank for the filter feed pump. The tank will also receive the treated flow from the Siltronic Pilot Plant.

Advanced Oxidation Feed Pump

Following the IPC will be a single 15-gpm electric centrifugal pump. This pump will be manually controlled, using the level in the IPC Effluent Tank. The flow rate will be adjusted with the use of a variable-frequency drive.

The Advanced Oxidation Pump will pump the wastewater flow through the advanced oxidation process, before discharging into the IPC Effluent Tank in the NW Natural Pilot Plant for further treatment.

Advanced Oxidation Process (AOP)

The advanced oxidation process (AOP) utilizes a combination of hydrogen peroxide and ultraviolet light to destroy the chlorinated organic solvents and cyanide in the Siltronic wastewater.

A hydrogen peroxide feed pump, oxidation-reduction potential (ORP) indicator and controller will deliver 50% hydrogen peroxide solution to an in-line static mixer to thoroughly mix the wastewater and hydrogen peroxide. The wastewater-peroxide mixture will pass through an ultraviolet reactor to destroy the chlorinated solvents and most cyanide.

Effluent Storage Tank

After the AOP, the treated wastewater will be discharged into a single 18,000-gallon storage tank. This tank will serve as a "batch holding tank" during the start up phase of the operation, and will be used to cool the potentially hot liquid, before introducing the flow into the NW Natural Pilot Plant.

Also, the plant effluent characteristics will be sampled from this tank.

Effluent Pump

A 15-gpm electric centrifugal pump will be used to pump the effluent from the storage tank to the NW Natural Pilot Plant for ultimate discharge to the local POTW. The flow from the Siltronic pilot will be measured and totalized prior to final discharge to the NW Natural pilot plant.

Residual Disposal

All residuals from the pilot treatment plant: settled solids from the IPC, will be properly disposed of. The residuals will be stored in a closed container within the containment zone prior to disposal.

Hoses

Two-inch hose will be used for the conveyance of the process water between the process tankage in the pilot plant. The proposed hose is a hard rubber 150-psi suction type hose with a spiral wound steel reinforcement running through its length.

Sampling and Analysis Plan

General

This Sampling and Analysis Plan covers the pilot wastewater treatment plants at both the NW Natural and Siltronic sites and their effluent discharges. All samples to be taken will be grab samples.

Influent and effluent samples will be taken in accordance with the March 31, 2009 "Discharge Limitations and Monitoring Requirements for the NW Natural/Gasco Site" from Oregon Department of Environmental Quality (DEQ).

The NW Natural pilot treatment facilities have been designed to remove:

- Iron and manganese;
- Cyanide
- Heavy metals
- Volatile and semi-volatile organic compounds, particularly polyaromatic hydrocarbons

The Siltronic pilot treatment facilities have been designed to remove:

- Iron and manganese;
- Cyanide
- Heavy metals
- Volatile and semi-volatile organic compounds, particularly polyaromatic hydrocarbons, and
- Chlorinated solvents, particularly vinyl chloride.

Effluent Flow Routing

All flow from the NW Natural pilot wastewater treatment plant will be discharged to the local POTW. The effluent flow rate will be instantaneously measured and totalized. All flow from the Siltronic pilot plant will be initially stored in an 18,000-gallon storage tank before being pumped and ultimately discharged to the NW Natural pilot plant.

Sample Locations

Both plants will utilize influent equalization tanks and effluent storage tanks. Grab samples will be taken from these tanks. Weekly grab samples will also be taken on the influent from the wells upstream of the equalization tanks to determine the actual water quality from the individual wells. In addition, process samples will be obtained from individual processes to facilitate the design of the individual processes.

Monitoring Program

Table 1 is a summary of discharge limitations summarized from the March 31, 2009 memorandum from the Oregon DEQ, and amended in its June 23 e-mail from Mr. Dana Bayuk. Table 2 is the Oregon DEQ's monitoring requirements for the pilot plant and subsequent facilities. Besides the required permit tests, Sevenson will perform other tests on influent and process flows as required to control and monitor process performance.

Sevenson will collect samples and conduct the analyses for the following reasons:

- To satisfy the discharge reporting requirements of the regulatory agency.
- To form a rational basis for controlling the pilot treatment processes.
- To define the operational efficiency of the pilot plants.
- To develop a historical record of the conditions under which the plant has been operated, as an aid to the design of the full-scale plant.

Table 2 shows the Oregon DEQ's monitoring schedule that will be used for both pilot plant operations. Besides the required tests, Sevenson will perform other tests on internal process flows as required to control and monitor process performance, as shown in Tables 3 and 4 for NW Natural and Siltronic, respectively.

Also, any sludges or sludge cakes generated will be tested for total solids. Also, all treatment chemicals used will be tracked throughout the pilot test period for final design purposes.

Table 1: Discharge Limitations for NW Natural/Gasco Site[1]

Discharge Limitations		
Parameter	**Monthly Average**	**Daily Maximum**
Benzene	0.66 (µg/L)	1.1 (µg/L)
Benzo(a)Anthracene	Not to exceed EPA Method 625 Quantitation Limit of 1 µg/L	
Benzo(a)Pyrene	Not to exceed EPA Method 625 Quantitation Limit of 1 µg/L	
Benzo(b)Flouranthene	Not to exceed EPA Method 625 Quantitation Limit of 1 µg/L	
Benzo(k)Flouranthene	Not to exceed EPA Method 625 Quantitation Limit of 1 µg/L	
Copper	Not to exceed EPA Method 200.8 Quantitation Limit of 10 µg/L	17.7 (µg/L)
Chromium VI	Not to exceed EPA Method 218.6 Quantitation Limit of 10 µg/L	16 (µg/L)
Chrysene	Not to exceed EPA Method 625 Quantitation Limit of 1 µg/L	
Free Cyanide	Not to exceed ASTM Method 4282-02 Quantitation Limit of 10 µg/L	
Dibenzo(a,h)Anthracene	Not to exceed EPA Method 625 Quantitation Limit of 1 µg/L	
Indeno(1,2,3-Cd)Pyrene	Not to exceed EPA Method 625 Quantitation Limit of 1 µg/L	
Iron (Dissolved)	300.0 (µg/L)	520 (µg/L)
Manganese (Dissolved)	50.0 (µg/L)	86.6 (µg/L)
Mercury	Not to exceed EPA Method 245.7 Quantitation Limit of 0.01 µg/L	
Pentachlorophenol	Not to exceed EPA Method 625 Quantitation Limit of 2 µg/L	
pH	6.5 S.U.	8.5 S.U.
Temperature	7-day Avg. of the Daily Maximums Not to Exceed 68 ºF	

[1] Unless indicated as dissolved, total metal concentration will be tested. Effluent samples will be tested for both dissolved and total metals.

Table 2: Oregon DEQ Monitoring Requirements for the NW Natural/Gasco Site

Minimum Monitoring			
Parameter	**Minimum Frequency**		**Sample Type**
	During Pilot Study	**All Other Periods**	
Volume Discharged	Daily, when discharging	Daily, when discharging	Metering
Temperature	Daily, when discharging	Daily, when discharging	Recorder
Bioassay Testing	-	Annual	Grab
Outfall Pipe	-	Annual	Inspection
pH	Weekly, when discharging	Monthly, when discharging	Grab
Hardness	Weekly, when discharging	Monthly, when discharging	Grab
Free Cyanide	Weekly, when discharging	Monthly, when discharging	Grab
Total Cyanide	Weekly, when discharging	Monthly, when discharging	Grab
Available Cyanide	Weekly, when discharging	Monthly, when discharging	Grab
Weak-acid Dissociable Cyanide	Weekly, when discharging	Monthly, when discharging	Grab
PAHs			
Acenaphthylene	Weekly, when discharging	Monthly, when discharging	Grab
Acenaphthene	Weekly, when discharging	Monthly, when discharging	Grab
Anthracene	Weekly, when discharging	Monthly, when discharging	Grab
Benzo(a)Anthracene	Weekly, when discharging	Monthly, when discharging	Grab
Benzo(a)Pyrene	Weekly, when discharging	Monthly, when discharging	Grab
Benzo(b)Flouranthene	Weekly, when discharging	Monthly, when discharging	Grab
Benzo(k)Flouranthene	Weekly, when discharging	Monthly, when discharging	Grab
Carbazole	Weekly, when discharging	Monthly, when discharging	Grab
Chrysene	Weekly, when discharging	Monthly, when discharging	Grab
Dibenzo(a,h)Anthracene	Weekly, when discharging	Monthly, when discharging	Grab
Dibenzofuran	Weekly, when discharging	Monthly, when discharging	Grab
Flouranthene	Weekly, when discharging	Monthly, when discharging	Grab
Flourene	Weekly, when discharging	Monthly, when discharging	Grab
Indeno(1,2,3-Cd) Pyrene	Weekly, when discharging	Monthly, when discharging	Grab
2-Methlynaphthalene	Weekly, when discharging	Monthly, when discharging	Grab
Naphthalene	Weekly, when discharging	Monthly, when discharging	Grab
Pyrene	Weekly, when discharging	Monthly, when discharging	Grab

Table 2 (Cont'd): Oregon DEQ Monitoring Requirements for the NW Natural Site

Minimum Monitoring			
Parameter	**Minimum Frequency**		**Sample Type**
	During Pilot Study	**All Other Periods**	
Metals[2]			
Arsenic (organic)	Weekly, when discharging	Monthly, when discharging	Grab
Arsenic (inorganic)[3]	Weekly, when discharging	Monthly, when discharging	Grab
Cadmium	Weekly, when discharging	Monthly, when discharging	Grab
Chromium III	Weekly, when discharging	Monthly, when discharging	Grab
Chromium VI	Weekly, when discharging	Monthly, when discharging	Grab
Copper	Weekly, when discharging	Monthly, when discharging	Grab
Iron (dissolved)	Weekly, when discharging	Monthly, when discharging	Grab
Iron (total)	Weekly, when discharging	Monthly, when discharging	Grab
Lead	Weekly, when discharging	Monthly, when discharging	Grab
Manganese (dissolved)	Weekly, when discharging	Monthly, when discharging	Grab
Mercury	Weekly, when discharging	Monthly, when discharging	Grab
Nickel	Weekly, when discharging	Monthly, when discharging	Grab
Selenium	Weekly, when discharging	Monthly, when discharging	Grab
Silver	Weekly, when discharging	Monthly, when discharging	Grab

[2] Unless indicated as dissolved, total metal concentration will be tested. Effluent samples will be tested for both dissolved and total metal concentrations.
[3] Speciation to be conducted at least once during the pilot testing and monthly during initial full-scale operation

Table 2 (Cont'd): Oregon DEQ Monitoring Requirements for NW Natural Site

Minimum Monitoring (Continued)			
Parameter	**Minimum Frequency**		**Sample Type**
	During Pilot Study	**All Other Periods**	
VOCs			
Acetone	Weekly, when discharging	Monthly, when discharging	Grab
Benzene	Weekly, when discharging	Monthly, when discharging	Grab
2-Butanone	Weekly, when discharging	Monthly, when discharging	Grab
1,1-dichloroethene	Weekly, when discharging	Monthly, when discharging	Grab
cis-1,2-dichloroethene	Weekly, when discharging	Monthly, when discharging	Grab
Ethylbenzene	Weekly, when discharging	Monthly, when discharging	Grab
Tetrachloroethene	Weekly, when discharging	Monthly, when discharging	Grab
Toluene	Weekly, when discharging	Monthly, when discharging	Grab
Trans-1,2-dichloroethene	Weekly, when discharging	Monthly, when discharging	Grab
Trichloroethene	Weekly, when discharging	Monthly, when discharging	Grab
1,2,4 trimethylbenzene	Weekly, when discharging	Monthly, when discharging	Grab
1,3,5 trimethylbenzene	Weekly, when discharging	Monthly, when discharging	Grab
Vinyl chloride	Weekly, when discharging	Monthly, when discharging	Grab
Xylene	Weekly, when discharging	Monthly, when discharging	Grab
Phenols			
2-Chlorophenol	Weekly, when discharging	Monthly, when discharging	Grab
2,4-Dichlorophenol	Weekly, when discharging	Monthly, when discharging	Grab
2,4-Dimethylphenol	Weekly, when discharging	Monthly, when discharging	Grab
2-methyl-4,6-Dinitrophenol	Weekly, when discharging	Monthly, when discharging	Grab
2-methylphenol	Weekly, when discharging	Monthly, when discharging	Grab
2-nitrophenol	Weekly, when discharging	Monthly, when discharging	Grab
4-nitrophenol	Weekly, when discharging	Monthly, when discharging	Grab
2,4,5-Trichlorophenol	Weekly, when discharging	Monthly, when discharging	Grab
2,4,6-Trichlorophenol	Weekly, when discharging	Monthly, when discharging	Grab
Pentachlorophenol	Weekly, when discharging	Monthly, when discharging	Grab
Phenol	Weekly, when discharging	Monthly, when discharging	Grab

Notes

1. After receiving and reviewing the discharge data from several months of monitoring, the Department may make the determination that the monitoring of certain parameters will no longer be necessary, should continue, or assigning discharge limitations is warranted.
2. The quantitation limits specified in the November 2007 DEQ memorandum pertaining to water quality quantitation limits must be addressed for each applicable parameter.

Table 3: Process Monitoring Sampling Schedule—NW Natural[4]

Parameter	Influent Wells	Influent Equalization Tank	Clarifier Influent	Clarifier Effluent	Cyanide Destruct Tank Effluent	Bag Filter Effluent	Carbon Midpoint	Carbon Effluent	Final Effluent
Flow	W	D							D
pH	W	D	D	D	D	D			D
Oxidation-reduction potential (ORP)			D	D	D				D
Temperature[5]	W	D			D				D
Oil & Grease	W	W							W
Total suspended solids		D				D			D
Total & dissolved iron	W	D	D	D		D			D
Total & dissolved manganese	W	D	D	D		D			D
Total, amenable, WAD, available & free cyanide		D			D	D			D
Heavy metals	W	D				D			D
Total hardness		W				W			W
Total organic carbon	W	D			D	D	D	D	D
Volatile organic compounds	W	D			D		D	D	D
Semi-volatile compounds	W	D			D		D	D	D

[4] All samples grab samples, except pH, ORP, & temperature
[5] Temperature continuously recorded

Table 4: Process Monitoring Sampling Schedule—Siltronic[6]

Parameter	Influent	Equalization Tank	Clarifier Effluent	Advanced Oxidation Process Effluent to NW Natural Plant	Clarifier Sludge Solids
Flow	D	W		D	
pH	D	W	D	D	
Oxidation-reduction potential (ORP)			D	D	
Temperature[7]	D	W	D	D	
Oil & Grease	W	W		W	
Total suspended solids	D			D	D
Total dissolved solids	D		D		
Total & dissolved iron	D	W		D	
Total & dissolved manganese	D	W		D	
Total, amenable, WAD, available & free cyanide	D			D	
Heavy metals	D	W		D	
Total hardness	W			W	
Total calcium, as CaCO3	D		D		
Total alkalinity, as CaCO3	D		D		
Total organic carbon	D	W		D	
Volatile organic compounds	D	W		D	D
Semi-volatile compounds	D	W		D	D

SAMPLING LEGEND
D—Daily
W--Weekly

[6] All samples grab samples, except pH, ORP & temperature
[7] Temperature continuously recorded

Sample Collection and Handling

All samples collected for off-site laboratory analysis will be stored in ice and preserved in accordance with the requirements of the particular analytical method. All samples will be transported by courier on the day they are collected for analysis at a local analytical laboratory. One exception may be the analysis for free cyanide using ASTM Method 4282-95 which is performed in a limited number of laboratories and may need to be sent away for special testing.

Sample Analytical Methods and Mean Reporting Limits

While the analytical laboratory has not been finally selected, a major consideration in the selection will be the ability of the laboratory to analyze for the required parameters down to the Method Reporting Limit (MRL) as specified by Oregon DEQ in Table 1.
Sevenson will also provide split samples to Agency representatives, should it be required.

Pilot Plant Schedule

It is anticipated that the pilot plant would be started up in late May 2009 and continue approximately 4-6 weeks, depending upon the results of the pilot work and the effectiveness of the selected processes in meeting DEQ's discharge limitations. The projected schedule is shown in Appendix C.

Appendix A: Pilot Plant Design and Materials Balance

NW Natural

NW NATURAL GROUNDWATER PILOT PLANT PROCESS DESIGN		
PRELIMINARY DESIGN DATA --50 GPM		**COMMENTS/ASSUMPTIONS**
INFLUENT CHARACTERISTICS--WASTEWATER		
DESIGN AVERAGE FLOW, GPD	18,000	6-Hour Days
, GPM	50	
AVERAGE TOTAL ORGANIC CARBON, LBS/DAY	6.0	@ 40 mg/L
TOTAL SUSPENDED SOLIDS, LBS/DAY	3.0	@ 20 mg/L
TOTAL CYANIDE, LBS/DAY	0.2	@ 1.5 mg/L
TOTAL IRON, LBS/DAY	12	@ 80 mg/L
TOTAL MANGANESE, LBS/DAY	0.2	@ 1 mg/L
REQUIRED EFFLUENT CHARACTERISTICS		
TOC, MG/L	0.05	Assumed
, LBS/DAY	0.01	
, % REMOVAL	99.9%	
VOCs, MG/L	0.02	Approximate (individual values checked)
, LBS/DAY	0.003	
SVOCs, MG/L	0.03	
, LBS/DAY	0.005	Approximate (individual values checked)
TSS, MG/L	0.04	Assumed
, LBS/DAY	0.01	
, % REMOVAL	99.8%	
FREE CYANIDE, MG/L	0.01	DEQ
, LBS/DAY	0.0180	
, % REMOVAL	92.0%	
DISSOLVED IRON, MG/L	0.3	DEQ
, LBS/DAY	0.0	
, % REMOVAL	99.6%	
DISSOLVED MANGANESE, MG/L	0.05	DEQ
, LBS/DAY	0.01	
, % REMOVAL	95.0%	
INFLUENT EQUALIZATION TANKS		Closed tanks with level control
TYPE	FRAC	
NO OF UNITS INSTALLED	2	
UNIT VOLUME, GALS	21,000	
VOLUME, GALS	42,000	
DETENTION TIME, DAYS	4.7	

REACTOR FEED PUMPS		Controlled off reactor level
TYPE	CENTRIFUGAL	
NO OF UNITS	2	
UNIT CAPACITY, GPM	100	
TDH, FT	20	
UNIT HP	3	with VFD
MAZZEI EDUCTORS--FE AERATION IN RECIRC		
STOICHIOMETRIC FACTOR IRON	0.1432	
STOICHIOMETRIC FACTOR MANGANESE	0.2912	
ASSUMED INFLUENT OXYGEN, mg/L	0	
DESIRED RESIDUAL OXYGEN, mg/L	5	
OXYGEN REQUIRED, mg/l	17	
INFLUENT FLOW METERS		
TYPE	MAGNETIC	Tied to VFDs
NUMBER	2	
SIZE, INCHES	2	
CAUSTIC FEED PUMPS		pH Adjustment as required
TYPE	Diaphragm	
CONTROL	pH	
NUMBER OF UNITS	1	
PROJECTED USAGE, GALS/DAY	18	Treatability using 25%
PROJECTED USAGE, LBS/DAY	234	
, GALS/HOUR	2.3	8 hr days
UNIT CAPACITY, GALS/HR	0-4	
STORAGE PROVIDED, GALS	260	Totes
STORAGE PROVIDED, DAYS	14.4	
HYDROGEN PEROXIDE FEED PUMPS		CYANIDE OXIDATION
TYPE	Diaphragm	pH = 10.2
CONTROL	Paced off ORP	ORP = 650 mv
NUMBER OF UNITS	1	
PROJECTED USAGE, GALS/DAY	7	Treatability & Estimate
PROJECTED USAGE, LBS/DAY	72	Estimate
, GALS/HOUR	0.9	
UNIT CAPACITY, GALS/HOUR	0-8	
STORAGE PROVIDED, GALS	260	Totes
STORAGE PROVIDED, DAYS	36.1	
CYANIDE REACTOR		
DESIRED DETENTION TIME, MINS	120	Oxidation to Cyanate
NUMBER OF UNITS	1	
LENGTH, FT	20	
WIDTH, FT	6	
DEPTH	6	
VOLUME, CU FT	720	
VOLUME, GALS	5,386	
DETENTION TIME, MINS	108	

SULFURIC ACID FEED PUMPS		pH Adjustment 8-8.5
TYPE	Diaphragm	
CONTROL	Paced off pH	
NUMBER OF UNITS	1	
PROJECTED USAGE @ 28 mg/L, LBS/DAY	6	Estimate
, GALS/HOUR	0.02	
, GALS/DAY	0.2	
UNIT CAPACITY, GALS/HOUR	0-2	
STORAGE PROVIDED, GALS	20	Drum
STORAGE PROVIDED, DAYS	127.5	
IN-LINE MIXER		
NUMBER	1	
TYPE	IN LINE STATIC	
SIZE, INCHES	2	
INCLINED-PLATE CLARIFIER		
TYPE	INCLINED PLATE	
NUMBER	1	
DIMENSIONS, FT		
LENGTH	8	
WIDTH	4	
HEIGHT	8	
PROJECTED SETTLING AREA, SQ FT	250	
LOADING RATE, GPM/SQ FT	0.20	
SOLIDS PRODUCTION		
INFLUENT SOILIDS	2	@ 75% Removal of Influent
CHEMICAL SOLIDS	36	@ 3 X Influent Iron
TOTAL SOLIDS, LBS/DAY	38	
, CONCENTRATION @	3%	
, LBS/DAY	1,276	
, GALS/DAY	150	
, GALS/MIN @ 10 MINS/HR	0.6	
IPC EFFLUENT TANK		
TYPE	Polypropylene	
NO OF UNITS INSTALLED	1	
VOLUME, GALS	2,500	
DETENTION TIME, MINS	50.0	
SLUDGE PUMP		
TYPE	DIAPHRAGM	
NUMBER	1	
CAPACITY, GPM	15	Sandpiper S05 Al
REQUIRED AIR, CFM	14	
AIR COMPRESSOR		
TYPE		
CAPACITY, CFM	25	
PRESSURE, PSI	125	
SLUDGE THICKENER/STORAGE		
NO OF UNITS	1	
UNIT VOLUME, GALS	2,500	
TOTAL VOLUME, GALS	2,500	
SLUDGE FEED, GALS/DAY	150	
STORAGE CAPACITY, DAYS	16.7	
THICKENED SLUDGE, LBS/DAY	34	@ 90% Solids capture
THICKENED SLUDGE, 2 x INFLUENT	6%	
THICKENED SLUDGE, GALS	67	
RECIRCULATED OVERFLOW, GALS/DAY	83	

ANIONIC POLYMER FEED PUMP		Settling Aid
TYPE	Diaphragm	
CONTROL	Manual Stroke	
NUMBER OF UNITS	1	
PROJECTED USAGE @ 8.6 LBS/GAL, LBS/DAY	0.8	@ 5 mg/L
PROJECTED USAGE @ 8.6 LBS/GAL, GALS/DAY	0.1	20-Gallon Carboy
, GALS/HOUR	0.01	
UNIT CAPACITY, GALS/HR	0-1	
DILUTION WATER @ 0.25%, GALS/DAY	36	
, GALS/HOUR	3	
FILTER/GAC FEED PUMPS		
TYPE	CENTRIFUGAL	
NO OF UNITS	1	
UNIT CAPACITY, GPM	75	
TDH, FT	100	
UNIT HP	25.0	
BAG FILTERS		Metals/solids removal
NO OF UNITS	2	In series
BAG MEDIA, MICRONS	10-->5	
GRANULAR ACTIVATED CARBON VESSELS		Organics Removal
DESIGN PARAMETERS		
CONTACT TIME, MINS	15	
LOADING RATE, GPM/SQ FT	4	
NO OF UNITS	2	In Parallel
UNIT DIAMETER, FT	6	
UNIT HEIGHT, FT	10	
CARBON DEPTH, FT	2	
UNIT AREA, SQ FT	28	
TOTAL AREA, SQ FT	57	
EFFECTIVE UNIT VOLUME, CU FT	57	
TOTAL EFFECTIVE VOLUME, CU FT	113	
HYDRAULIC LOADING, GPM/SQ FT	1.8	
LBS CARBON/UNIT @ 30 LBS/CU FT	1,696	
TOTAL AVAILABLE CARBON, LBS	3,391	
EMPTY BED CONTACT TIME , MINS	16.9	
TOTAL ORGANICS TO CARBON UNITS, LBS/DAY	4.5	25% Removal across oxidation/sedimentation
% TOTAL ORGANICS REMOVAL	99%	
EFFLUENT ORGANICS, LBS/DAY	0.05	
, mg/L	0.30	
UTILIZATION RATE, LBS TOCr/LB CARBON	0.10	
UTILIZATION RATE, LBS/CARBON/DAY	45	
, LBS/YEAR	16,274	
ESTIMATED BREAKTHROUGH LEAD COLUMN, DAYS	38	
TOTAL BED LIFE, DAYS	76	

EFFLUENT HOLDING TANK		
TYPE	FRAC TANK	
NO OF UNITS INSTALLED	2	
VOLUME, GALS	20,000	
DETENTION TIME, HRS	17.8	
EFFLUENT/GAC BACKWASH PUMPS		
TYPE	CENTRIFUGAL	
NO OF UNITS INSTALLED	2	
UNIT CAPACITY, GPM	339	Backwash Rate = 12 gpm/sq ft
TDH, FT	60	
UNIT BHP	10	
BAG FILTERS		Carbon fines removal removal
NO OF UNITS	1	
BAG MEDIA, MICRONS	0.5	
EFFLUENT FLOW METER		
TYPE	MAGNETIC	
SIZE, INCHES	2	

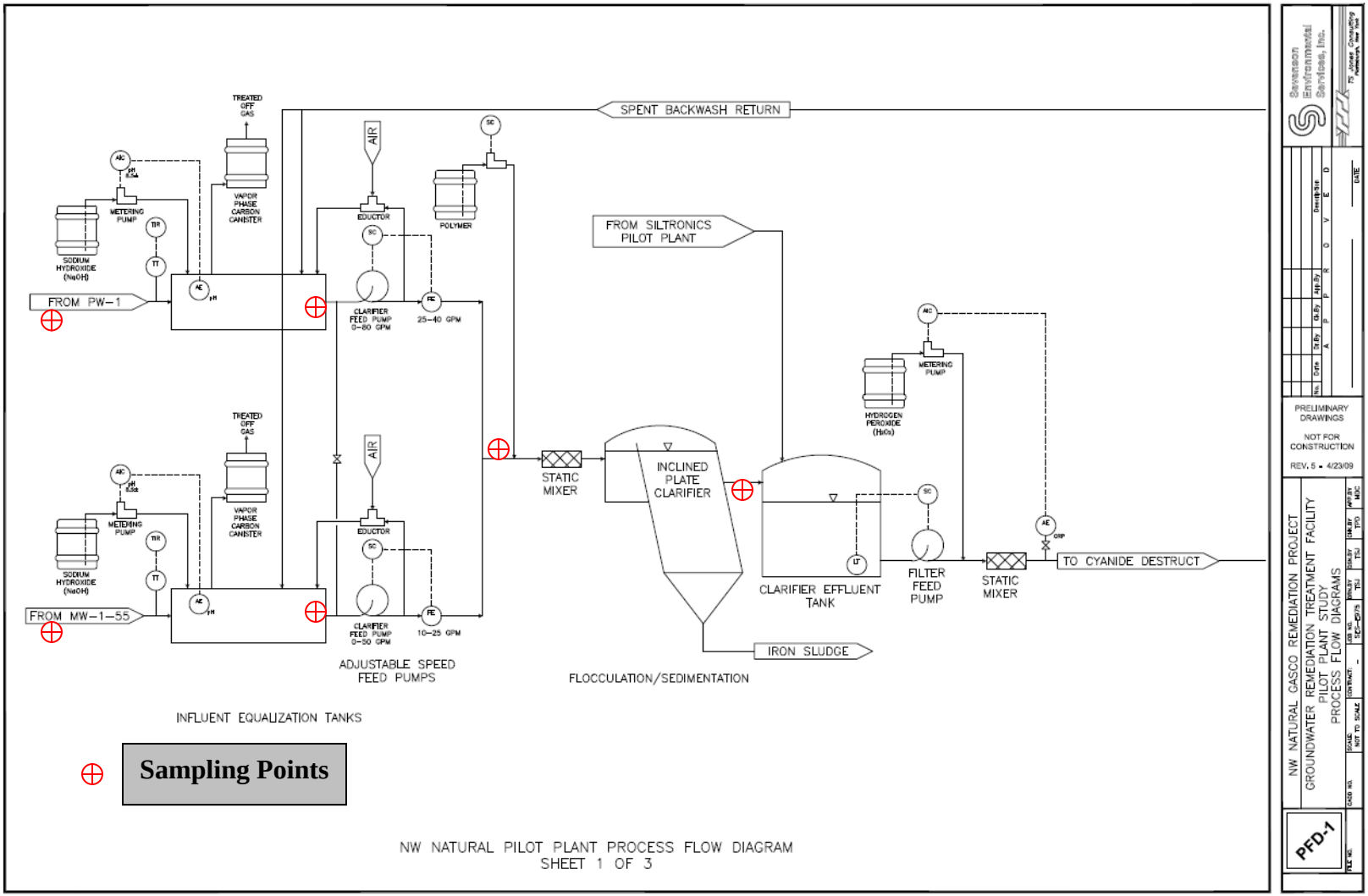
Siltronic

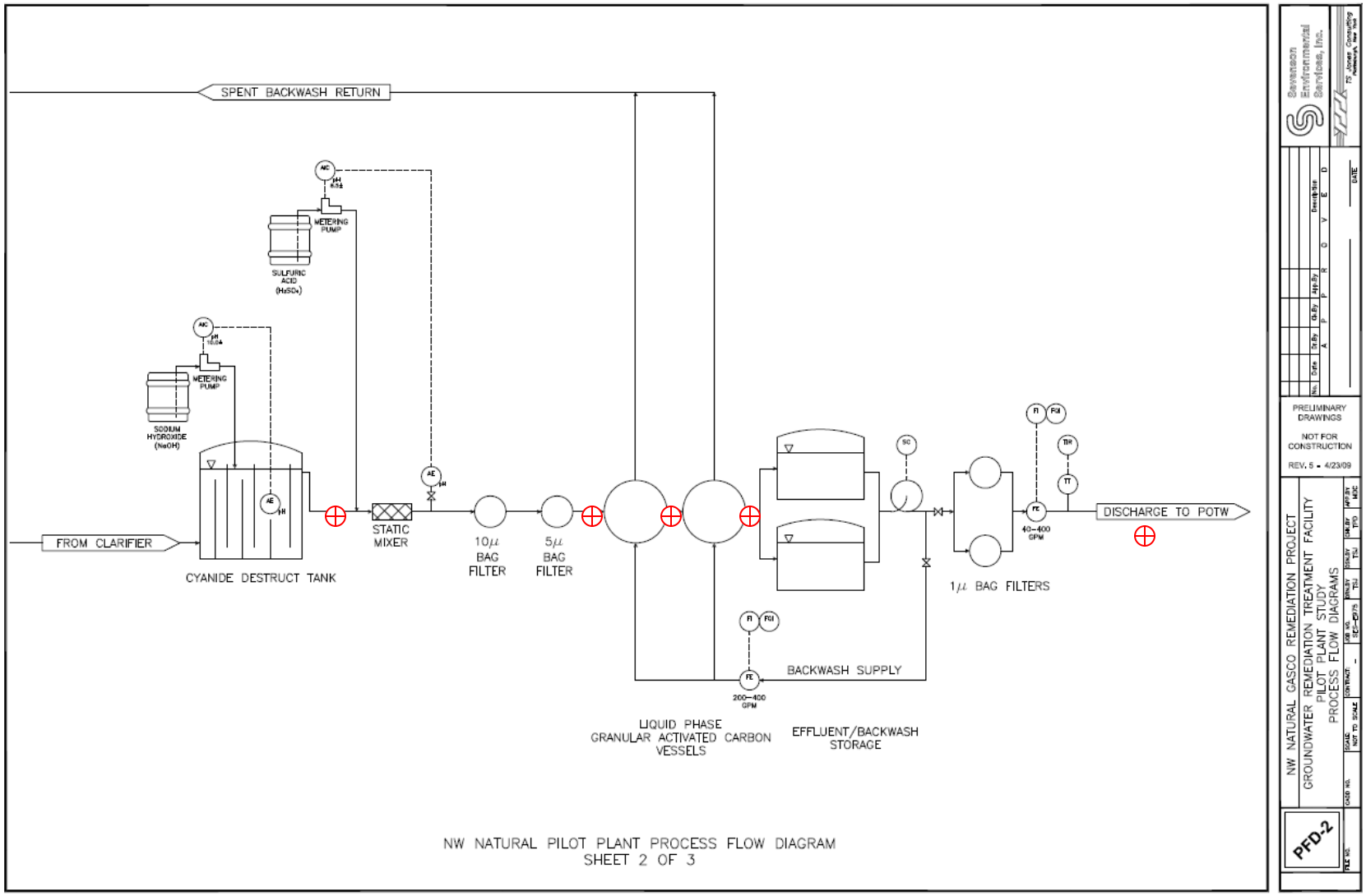
SILTRONICS GROUNDWATER PILOT PLANT PROCESS DESIGN		
PRELIMINARY DESIGN DATA --15 GPM		**COMMENTS/ASSUMPTIONS**
INFLUENT CHARACTERISTICS--WASTEWATER		
DESIGN AVERAGE FLOW, GPD	5,400	6-Hour Days
, GPM	15	
AVERAGE TOTAL ORGANIC CARBON, LBS/DAY	1.1	@ 25 mg/L
TOTAL SUSPENDED SOLIDS, LBS/DAY	0.9	@ 20 mg/L
TOTAL CYANIDE, LBS/DAY	0.02	@ 0.5 mg/L
TOTAL IRON, LBS/DAY	2.25	@ 50 mg/L
TOTAL MANGANESE, LBS/DAY	0.05	@ 1 mg/L
REQUIRED EFFLUENT CHARACTERISTICS		
TOC, MG/L	0.05	Assumed
, LBS/DAY	0.00	
, % REMOVAL	99.8%	
TSS, MG/L	0.04	Assumed
, LBS/DAY	0.00	
, % REMOVAL	99.8%	
TOTAL CYANIDE, MG/L	0.0014	DEQ
, LBS/DAY	0.0025	
, % REMOVAL	88.8%	
TOTAL IRON, MG/L	0.3	DEQ
, LBS/DAY	0.01	
, % REMOVAL	99.4%	
TOTAL MANGANESE, MG/L	0.05	DEQ
, LBS/DAY	0.002	
, % REMOVAL	95.0%	
INFLUENT EQUALIZATION TANK		Closed tanks with level control
TYPE	FRAC	
NO OF UNITS INSTALLED	1	
UNIT VOLUME, GALS	21,000	
VOLUME, GALS	21,000	
DETENTION TIME, DAYS	3.9	
REACTOR FEED PUMP		Controlled off reactor level
TYPE	CENTRIFUGAL	
NO OF UNITS	1	
UNIT CAPACITY, GPM	30	with 100% recycle
TDH, FT	20	
UNIT HP	0.5	with VFD

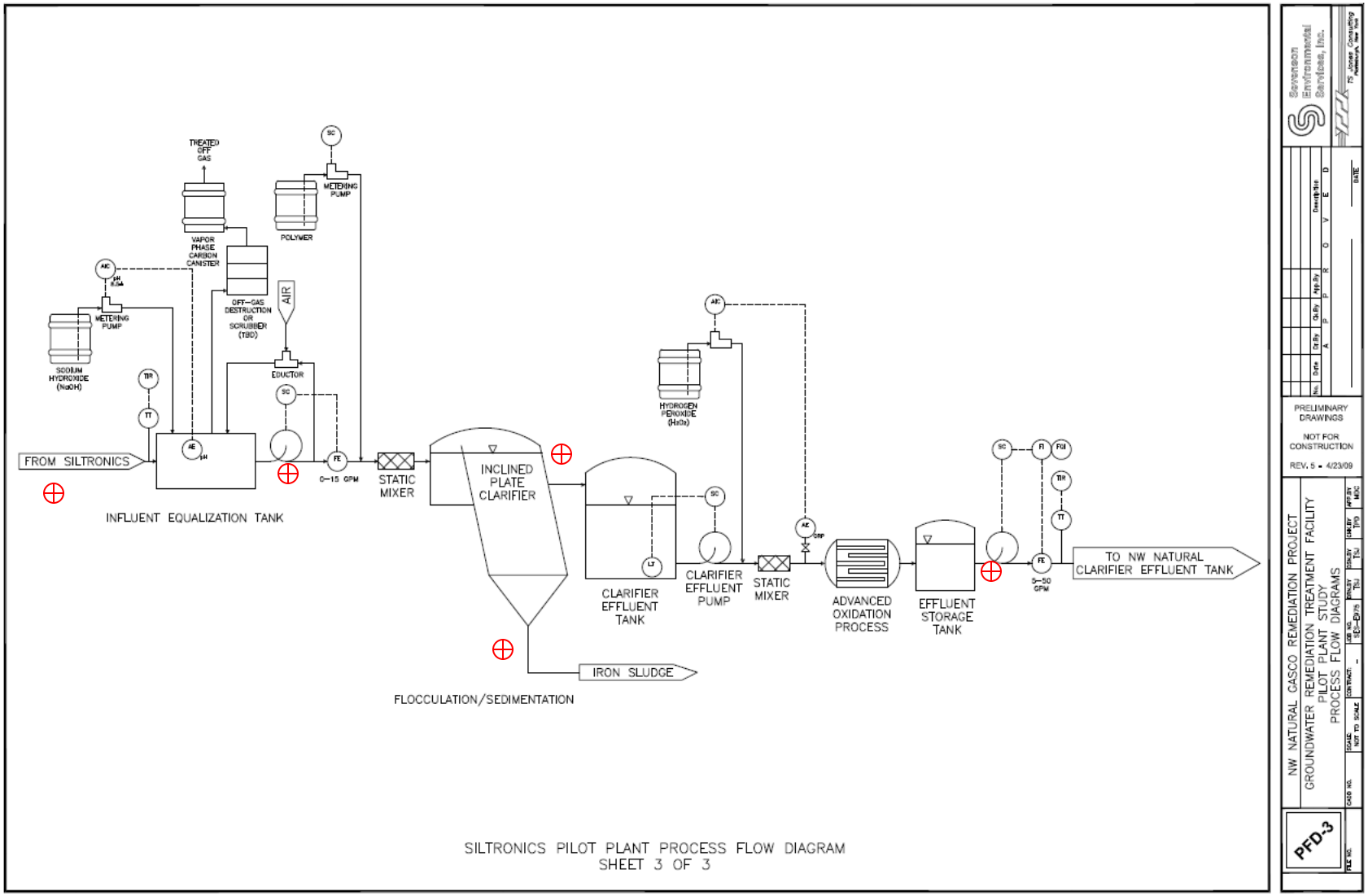
MAZZEI EDUCTORS--FE AERATION IN RECIRC		
STOICHIOMETRIC FACTOR IRON	0.1432	
STOICHIOMETRIC FACTOR MANGANESE	0.2912	
ASSUMED INFLUENT OXYGEN, mg/L	0	
DESIRED RESIDUAL OXYGEN, mg/L	5	
OXYGEN REQUIRED, mg/l	12	
INFLUENT FLOW METER		
TYPE	MAGNETIC	Tied to VFD
NUMBER	1	
SIZE, INCHES	1	
CAUSTIC FEED PUMP		pH Adjustment as required
TYPE	Diaphragm	
CONTROL	pH	
NUMBER OF UNITS	1	
PROJECTED USAGE, GALS/DAY	5	Treatability using 25%
PROJECTED USAGE, LBS/DAY	70	
, GALS/HOUR	0.7	8 hr days
UNIT CAPACITY, GALS/HR	0-2	
STORAGE PROVIDED, GALS	260	Tote
STORAGE PROVIDED, DAYS	48.1	
IN-LINE MIXER		
NUMBER	1	
TYPE	IN LINE STATIC	
SIZE, INCHES	1	
INCLINED-PLATE CLARIFIER		
TYPE	INCLINED PLATE	
NUMBER	1	
DIMENSIONS, FT		
LENGTH	8	
WIDTH	4	
HEIGHT	8	
PROJECTED SETTLING AREA, SQ FT	80	
LOADING RATE, GPM/SQ FT	0.19	
SOLIDS PRODUCTION		
INFLUENT SOILIDS	1	@ 75% Removal of Influent
CHEMICAL SOLIDS	7	@ 3 X Influent Iron
TOTAL SOLIDS, LBS/DAY	8	
, CONCENTRATION @	3%	
, LBS/DAY	255	
, GALS/DAY	30	
, GALS/MIN @ 10 MINS/HR	0.1	
IPC EFFLUENT TANK		
TYPE	Polypropylene	
NO OF UNITS INSTALLED	1	
VOLUME, GALS	2,500	
DETENTION TIME, MINS	0.5	

HYDROGEN PEROXIDE FEED PUMP		CYANIDE OXIDATION
TYPE	Diaphragm	
CONTROL	Paced off ORP	ORP = 650 mv
NUMBER OF UNITS	1	
PROJECTED USAGE, GALS/DAY	2	Treatability & Estimate
PROJECTED USAGE, LBS/DAY	22	Estimate
, GALS/HOUR	0.3	
UNIT CAPACITY, GALS/HOUR	0-8	
TOTAL CAPACITY, GALS/HOUR	0-16	
STORAGE PROVIDED, GALS	260	Totes
STORAGE PROVIDED, DAYS	120.4	
IN-LINE MIXER		
NUMBER	1	
TYPE	IN LINE STATIC	
SIZE, INCHES	1	
ADVANCED OXIDATION FEED PUMP		Controlled off reactor level
TYPE	CENTRIFUGAL	
NO OF UNITS	1	
UNIT CAPACITY, GPM	15	
TDH, FT	20	
UNIT HP	0.5	with VFD
ADVANCED OXIDATION REACTOR		Ultraviolet Lights
DESIRED DETENTION TIME, MINS	90	Oxidation of halogenated organics
NUMBER OF UNITS	1	
LENGTH, FT	6	
WIDTH, FT	6	
DEPTH	6	
VOLUME, CU FT	216	
VOLUME, GALS	1,616	
DETENTION TIME, MINS	108	
EFFLUENT HOLDING TANK		
TYPE	FRAC TANK	
NO OF UNITS INSTALLED	1	
VOLUME, GALS	18,000	
DETENTION TIME, HRS	26.7	
EFFLUENT PUMP		
TYPE	CENTRIFUGAL	
NO OF UNITS INSTALLED	1	
UNIT CAPACITY, GPM	25	
TDH, FT	50	
UNIT BHP	0.5	
EFFLUENT FLOW METER		
TYPE	MAGNETIC	
SIZE, INCHES	1	

Appendix B: Pilot Plant Process Flow Diagrams


SPENT BACKWASH RETURN
TREATED OFF GAS
VAPOR PHASE CARBON CANISTER
METERING PUMP
SODIUM HYDROXIDE (NaOH)
FROM PW-1
FROM MW-1-55
AIR
EDUCTOR
POLYMER
CLARIFIER FEED PUMP 0-60 GPM
25-40 GPM
CLARIFIER FEED PUMP 0-50 GPM
10-25 GPM
ADJUSTABLE SPEED FEED PUMPS
INFLUENT EQUALIZATION TANKS
FROM SILTRONICS PILOT PLANT
STATIC MIXER
INCLINED PLATE CLARIFIER
IRON SLUDGE
FLOCCULATION/SEDIMENTATION
CLARIFIER EFFLUENT TANK
HYDROGEN PEROXIDE (H2O2)
FILTER FEED PUMP
TO CYANIDE DESTRUCT
Sampling Points
NW NATURAL PILOT PLANT PROCESS FLOW DIAGRAM
SHEET 1 OF 3
Sevenson Environmental Services, Inc.
PRELIMINARY DRAWINGS
NOT FOR CONSTRUCTION
REV. 5 - 4/23/09
NW NATURAL GASCO REMEDIATION PROJECT
GROUNDWATER REMEDIATION TREATMENT FACILITY
PILOT PLANT STUDY
PROCESS FLOW DIAGRAMS
PFD-1


SPENT BACKWASH RETURN
METERING PUMP
SULFURIC ACID (H_2SO_4)
METERING PUMP
SODIUM HYDROXIDE (NaOH)
FROM CLARIFIER
CYANIDE DESTRUCT TANK
STATIC MIXER
10μ BAG FILTER
5μ BAG FILTER
LIQUID PHASE GRANULAR ACTIVATED CARBON VESSELS
EFFLUENT/BACKWASH STORAGE
BACKWASH SUPPLY
200–400 GPM
1μ BAG FILTERS
40–400 GPM
DISCHARGE TO POTW
NW NATURAL PILOT PLANT PROCESS FLOW DIAGRAM
SHEET 2 OF 3
PRELIMINARY DRAWINGS
NOT FOR CONSTRUCTION
REV. 5 - 4/23/09
NW NATURAL GASCO REMEDIATION PROJECT
GROUNDWATER REMEDIATION TREATMENT FACILITY
PILOT PLANT STUDY
PROCESS FLOW DIAGRAMS
PFD-2


TREATED OFF GAS
VAPOR PHASE CARBON CANISTER
OFF-GAS DESTRUCTION OR SCRUBBER (TBD)
AIR
EDUCTOR
METERING PUMP
POLYMER
SODIUM HYDROXIDE (NaOH)
FROM SILTRONICS
INFLUENT EQUALIZATION TANK
0-15 GPM
STATIC MIXER
INCLINED PLATE CLARIFIER
FLOCCULATION/SEDIMENTATION
IRON SLUDGE
HYDROGEN PEROXIDE (H2O2)
CLARIFIER EFFLUENT TANK
CLARIFIER EFFLUENT PUMP
STATIC MIXER
ADVANCED OXIDATION PROCESS
EFFLUENT STORAGE TANK
5-50 GPM
TO NW NATURAL CLARIFIER EFFLUENT TANK
SILTRONICS PILOT PLANT PROCESS FLOW DIAGRAM
SHEET 3 OF 3
PRELIMINARY DRAWINGS
NOT FOR CONSTRUCTION
REV. 5 - 4/23/09
NW NATURAL GASCO REMEDIATION PROJECT
GROUNDWATER REMEDIATION TREATMENT FACILITY
PILOT PLANT STUDY
PROCESS FLOW DIAGRAMS
PFD-3

Appendix C: Pilot Plant Schedule

APPENDIX M
AQUITARD GEOLOGY DATA TABLE

Appendix M
Deep Aquitard Isopatch Data

Well	Northing	Easting	GPS elevation	Depth to Top of Deep Aquitard	Depth to Bottom of Deep Aquitard	Elevation of Top of Deep Aquitard	Elevation of Bottom of Deep Aquitard	Thickness of Deep Aquitard	Total Deep Aquitard Thickness
MW-5-175			25.20	NA	NA	NA	NA	NA	NA
MW-16-125			30.49	Boring does not reach -100 ft elevation		NA	NA	NA	NA
MW-21-165	705626.2	7623661.8	20.50	121	125	-100.5	-104.5	4	12.5
MW-21-165			20.50	125.5	132	-105	-111.5	6.5	
MW-21-165			20.50	135	137	-114.5	-116.5	2	
MW-18-180	705444.0	7623930.0	31.70	140	156	-108.3	-124.3	16	16
MW-19-180	705298.0	7624240.0	27.28	129	130	-101.72	-102.72	1	2.8
MW-19-180			27.28	131	131.1	-103.72	-103.82	0.1	
MW-19-180			27.28	131.5	131.6	-104.22	-104.32	0.1	
MW-19-180			27.28	132	132.1	-104.72	-104.82	0.1	
MW-19-180			27.28	132.5	132.6	-105.22	-105.32	0.1	
MW-19-180			27.28	135	136	-107.72	-108.72	1	
MW-19-180			27.28	138.5	138.9	-111.22	-111.62	0.4	
MW-20-120			25.63	128	128.3	-102.37	-102.67	0.3	1
MW-20-120			25.63	129	129.4	-103.37	-103.77	0.4	
MW-20-120			25.63	133.5	133.8	-107.87	-108.17	0.3	
WS-11-161	705147.4	7624628.3	31.94	146.5	147	-114.565	-115.065	0.5	3
WS-11-161			31.94	150	152	-118.065	-120.065	2	
WS-11-161			31.94	153	153.5	-121.065	-121.565	0.5	
WS-12-161	704998.6	7624836.7	33.13	134	135.5	-100.873	-102.373	1.5	7
WS-12-161			33.13	137	141	-103.873	-107.873	4	
WS-12-161			33.13	144	145.5	-110.873	-112.373	1.5	
WS-13	704633.3	7624575.1	33.43	132	139	-98.57	-105.57	7	18
WS-13	704633.3	7624575.1	33.43	139.5	142	-106.07	-108.57	2.5	
WS-13	704633.3	7624575.1	33.43	142	142.5	-108.57	-109.07	0.5	
WS-13	704633.3	7624575.1	33.43	142.5	143	-109.07	-109.57	0.5	
WS-13	704633.3	7624575.1	33.43	143	144	-109.57	-110.57	1	
WS-13	704633.3	7624575.1	33.43	144.5	145.5	-111.07	-112.07	1	
WS-13	704633.3	7624575.1	33.43	148	151	-114.57	-117.57	3	
WS-13	704633.3	7624575.1	33.43	151.5	154	-118.07	-120.57	2.5	

Appendix M
Deep Aquitard Isopatch Data

Well	Northing	Easting	GPS elevation	Depth to Top of Deep Aquitard	Depth to Bottom of Deep Aquitard	Elevation of Top of Deep Aquitard	Elevation of Bottom of Deep Aquitard	Thickness of Deep Aquitard	Total Deep Aquitard Thickness
WS-14-161	705182.5	7624485.7	32.40	141.5	142	-109.1	-109.6	0.5	6.5
WS-14-161			32.40	143	148.5	-110.6	-116.1	5.5	
WS-14-161			32.40	149	149.5	-116.6	-117.1	0.5	
WS-15-140	704727.6	7624438.4	34.66	136	137	-101.34	-102.34	1	13.5
WS-15-140			34.66	142.5	143.5	-107.84	-108.84	1	
WS-15-140			34.66	144.5	147.5	-109.84	-112.84	3	
WS-15-140			34.66	147.5	154	-112.84	-119.34	6.5	
WS-15-140			34.66	154	156	-119.34	-121.34	2	
WS-16-161	704964.3	7624326.3	34.61	136.5	137	-101.89	-102.39	0.5	10
WS-16-161			34.61	139	143	-104.39	-108.39	4	
WS-16-161			34.61	144	146	-109.39	-111.39	2	
WS-16-161			34.61	149.5	153	-114.89	-118.39	3.5	
TG-1	705521.3	7623806.0	19.60	118.5	139	-98.9	-119.4	20.5	20.5
TG-2	705401.7	7623941.3	32.50	133	135	-100.5	-102.5	2	14
TG-2	705401.7	7623941.3	32.50	138	150	-105.5	-117.5	12	
TG-3	705336.2	7624102.0	32.50	138	139	-105.5	-106.5	1	3
TG-3			32.50	142	143	-109.5	-110.5	1	
TG-3			32.50	152	153	-119.5	-120.5	1	
TG-4	705276.1	7624230.2	28.60	132	134.5	-103.4	-105.9	2.5	3.5
TG-4			28.60	143	144	-114.4	-115.4	1	
TG-5A	705187.5	7624332.5	25.30	132.5	134	-107.2	-108.7	1.5	1.5
TG-6	705594.2	7623523.2	21.50	122.6	123.3	-101.1	-101.8	0.7	1.7
TG-6			21.50	124.1	124.5	-102.6	-103	0.4	
TG-6			21.50	125.4	126	-103.9	-104.5	0.6	
TG-7	705316.3	7623879.7	33.70	131	135	-97.3	-101.3	4	5
TG-7			33.70	145	150	-111.3	-116.3	5	
TG-8	705110.4	7624222.5	36.70	135	137.5	-98.3	-100.8	2.5	2.5
TG-8			36.70	150	152.5	-113.3	-115.8	2.5	
TG-9	705454.6	7623852.7	31.40	137	138.5	-105.6	-107.1	1.5	8.5
TG-9			31.40	143	146	-111.6	-114.6	3	

Appendix M
Deep Aquitard Isopatch Data

Well	Northing	Easting	GPS elevation	Depth to Top of Deep Aquitard	Depth to Bottom of Deep Aquitard	Elevation of Top of Deep Aquitard	Elevation of Bottom of Deep Aquitard	Thickness of Deep Aquitard	Total Deep Aquitard Thickness
TG-9			31.40	147	151	-115.6	-119.6	4	
TG-10	705258.1	7624361.7	25.00	145	146.5	-120	-121.5	1.5	1.5
TG-11	705189.6	7624150.2	36.90	138	140	-101.1	-103.1	2	4
TG-11			36.90	142	144	-105.1	-107.1	2	
TG-12	705032.5	7624318.8	27.00	125.5	129.5	-98.5	-102.5	2.5	6
TG-12			27.00	133	136.5	-106	-109.5	3.5	
TG-15	705332.3	7623961.9	33.60	133.8	139	-100.2	-105.4	5.2	9.9
TG-15	705332.3	7623961.9	33.60	142.9	144.7	-109.3	-111.1	1.8	
TG-15	705332.3	7623961.9	33.60	149.7	152.6	-116.1	-119	2.9	
TG-16	705157.6	7623823.8	35.60	146	147.5	-110.4	-111.9	1.5	1.5
TG-1S	705123.1	7624613.2	35.20	142.4	143.7	-107.2	-108.5	1.3	3
TG-1S			35.20	146.2	147	-111	-111.8	0.8	
TG-1S			35.20	150	150.9	-114.8	-115.7	0.9	
TG-2S	704953.2	7624856.6	35.70	136.9	138.8	-101.2	-103.1	1.9	5.7
TG-2S	704953.2	7624856.6	35.70	142.4	144.1	-106.7	-108.4	1.7	
TG-2S	704953.2	7624856.6	35.70	149.2	151.3	-113.5	-115.6	2.1	
TG-3S	704877.7	7624265.5	35.00	132	139.5	-97	-104.5	4.5	10
TG-3S			35.00	141	144	-106	-109	3	
TG-3S			35.00	146	148.5	-111	-113.5	2.5	
TG-4S	705112.8	7624436.7	33.60	136.5	139.5	-102.9	-105.9	3	5.5
TG-4S			33.60	144	146.5	-110.4	-112.9	2.5	
TG-5S	704719.1	7624443.6	34.50	136	136.9	-101.5	-102.4	0.9	10.7
TG-5S			34.50	138.1	144.9	-103.6	-110.4	6.8	
TG-5S			34.50	146.2	149.2	-111.7	-114.7	3	
TG-6S	704598.5	7624577.8	34.60	133.7	136.9	-99.1	-102.3	3.2	10
TG-6S			34.60	140.7	142	-106.1	-107.4	1.3	
TG-6S			34.60	142.8	148.3	-108.2	-113.7	5.5	
TG-7S	705069.4	7624690.9	35.30	143.2	145.3	-107.9	-110	2.1	3.1
TG-7S			35.30	151	152	-115.7	-116.7	1	
TG-8S	704895.4	7624770.2	35.20	132.7	137.4	-97.5	-102.2	4.7	10

Appendix M
Deep Aquitard Isopatch Data

Well	Northing	Easting	GPS elevation	Depth to Top of Deep Aquitard	Depth to Bottom of Deep Aquitard	Elevation of Top of Deep Aquitard	Elevation of Bottom of Deep Aquitard	Thickness of Deep Aquitard	Total Deep Aquitard Thickness
TG-8S			35.20	138.5	142.6	-103.3	-107.4	4.1	
TG-8S			35.20	146.1	147.3	-110.9	-112.1	1.2	
TG-12S	705195.5	7624494.2	34.00	148.4	149.4	-114.4	-115.4	1	2.6
TG-12S			34.00	152.3	153.9	-118.3	-119.9	1.6	
GS-03	705918.0	7623381.0	5.50	108.5	109	-103	-103.5	0.5	7
GS-03			5.50	111	117.5	-105.5	-112	6.5	
GS-04	705808.0	7623569.0	4.40	110	114	-105.6	-109.6	4	4
GS-10	705235.0	7624654.0	2.50	119	120	-116.5	-117.5	1	6.5
GS-10			2.50	122	129	-119.5	-126.5	5.5	
GS-12	705008.0	7624999.0	5.20	123	132.5	-117.8	-127.3	9.5	9.5
GP-25	705241.9	7624678.5	1.40	118.7	119	-117.3	-117.6	0.3	0.3
GP-26	705316.2	7624625.1	-8.10	88	93	-96.1	-101.1	5	7
GP-26			-8.10	96	98	-104.1	-106.1	2	
GP-27	705325.8	7624736.8	-32.10	75.5	78	-107.6	-110.1	2.5	2.5
GP-28	705168.7	7624798.9	3.40			3.4	3.4	0	0
GP-33	704911.0	7624993.0	32.90	140	140.5	-107.1	-107.6	0.5	3.7
GP-33			32.90	143.2	144	-110.3	-111.1	0.8	
GP-33			32.90	148.2	150.6	-115.3	-117.7	2.4	
GP-36	704836.0	7625091.0	32.90	128.5	134	-95.6	-101.1	5.5	22.3
GP-36			32.90	135	136.5	-102.1	-103.6	1.5	
GP-36			32.90	136.7	140	-103.8	-107.1	3.3	
GP-36			32.90	140.5	141	-107.6	-108.1	0.5	
GP-36			32.90	142	145	-109.1	-112.1	3	
GP-36			32.90	145	150.5	-112.1	-117.6	5.5	
GP-36			32.90	151	151.5	-118.1	-118.6	0.5	
GP-36			32.90	152.5	155	-119.6	-122.1	2.5	
SIL-01			33.00	140	143	-107	-110	3	3
SIL-02			35.00	149	156	-114	-121	7	7
SIL-03			35.00						NA
RP-11-216			34.04	144	154	-109.96	-119.96	10	10

Appendix M
Deep Aquitard Isopatch Data

Well	Northing	Easting	GPS elevation	Depth to Top of Deep Aquitard	Depth to Bottom of Deep Aquitard	Elevation of Top of Deep Aquitard	Elevation of Bottom of Deep Aquitard	Thickness of Deep Aquitard	Total Deep Aquitard Thickness
P-5			34.22						NA
P-6			35.38						NA
P-7			34.98						NA