Final

2014 Conceptual Site Model Update for OU2 and OU4 Former Process Area

Prepared for

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Contents

Appendixes

Tables

Figures

Plates

Acronyms and Abbreviations

%RE	TarGOST response
amsl	above mean sea level
AST	aboveground storage tank
bgs	below ground surface
C	centigrade
cm/s	centimeters per second
CSM	conceptual site model
CUL	cleanup level
DAF	dissolved air flotation
DNAPL	dense non-aqueous phase liquid
EPA	U.S. Environmental Protection Agency
FFS	focused feasibility study
FPA	Former Process Area
FS	feasibility study
ft	feet
ft^2	square feet
g/cc	grams per cubic centimeter
g/mL	grams per milliliter
GAC	granular activated carbon
gpm	gallons per minute
GWTP	groundwater treatment plant
HPAH	high molecular weight polynuclear aromatic hydrocarbons
LIF	laser-induced fluorescence
LNAPL	light non-aqueous phase liquid
LPAH	low molecular weight polynuclear aromatic hydrocarbons
MCL	maximum contaminant level
mg/L	milligrams per liter
MLLW	mean lower low water
mm	millimeters
MTCA	Model Toxics Control Act
MVS	Mining Visualization Software
NAPL	non-aqueous phase liquid
NPDES	National Pollutant Discharge Elimination System

OU	operable unit
PAH	polynuclear aromatic hydrocarbons
PCP	pentachlorophenol
ppm	parts per million
QAPP	quality assurance project plan
RAO	remedial action objective
RI	remedial investigation
ROD	Record of Decision
SVOC	semivolatile organic compound
TarGOST	Tar-specific Green Optical Scanning Tool
TPH	total petroleum hydrocarbons
TPH-Dx	total petroleum hydrocarbons -diesel
USACE	U.S. Army Corps of Engineers
USCS	Unified Soil Classification System

Executive Summary

This document presents an updated conceptual site model (CSM) for the Former Process Area (FPA) located within Wyckoff/Eagle Harbor Soil and Groundwater Operable Unit 2 (OU2) and Operable Unit 4 (OU4), respectively. This is an update to the previous 2007 CSM Update - *Groundwater Conceptual Site Model Update Report for the Former Process Area, Wyckoff/Eagle Harbor Superfund Site, Soil and Groundwater Operable Units.* This report incorporates new information on the subsurface distribution of non-aqueous phase liquid (NAPL) obtained from a recently completed Tar-specific Green Optical Scanning Tool (TarGOST) investigation, as well as other information obtained from site-related activities. This 2014 CSM Update is considered a companion document to the 2007 CSM Update.

For the TarGOST investigation, a total of 141 TarGOST probes and 20 confirmation borings were advanced over two investigation phases between January and March 2013. The resulting dataset was evaluated using multiple methodologies to determine the nature and extent of contamination and the distribution of NAPL in the Upper Aquifer. The following points, organized by hydrostratigraphic unit and evaluation methodology, summarize the investigation findings regarding NAPL distribution in the subsurface FPA.

Upper Aquifer

Confirmation Core Visual NAPL Observations

The evaluation of the confirmation core visual NAPL observations with the ex situ TarGOST results indicates that a TarGOST response (%RE) between 5%RE and 10%RE can be justifiably selected as representing the presence of NAPL. Based on stakeholder review and approval, TarGOST responses of 10%RE and greater are inferred to indicate that NAPL is present at measured locations.

TarGOST Log Fence Diagrams

The preparation and analysis of TarGOST log fence diagrams provide the following important and relevant observations of NAPL distribution in the Upper Aquifer:

- In general, NAPL is thickest in the center of the site where higher TarGOST responses are located, then transitions to thinner lenses with lower response as the fence diagrams move radially away from the center of the FPA and potential source(s).
- Beyond the center of the FPA and potential sources, the NAPL lenses are vertically distributed but not in any obvious patterns with depth. This distribution is likely a result of multiple source areas, preferential pathways associated with interbedded lithologies, and interaction with variable fluid densities resulting from the Upper Aquifer’s transition from freshwater to saltwater and operation of the hydraulic containment system.
- Deeper (near Aquitard) TarGOST responses at greater than 10 percent appear to terminate at or above the TarGOST boring refusal depths. In general, where comparable lithology is available, TarGOST boring refusal is coincident with or slightly below the transition from the Upper Aquifer to the glacial till (e.g. a layer within the Aquitard). These factors suggest that the glacial till is restricting the migration of NAPL to lower elevations.
- Along the FPA’s west side and north end, elevated TarGOST readings were measured adjacent to the outer sheet pile wall at depths at and above the glacial till layer. In these areas, the sheet pile wall driven depths are greater than the deepest elevated TarGOST responses.

Comparison of Boring Data, Soil Type, and NAPL Observations

Confirmation boring data, soil type, and NAPL observations were compared to evaluate the association of NAPL with soil type. Results indicate a tendency for NAPL to preferentially inhabit coarser-grained soil. Eighty-two percent of the NAPL was observed in coarser-grained material consisting of marine sand or marine sand and gravel, and 15.5 percent of NAPL was observed in finer-grained material consisting of marine silt or marine sediment.

Mining Visualization Software Data Interpolation

Soil observations and TarGOST response data were interpolated in three dimensions using Mining Visualization Software (MVS). Important and relevant observations of NAPL distribution in the Upper Aquifer resulting from this analysis are as follows:

- Review of the MVS visualizations indicates the NAPL has partially separated vertically with some migration downward to the Aquitard with further migration downslope, some migration horizontally along the water table, and some in between these two zones but with a downward slope. Based on these observations, the Upper Aquifer was segregated into three vertical compartments: Compartment 1 – vadose zone to just below the water table (ground surface to -5 mean lower low water [MLLW]), Compartment 2 – the intermediate zone (-5 MLLW to 10 feet above the Aquitard), and Compartment 3 – above the Aquitard (10 feet above the Aquitard to boring refusal depth).
- Volume estimates of NAPL-affected soil developed using these MVS interpolations are presented in Table 5-1. Approximately 68,500 cubic yards of NAPL-affected soil are estimated to be present in the FPA distributed as follows: 55 percent is in Compartment 1, 18 percent in Compartment 2, and 28 percent in Compartment 3. This estimate is considered to represent a low-end estimate of NAPL-affected soil volume at the site. It is 27 percent lower than the previous U.S. Army Corps of Engineers (USACE) estimate of 94,400 cubic yards, and 37 percent lower than the high-end estimate developed using the Thiessen Polygon method.
- A comparison of interpolated soil layers (as defined by the Unified Soil Classification System) with the TarGOST NAPL model provides a preliminary estimate of the combined NAPL distribution by geologic unit. Eighty percent of the NAPL was estimated to be contained in coarser-grained material consisting of gravel and sand, and 18 percent of NAPL was estimated to be contained in finer-grained material consisting of silt and clay. The relative distribution of these model results is consistent with NAPL/material distribution observed in the TarGOST confirmation borings – 82 to 15.5 percent of NAPL in coarse- to fine-grained material, respectively.

Thiessen Polygon Soil Volume and NAPL Volume Analysis

Important and relevant observations from the Thiessen Polygon soil and NAPL volume analysis approach are as follows:

- In comparison to potential sources, the thickest accumulations of NAPL-affected material (greater than 20 feet thick) appear to be concentrated in the center of the FPA near the Retort area, as well as to the east by the Naphthalene Block Excavation Area. Lesser but still significant accumulations of NAPL-affected material appear to be associated with other potential sources such as the Old Sump to the east; the shop building to the north; the sump associated with a concrete pit for an outhouse, also to the north; the discharge point from a buried drain to the west; and the former floating dock, also to the west.
- Volume estimates of NAPL-affected soil developed using the Thiessen Polygon approach indicate approximately 109,069 cubic yards of NAPL-affected soil are estimated to be present in the FPA. Fifty-two percent is present in Compartment 1 (5 percent in Compartment 1a and 47 percent in Compartment 1b), 23 percent is present in Compartment 2, and 25 percent is present in Compartment 3. This estimate is considered a high-end estimate of NAPL-affected soil volume at the site. It is 16 percent higher than the previous USACE estimate of 94,400 cubic yards, and 59 percent higher than the low-end estimate developed using the MVS interpolations.
- NAPL volume was roughly estimated by applying the dilution series for TarGOST signal calibration completed under OU1 field investigation activities in 2012, integrating the TarGOST response by boring

and interpolating to the surface. Rounding to the appropriate significant digit using this method, approximately 650,000 gallons of NAPL are estimated to be present in the Upper Aquifer. Forty-five percent is estimated to be in Compartment 1 (5 percent in Compartment 1a and 40 percent in Compartment 1b), 19 percent in Compartment 2, and 36 percent in Compartment 3. The NAPL volume estimates provided should not be considered as absolute, but are provided for relative comparison with application of potential remedial technologies. This provides an estimate of NAPL phase contaminant volume in the Upper Aquifer, which can be roughly compared with the previous USACE NAPL volume estimate of 1,200,000 gallons. This methodology provides the most benefit as a tool for estimating the relative mass reduction resulting from implementation of potential remedial action alternatives. This tool would be useful for evaluating the relative remedy protectiveness and to support the estimation of relative duration to reach remedial action objectives for the potential alternatives.

Lower Aquifer Nature and Extent of Contamination

Nature and extent of contamination in the Lower Aquifer were evaluated using water quality results from the May 2013 sampling event and NAPL measured in monitoring wells in June 2012. Important and relevant observations for the Lower Aquifer are as follows:

- The results show two areas where acenaphthene (and other polynuclear aromatic hydrocarbons [PAH] constituent concentrations) are consistently detected near or above cleanup levels (CUL). One area is in the northern portion of the FPA and encompasses monitoring wells CW05, CW15, P-3L; and VG-2L; the other area is in the southwest portion of the FPA, surrounding piezometer PZ-11.
- In general, acenaphthene concentrations appear to be relatively stable above the CUL wells CW15, P3L, and VG2L, and are increasing at CW05 in the northern portion of the FPA. In the southwest portion of the FPA, acenaphthene concentrations are relatively stable, with slight fluctuations above the CUL since May 2010.
- The June 2012 NAPL measurements indicate the presence of NAPL in three Lower Aquifer wells (CW-15, P-3L, and VG-2L) in the northern portion of the FPA. This corresponds with an area where acenaphthene and other PAH constituent concentrations are consistently detected near or above CULs. In 2012, NAPL measurements were not attempted at monitoring well PZ-11; however, based on PZ-11 water quality results, the presence of NAPL in this well is possible.

Aquitard Nature and Extent

The nature and extent of contamination in the Aquitard was estimated through indirect observations, specifically NAPL presence above and below the Aquitard, and pool height pressures required for NAPL entry into the Aquitard. Interpretation of these lines of evidence suggests that NAPL and dissolved constituents are likely present in the Aquitard in the northern portion of the FPA and possibly in the center of the FPA. At the north end of the FPA, Lower Aquifer water quality effects align with NAPL thicknesses observed in the Upper Aquifer that exceed the required height for NAPL entry into the Aquitard (as observed at TarGOST location 2013T-043). Furthermore, the Aquitard thickness is estimated to be thinner in this vicinity at approximately 8 to 25 feet, and the Aquitard surface itself is thought to have several depressions where NAPL could pool.

SECTION 1

Introduction

This document presents an updated conceptual site model (CSM) for the Former Process Area (FPA) located within Wyckoff/Eagle Harbor Soil and Groundwater Operable Units. The FPA CSM was updated to incorporate new information on the subsurface distribution of non-aqueous phase liquid (NAPL) obtained from a recently completed Tar-specific Green Optical Scanning Tool (TarGOST) investigation, as well as other information obtained from site-related activities.

A CSM is typically a graphical and narrative representation of a contaminated site that illustrates relationships between contaminant sources (primary and secondary), release mechanisms, routes of migration (air, vadose zone, groundwater, surface water/sediment, and biota), contaminant degradation and non-degradation processes, and potential receptors. The CSM, which is constantly evolving as new information on a contaminated site is acquired, is an important stakeholder communication and remedy selection tool. Updates to this FPA CSM may occur in the future as new information, such as updates to the 3-D geostatistical geology and TarGOST model or Upper Aquifer water quality data, become available.

The FPA CSM was last updated in 2007 to summarize groundwater conditions predicated on completion of a contingent containment remedy, which was described in the 2000 Record of Decision (ROD) for the Wyckoff Soil and Groundwater Operable Units. The contingent containment remedy has not been fully implemented and the U.S. Environmental Protection Agency (EPA) is currently reevaluating source removal options for the Soil and Groundwater Operable Units in a focused feasibility study (FFS. Certain background and detailed hydrogeologic information presented in *Groundwater Conceptual Site Model Update Report for the Former Process Area, Wyckoff/Eagle Harbor Superfund Site, Soil and Groundwater Operable Units* (2007 CSM Update; CH2M HILL 2007b) is not repeated in this updated FPA CSM, as they are not directly pertinent to source removal. As such, the 2007 CSM Update is considered a companion document to this updated FPA CSM.

1.1 Site Location and Description

The Wyckoff/Eagle Harbor Superfund Site (also referred to in this report as the “Wyckoff Site” or the “Site”) is located on the east side of Bainbridge Island in central Puget Sound, Washington (Figure 1-1). The Site includes the former Wyckoff Company wood treatment facility and subtidal/intertidal sediments in Eagle Harbor. Different environmental media, sources of contamination, enforcement strategies, and environmental risks in different areas of the Site led to the division of the site into four operable units (OUs):

- OU1, the East Harbor OU (subtidal and intertidal sediments in Eagle Harbor contaminated by polynuclear aromatic hydrocarbons [PAHs])
- OU2, the Wyckoff Soil OU (unsaturated soil contaminated with PAHs and pentachlorophenol [PCP]). This is also referred to as the Soil OU.
- OU3, the West Harbor OU (subtidal and intertidal sediments in Eagle Harbor contaminated by metals, primarily mercury, and upland sources)
- OU4, the Wyckoff Groundwater OU (the saturated soil and groundwater beneath OU2). This is also referred to as the Groundwater OU.

Overall, the Wyckoff property occupied approximately 57 acres; of this, about 18 acres are in OU2. OU2 consists of three areas: the FPA, the Former Log Storage/Peeler Area, and the Well CW01 Area. This CSM Update Report primarily addresses those portions of OU2 and OU4 lying beneath the approximate 8-acre FPA, where the majority of known remaining NAPL occurs (Figure 1-2).

SECTION 2

Background

This section presents information associated with ongoing and recently completed investigation activities that generated the information used to prepare and update the FPA CSM. This section summarizes the work performed. The results are presented in Sections 3, 4, and 5.

2.1 Groundwater Investigation History

Numerous investigations have been conducted at the Wyckoff Site since the 1970s. Table 2-1 provides a chronological list of groundwater investigations conducted at the Wyckoff Site to date. A brief summary is also provided for recent investigations and studies that are the primary data sources evaluated in this FPA CSM Update.

A Focused Remedial Investigation/Feasibility Study (RI/FS) for groundwater was completed in 1994. The purpose of the focused RI/FS was to provide information for implementing interim actions while the full RI/FS for the Soil and Groundwater OUs was being conducted. The focused RI/FS assessed the risks posed by contaminants present in the groundwater to human health and the environment, the integrity of water supply wells located within the FPA, and the condition of the existing interim action groundwater extraction and treatment systems. Additional well installation and groundwater sampling were conducted as part of the 1995 Supplemental RI for the Soil and Groundwater OUs.

A Record of Decision (ROD) for OU2/OU4 was issued in 2000 (EPA, 2000). The remedy selected for the site included constructing a sheet pile wall around the highly contaminated portion of the FPA and completing a thermal remediation pilot study within this area. If the pilot study was successful at meeting performance expectations, then full-scale thermal remediation was to be implemented. However, the pilot was not successful; therefore, the contingency remedy, Containment with a sheet pile wall and groundwater extraction and treatment, was implemented.

Installation of the sheet pile wall was completed in 2001. Operation of the groundwater extraction and treatment system is ongoing. Groundwater monitoring to demonstrate hydraulic containment and monitor changes in contaminant levels in the Upper and Lower Aquifers was initiated in 2004.

Recently completed groundwater investigations and studies include the Wyckoff Upland NAPL Field Investigation (the Upland Investigation) and the sheet pile wall evaluation in 2013.

2.1.1 Groundwater Monitoring

Groundwater monitoring to demonstrate hydraulic containment and monitor changes in contaminant levels in the Upper and Lower Aquifers was initiated in 2004. The hydraulic containment monitoring program involves continuous water-level monitoring using data loggers installed in Upper and Lower Aquifer wells and evaluating vertical gradients between the aquifers.

The groundwater sampling program includes groundwater quality sampling at 24 Lower Aquifer wells and piezometers and one Upper Aquifer well. The groundwater samples are analyzed for semi-volatile organic compounds (SVOCs), PAHs, PCP, and total petroleum hydrocarbons (TPH)- diesel (TPH-Dx) and TPH-motor oil.

2.1.2 Upland NAPL Field Investigation

The Wyckoff Upland Investigation was conducted by CH2M HILL for the EPA in 2013 to support the OU2/OU4 FFS. Field data were collected using Dakota Technologies' TarGOST. TarGOST is a laser-induced fluorescence (LIF) field tool used to semi-quantitatively determine the relative distribution of NAPL in the subsurface. The TarGOST data generated from the field investigation will be used to help define the remedial target area(s) in support of the FFS technology screening, alternatives development, and alternatives evaluation steps.

Specific objectives for the Upland Investigation relevant to TarGOST data collection and data evaluation included:

- Evaluate the horizontal and vertical extent of NAPL within the defined area.
- Assess NAPL occurrence in relation to hydrostratigraphy.
- Evaluate NAPL mobility and the potential for NAPL to migrate through the Aquitard and/or sheet pile wall.

The Upland Investigation included advancing 141 TarGOST probes and 20 confirmation borings over two investigation phases between January and March 2013. TarGOST investigation activities were conducted in accordance with procedures outlined in the *2013 Wyckoff Upland NAPL Investigation Quality Assurance Project Plan* (QAPP) (CH2M HILL, 2013a). The Upland Investigation included the following field activities:

1. **TarGOST LIF Probing (Phase 1 – January 14 through February 8, 2013).** An initial round of field screening using the TarGOST technology to semi-quantitatively assess the presence or absence of NAPL, as guided by historical NAPL occurrences. Phase 1 TarGOST probes were advanced at 77 locations.
2. **TarGOST LIF Probing (Phase 2 – February 25 through March 22, 2013).** A second round of TarGOST investigation, to extend the Phase 1 grid and evaluate spatial data gaps, was conducted based on Phase 1 results. A total of 64 Phase 2 locations were completed.
3. **Confirmation Soil Coring (Phase 1 and Phase 2).** Soil cores were collected through either sonic or direct-push drilling methods and visually logged, and then selected intervals were analyzed ex situ using the TarGOST technology to verify in situ results and to correlate with field observations (visual NAPL and water sheen testing observations). Confirmation soil cores were advanced at 10 selected TarGOST Phase 1 locations and 10 Phase 2 locations. Soil lithology and geologic unit interpretations were logged for each soil core.

TarGOST replicate probes were completed at selected locations to evaluate signal response (as percent RE) variability. Seven field replicates were also completed for a total of 84 Phase 1 TarGOST probes. The TarGOST probes were advanced to refusal, expected to be the glacial till layer, at the majority of the exploration locations.

2.1.3 Sheet Pile Wall Evaluation

An investigation was completed in 2013 to indirectly assess the integrity of the sheet pile wall and identify possible pathways for NAPL migration beyond the sheet pile wall. The conceptual model for the sheet pile wall is that it can physically impede NAPL migration from the upland area. The sheet pile wall is also expected to physically impede groundwater flow such that there is limited hydraulic communication between the Upper Aquifer and Eagle Harbor.

The integrity of the sheet pile wall was evaluated using field measurements collected from January through May 2013, as well as other data analysis. Collected data included the following:

- Measurement of conductivity profiles (static measurement of salinity while lowering a programmable multi-meter instrument through the water column) under pumping and non-pumping conditions in sheet pile wall seams and monitoring wells located near the sheet pile wall. Conductivity profiles were measured for seams 1 through 5, seam 7, as well as nearby Upper and Lower Aquifer wells. In addition, salinity measurements were performed in Eagle Harbor for comparison purposes.
- Conductivity measurements of water purged from the seams under pumping conditions.
- Water level measurements using transducers.

Other data collected or used for this assessment included the following:

- Groundwater level data

- Groundwater monitoring data (NAPL measurements)
- Sheet pile wall as-built drawings and measurements
- Boring logs and well construction diagrams for wells near the sheet pile wall

Collectively, these data were integrated into a multiple lines of evidence approach to assess the integrity of the wall with respect to groundwater and potential NAPL migration. The lines of evidence examined included the following:

- A recent history of gradient reversals in the 10 well pairs used to monitor hydraulic containment effectiveness
- Vertical profiles of specific conductance in monitoring wells near the sheet pile wall to evaluate salinity effects and potential interaction with Eagle Harbor
- Tidal efficiencies of Upper Aquifer wells calculated from water level monitoring data obtained under non-pumping conditions
- Seam testing, including vertical specific conductance profiling, specific conductance monitoring while pumping out the seams, and subsequent water level recovery monitoring
- The distribution of NAPL as designated by TarGOST results near the sheet pile wall, relative to the sheet pile wall driven depths and soil type

SECTION 3

Current Conditions

The selected remedy for the Soil and Groundwater OUs presented in the 2000 ROD (Section 12.1) was Alternative 3, Thermal Remediation. In addition to the selected remedy, the ROD identified a Contingency Remedy as follows:

"If the pilot test [for thermal remediation] does not reasonably achieve performance expectations, then Alternative 2b, Containment with a Sheet Pile Wall Remedy, will be implemented."

The contingency remedy was implemented in 2004 after the thermal treatment pilot study failed to meet remedial action objectives (RAOs).

3.1 Remedy Components

The contingency remedy includes the following components:

- **Sheet Pile Wall** – The 1,870-foot-long sheet pile wall was installed in 2001.
- **Groundwater Extraction and Treatment System** – The groundwater extraction and treatment system has been operating since 1990. The treatment system was replaced in 2010.
- **Long-term Monitoring** – Groundwater monitoring to demonstrate hydraulic containment and monitor changes in contaminant levels in the Upper and Lower Aquifers was initiated in 2004.
- **Institutional Controls –** Institutional controls in the form of a Prospective Purchasers Agreement with the City of Bainbridge Island and EPA have been implemented to prevent access to groundwater. Engineering controls including fencing and access controls have been implemented to restrict site use to prevent direct exposure to surface soil.

The following component of the containment remedy has yet to be implemented:

- **Site Cap –** A low-permeability cap would reduce the amount of precipitation recharge entering the FPA that needs to be treated and would prevent direct contact with contaminated soil.

3.1.1 Sheet Pile Wall

Construction of the sheet pile wall was completed in February 2001. The sheet pile wall is located around the outer, shoreline perimeter of the facility. This wall is approximately 1,870 feet long and extends approximately 20 to 90 feet bgs (CH2M HILL, 2004a). It was constructed with the intention to embed (for example, key) the bottom of the wall into the Aquitard. A second sheet pile wall was constructed to isolate the thermal remediation pilot study area (CH2M HILL, 2004a). This wall has a total length of 536 feet and is located in the interior portion of the site. The two sheet pile walls are informally referred to in this document as the perimeter and inner walls.

3.1.2 Groundwater Extraction and Treatment System

The groundwater extraction system consists of dual extraction (groundwater/NAPL) wells. Seven recovery wells (RPW1, RPW2, RPW4, RPW5, RPW6, PW8, and PW9) and two former pilot extraction wells (E-02 and E-06) screened in the Upper Aquifer are currently used (see Figure 3-1). The extraction wells recover groundwater, light non-aqueous phase liquid (LNAPL), and dense non-aqueous phase liquid (DNAPL). The system was designed to hydraulically contain contaminated groundwater and NAPL within the FPA by pumping groundwater from the Upper Aquifer to maintain an upward vertical gradient between the Lower and Upper Aquifers and to induce groundwater flow away from the site perimeter and toward the extraction wells. The groundwater/NAPL mix recovered by the extraction wells is separated, the groundwater treated at the onsite groundwater treatment plant (GWTP), and the treated water discharged to Puget Sound. The recovered NAPL is shipped to an offsite facility for incineration. NAPL is periodically pumped from the wells, although NAPL recovery is not a primary objective of the system. Groundwater and NAPL extraction volumes are measured and recorded for each well.

Figure 3-2 is an as-built drawing for the new GWTP, which was constructed in 2009 to replace the previous GWTP. The groundwater/NAPL mix from the recovery wells is pumped to a 51,000-gallon equalization tank at the GWTP where a majority of the NAPL removal occurs. Any residual NAPL and suspended solids are then removed from the influent using dissolved air flotation (DAF) separation, which is aided by a polymer injection system. The effluent from the DAF unit is filtered through a hydromation deep bed filter that uses walnut shell media for solids and oil removal. Effluent from the deep bed filter is polished through a series of granular activated carbon (GAC) units to reduce PCP and PAH concentrations below the maximum target discharge levels required under the National Pollutant Discharge Elimination System (NPDES) permit. Standby GAC units are available to allow for change-out of loaded lead units without requiring interruption of treatment operations. Effluent from the GAC units is directed to an effluent tank before it is discharged through an outfall. Influent and effluent water quality sampling and analysis is routinely performed to assess and confirm GWTP performance.

The GWTP and recovery well systems generally operate 24 hours per day 7 days a week during the rainy season and 24 hours per day 5 days a week during the summer months, but are shut down periodically because of low groundwater levels or for system maintenance.

3.1.3 Long-term Monitoring

The long-term monitoring program includes water level measurements to evaluate hydraulic containment. The monitoring program also includes monitor well groundwater sampling and analysis to evaluate contaminant concentration trends in the Lower Aquifer within the FPA and in the Upper Aquifer outside the FPA. Locations for all of the Wyckoff Site wells are shown on Figure 3-1, and information for each well (type, aquifer, elevations, and well construction details) are included in the well inventory provided in Table 3-1. Long-term monitoring results are presented annually in four quarterly water level monitoring reports evaluating hydraulic containment, and one annual report evaluating water quality conditions of the Lower Aquifer.

3.1.4 Volume of Water Treated

Table 3-2 shows groundwater extraction volumes by well. A total of 21,979,747 gallons were extracted from April 2012 through March 2013. The monthly groundwater extraction rate for all nine extraction wells in 2012 varied from 0 gallons per month in August 2012 to 3,381,757 gallons per month (77.2 gallons per minute [gpm]) in December 2012. Groundwater pumping rates generally follow a seasonal pattern that correlates with monthly rainfall totals (Figure 3-2). Average pumping rates were 1.6 gpm to 9.5 gpm at individual wells. As shown on Figure 3-2, approximately 72 percent of the groundwater extracted from April 2012 through March 2013 was from four wells (RPW2, RPW4, RPW5, and RPW7).

The number of aquifer pore volumes withdrawn by the groundwater extraction system for the same time period was estimated using the following equation:

$$NPV\ (year) = Q\ (year)/PV$$

Where NPV is the number of pore volumes, Q is the total annual pumping rate, and PV is the volume of contaminated Upper Aquifer groundwater within the FPA. Using the TarGOST results to define the area and volume of contaminated material, the volume of contaminated media is estimated at approximately 570,000 cubic yards (15,381,000 cubic feet). Assuming a total porosity of 0.3, the estimated pore volume of the Upper Aquifer is 4,614,000 cubic feet, or 34,517,000 gallons. Given these assumptions, 0.64 pore volumes were withdrawn by the groundwater extraction system from April 2012 through March 2013.

3.1.5 NAPL Removal per Year

Table 3-3 shows the volume of product (LNAPL and/or DNAPL) recovered from each extraction well from March 26, 2012 through March 25, 2013. A total of 1,287 gallons of NAPL (120 gallons LNAPL and 1,167 gallons DNAPL) were removed from seven recovery wells (RPW1, RPW2, RPW4, RPW5, RPW6, RPW8, and RPW9). Approximately 90 percent of the NAPL recovered during this period was from four wells (RPW1, RPW2, RPW5, and RPW8). For comparison, during a step test of the groundwater extraction system conducted in 1995, 1,460 gallons of NAPL were recovered from extraction wells RPW1, RPW2, RPW5, RPW6 and RPW8 over a 21-day period (CH2M HILL, 1996).

In addition to the NAPL recovered from the extraction wells, an estimated 2,945 gallons of NAPL were removed from the treatment plant tanks during the same time period. This is NAPL that is separated from the groundwater by the treatment plant.

A total of 4,232 gallons of NAPL were removed from the extraction wells and treatment plant.

3.1.6 Mass Removal per Year

As presented in Section 5.0, based on laboratory analysis results for product recovered from the Wyckoff Site, the average densities for the LNAPL and DNAPL are 0.988 grams per cubic centimeter (g/cc) and 1.033 g/cc, respectively. Given these densities, an estimated 988 pounds of LNAPL and 10,060 pounds of DNAPL (total 11,048 pounds of NAPL) were removed by the extraction wells, and 25,278 pounds of NAPL were removed from the treatment plant from April 2012 through March 2013 (see Table 3-3). A total of 36,326 pounds of product (LNAPL and DNAPL) were removed.

Table 3-4 shows the estimated mass of PAH, PCB, and oil and gas removed by the GWTP from March 27, 2012 through March 26, 2013. The mass removed was estimated using the weekly volume of extracted groundwater and influent concentration into sample port SP-0. An estimated 3,555 pounds of PAHs, 36 pounds of PCBs, and 4,097 pounds of oil and grease were removed and treated during this time period (1 year).

Hydrogeology

The hydrogeology of the Bainbridge Island area and the Wyckoff Site has been well-documented. This section describes the regional hydrogeology and the site hydrogeology in detail.

4.1 Regional Hydrogeology

The regional hydrostratigraphic units and groundwater flow directions are described in this section.

4.1.1 Hydrostratigraphic Units

The *Preliminary Geologic Map of Bainbridge Island* (Haugerud, 2005) shows the surficial deposits at the Wyckoff Site as "Modified Land (Holocene)," which is described as "sand and gravel as fill, or extensively graded natural deposits," and shows the areas immediately south and west of the Wyckoff Site as the Esperance Sand Member of the Vashon Drift (Qve). The subsurface beneath Bainbridge Island is divided by Frans, Bachmann, Sumioka, and Olsen (2011) into 11 hydrostratigraphic units based on their hydraulic and geologic characteristics. Frans et al. differentiated the surficial geologic units from Haugerud (2005) and the deposits at depth into aquifers (A) and confining units (C) based on their areal extent and general water-bearing characteristics. The hydrostratigraphic units at Bainbridge Island in descending order include:

1. Vashon Till Confining Unit (Qvt)
2. Vashon Advance Aquifer (Qva)
3. Upper Confining Unit (QC1)
4. QC1pi, permeable interbeds, included locally with QC1
5. Sea Level Aquifer (QA1)
6. Middle Confining Unit (QC2)
7. Glaciomarine Aquifer (QA2)
8. Lower Confining Unit (QC3)
9. Deep Aquifer (QA3)
10. Basal Confining Unit (QC4),
11. Bedrock (BR)

Note: The Frans et al. (2011) descriptions of the hydrogeologic units do not exactly match those by Kato and Warren and Robinson and Noble (2000) that were presented in the 2007 CSM Update (CH2M HILL, 2007b). Frans et al. present a comparison table of the terminology used in their study versus previous studies by Kato and Warren and Robinson and Noble and others.

Figure 4-1 is a surficial hydrogeologic map of Bainbridge Island from Frans et al. (2011) that shows the Upper Confining Unit (QC1) as the surficial hydrogeologic unit at the Wyckoff Site. The Vashon Till units (Qvt and Qva) are not shown as present at the Wyckoff Site, although the surficial hydrogeologic unit immediately south and west of the Wyckoff Site is the Vashon Advance Aquifer (Qva). Figure 4-2 is a schematic hydrogeologic cross-section from Puget Sound to the south to Murden Cove to the north, showing the relationships among the hydrostratigraphic units. Figure 4-3 is a schematic hydrogeologic cross-section from west to east, terminating at the Wyckoff Site.

The cross-sections show that the Wyckoff Site and Eagle Harbor are underlain by QC1 and all lower units except QC1pi. The Upper Aquifer beneath the FPA (the primary target aquifer for remediation at the site) is not shown on these cross-sections, and therefore does not appear to match with any unit described by Frans et al. (2011). The Aquitard underlying the Upper Aquifer in the FPA at the Wyckoff Site matches with the QC1 Upper Confining Unit described below. The Lower Aquifer beneath the FPA correlates with the Sea Level Aquifer (QA1), and the confining unit underlying the Lower Aquifer correlates with the Middle Confining Unit (QC2). The Frans et al. descriptions of these units (lightly edited and augmented for clarity) are presented below in descending order. Horizontal hydraulic conductivities, calculated by Frans et al. using specific capacity data from driller's logs, are also presented where available. Table 4-1 summarizes the thickness, top elevation, and estimated hydraulic conductivity for each hydrogeologic unit described by Frans et al.

4.1.2 Groundwater Flow Directions

Groundwater elevations in the Qva aquifer range from near 0 to 300 feet amsl, depending on location. Flow directions are generally radial, moving from central areas toward the shoreline or toward surface water bodies. The vertical hydraulic gradient is downward in the interior areas of the island and upward along the coastline (Frans et al., 2011).

The QA1 is a confined aquifer occurring, for the most part, below sea level. Groundwater elevations within the QA1 range from a high of over 100 feet amsl in the central portion of the island to approximately sea level near the shoreline. Generally, higher groundwater levels occur below the inland portion of the island and decrease toward the shoreline. Correspondingly, groundwater in the QA1 flows from the central portion of the island outward toward the shore, as shown on Figure 4-4. The vertical hydraulic gradient is downward in the interior areas of the island and upward along the coastline (Frans et al., 2011).

4.2 Site Hydrogeology

This section describes the hydrogeologic units, groundwater flow directions, and hydraulic interconnection between aquifers at the Wyckoff Site. As summarized in Section 2.0, numerous subsurface investigations and studies have been conducted at the site, including the installation of borings, monitoring wells, extraction wells, piezometers, and direct-push probes/cone penetrometers. Currently there are 77 wells at the site that can be used for monitoring. These are shown on Figure 3-1 and listed with their installation details in Table 3-1.

4.2.1 Hydrogeologic Units

Based on observations collected at onsite wells (the deepest of which is 127 feet bgs), three hydrogeologic units underlie the vadose zone beneath the Wyckoff Site: the Upper (unconfined) Aquifer, a silt/clay Aquitard, and the Lower (confined to semi-confined) Aquifer. Schematic cross-sections showing the relationships among the units and groundwater flow are shown on Figures 4-5 and 4-6. Figure 4-5 shows the locations of the schematic cross-sections A-A' and B-B' on Figure 4-6. Figure 4-6 shows the original groundwater conditions at the site (before the groundwater extraction system and sheet pile wall were operational), and current conditions.

A U.S. Army Corps of Engineers (USACE) report (2000) presented detailed cross-sections showing the relationships among and within the hydrogeologic units present at the Wyckoff Site. To supplement the following discussion, cross-section plates from this report are presented here as Figures 4-7 through 4-15 (USACE, 2000). Note, these cross-sections have not been updated with the more recent site borings. Figure 4-16 shows the topography of the Aquitard (defined as the glacial till), while Figure 4-17 shows the corresponding thickness of the Aquitard. The Aquitard topography and thickness were estimated using soil classification and other information from over 200 logs for soil borings, wells, and other investigative borings installed at the Wyckoff Site, including the TarGOST confirmation borings in 2013.

4.2.1.1 Buried Infrastructure

Figure 4-18 shows the locations where there is a potential for buried infrastructure/debris, such as building foundations, in the FPA. Some of these features are currently partially exposed at the ground surface, whereas others may have been covered during filling and regrading. The presence of this material is an important consideration when screening remedial technologies for effectiveness and implementability during the FFS.

4.2.1.2 Vadose Zone

The vadose zone generally consists of fill (see Figures 4-8 through 4-15). Based on depth to groundwater measurements collected on September 3, 2012 during the groundwater extraction system shutdown, the vadose zone ranges in thickness from approximately 6 feet at well CW13 in the western FPA to 13 feet at well VG-2U in the northeastern FPA under non-pumping conditions. Direct contact with contaminants present in the vadose zone is the primary human health exposure pathway at the site. Contaminants present in the vadose zone may also represent a source for leaching to groundwater.

4.2.1.3 Upper Aquifer

The Upper Aquifer primarily consists of marine sand and gravel. The Upper Aquifer is unconfined, with groundwater elevations ranging from approximately 7.5 to 10 feet mean lower low water (MLLW) under non-pumping conditions (based on September 2012 data). Groundwater elevations in the Upper Aquifer during active pumping ranged from 5.5 to 8.5 feet MLLW on July 25, 2012 (the synoptic event) and from 4.5 to 12 feet MLLW for the period between March 2012 and March 2013. Tidal influence within the Upper Aquifer has historically ranged in magnitude from 1 to 10 feet, with the highest tidally induced changes near the shoreline. Since the installation of the perimeter sheet-pile wall in 2001, tidal influence has been diminished, and most upper aquifer wells now show a tidal influence ranging from 0.1 to 4 feet.

Groundwater in the Upper Aquifer underneath the FPA is not currently extracted, nor is it expected to be extracted in the future, for potable, agricultural, or industrial purposes, because of saltwater intrusion caused by tidal flushing. High salinity levels are anticipated to remain in the future. The Washington State Department of Ecology has determined Upper Aquifer groundwater in the FPA to be non-potable because it is significantly affected by salinity. The assignment of a non-potable Class III designation (total dissolved solids greater than 10,000 milligrams per liter [mg/L]) to the Upper Aquifer groundwater present beneath the FPA is consistent with EPA’s definition of a potential source of drinking water.

Sheet Pile Wall

Although not a natural hydrogeologic unit, the sheet pile wall is an important feature because it represents a low permeability, vertically oriented flow barrier lying within the Upper Aquifer. The integrity of the sheet pile wall influences the Upper Aquifer’s hydraulic response to regional, seasonally induced water level changes and daily tidal cycles in Eagle Harbor. Sheet pile wall integrity also affects NAPL and dissolved phase contaminant transport.

As described in Section 2.1.3, multiple lines of evidence were evaluated to assess the sheet pile wall’s integrity (CH2M HILL, 2013c). The various lines of evidence indicate that the sheet pile wall has a relatively moderate to high degree of effectiveness in hydraulically isolating the upland side of the Upper Aquifer from the Eagle Harbor side. Currently, although there is some hydraulic flux through the sheet pile wall via the seams, a comparison of current to historical tidal efficiency factor measurements combined with the sheet pile wall construction information indicates that the current hydraulic flux through the sheet pile wall is significantly less than during pre-wall conditions.

4.2.1.4 Aquitard

A low permeability Aquitard separates the Upper Aquifer from the Lower Aquifer. The Aquitard is composed of marine silt, glacial deposits, and non-marine clay. The top of the Aquitard extends from near ground surface in the south-central portion of the Wyckoff Site to approximately 90 feet bgs along the northern portion of the site (see Figure 4-16). Based on numerous field explorations conducted during the RI for the Wyckoff Soil and Groundwater OUs (CH2M HILL, 1997) and various USACE exploratory drilling events (USACE, January 1998, April 1998, May 2000, October 2006), the Aquitard appears continuous throughout most of the site.

As shown on Figure 4-17, the Aquitard’s thickness ranges from 10 to 40 feet, with the thinnest areas located near the northeast corner of the site and in the central portion of the site. Borings drilled along the south hillside in 2004 to characterize the area for a possible upgradient cutoff wall (CH2M HILL, 2004b) identified gaps in the Aquitard in the southwest and southeast corners of the site upgradient of the FPA. Additional investigation in 2008 also identified a gap in the Aquitard in the southeast corner of the site. The locations of these gaps are shown on Figures 4-5, 4-16, and 4-17. Moreover, the last 200-foot segment of the sheet pile wall in the southeast corner of the site may not be keyed in Aquitard material (CH2M HILL, 2009). No Aquitard material was observed at boring PZ-03, which is located about 20 feet east of the end of the sheet pile wall. Boring PZ-03 is completed about 10 feet below the base of the wall. No Aquitard material was observed at boring SE-02, which is located about 100 feet northeast of the sheet pile wall.

4.2.1.5 Lower Aquifer

The Lower Aquifer is continuous across the Wyckoff Site and is strongly influenced by tides. The Lower Aquifer consists primarily of sand, with small amounts of silt, clay, and gravel. The lower boundary of this aquifer has not been characterized at the site. However, it is believed that this aquifer extends to approximately 200 or 250 feet bgs, based on the regional work of Frans et al. (2011) and the logs recorded for two deep onsite water supply wells that were decommissioned in 1997, and for a new water supply well that was completed in January 2002.

Groundwater in the Lower Aquifer (approximately 80 to 200 feet bgs) is considered potable (Class II B – Groundwater Not a Current Source but Potential Future Source,) although this aquifer has never been used for drinking water at the site.

4.2.2 Groundwater Flow Conditions

As shown on Figure 4-6, groundwater flow in both aquifers prior to installation of the sheet pile wall (original conditions) was from south to north, toward Eagle Harbor and Puget Sound. The flow was also upward from the Lower Aquifer to the Upper Aquifer as expected in a sea level groundwater discharge zone. Groundwater in the Upper Aquifer flowed from the southern portion of the Wyckoff Site north toward Eagle Harbor and Puget Sound, where it formerly discharged into the intertidal and subtidal zones. The perimeter sheet pile wall now impedes groundwater flow into Eagle Harbor while the pump-and-treat system extracts groundwater to maintain a net upward vertical hydraulic gradient from the Lower to Upper Aquifer and to maintain an inward flow gradient within the Upper Aquifer.

Groundwater elevations and flow directions in the Upper Aquifer are influenced both by groundwater extraction and by tidal fluctuation. The GWTP and groundwater recovery wells were shut down for an extended period for routine maintenance and because of low Upper Aquifer groundwater levels in the third quarter of 2012. The long-term shutdown allowed for a comparison of groundwater flow directions during pumping and non-pumping conditions and an evaluation of pumping influences on groundwater flow. Results of this evaluation were presented in a Technical Memorandum (CH2M HILL, 2013d). The effect of tidal fluctuation on groundwater elevations in the Upper Aquifer was evaluated for the 2013 sheet pile wall evaluation (CH2M HILL, 2013c). Results of both of these evaluations are summarized in Section 4.2.2.1.

4.2.2.1 Groundwater Flow Directions

Groundwater flow directions during pumping and non-pumping conditions were evaluated using data from two synoptic monitoring events. The first event occurred on July 25, 2012 at 12:55 PM, which represents a moment in time when the tidal elevation was approximately 3 feet MLLW on an incoming tide. At that measurement time, six production wells (RPW2, RPW4, RPW5, RPW8, E-02, and E-06) were extracting groundwater at a total rate of 44 gpm, with rates at the individual wells ranging from 4.8 gpm to 10.2 gpm. The second event occurred on September 3, 2012 at 9:01 PM, representing a moment in time when the tidal elevation was also approximately 3 feet MLLW on an incoming tide, and production wells had been off for over a month. Water levels were interpolated for Upper and Lower Aquifer monitoring wells for each of these events using the pressure transducer measurements.

Figures 4-19a and 4-19b show the groundwater elevations and inferred flow directions for the July 25th synoptic (pumping) event for both the Upper and Lower Aquifers, respectively. The Upper Aquifer flow map demonstrates inward hydraulic gradients toward the active production wells, and the Lower Aquifer map shows a horizontal hydraulic gradient toward Eagle Harbor and Puget Sound.

Figures 4-20a and 4-20b show the groundwater elevations and inferred flow directions for the September 3rd synoptic (non-pumping) event for the Upper and Lower Aquifers, respectively. The Upper Aquifer flow map shows a partial inward gradient toward the production wells with some gradient reversal toward the sheet pile wall. The outward gradients along the sheet pile wall are an artifact of the contour interpolation, which does not take into account the sheet pile wall as a hydraulic barrier to groundwater flow. The Lower Aquifer flow map shows horizontal gradients and groundwater flow toward Eagle Harbor and Puget Sound.

Figure 4-21 shows the difference between the July 25th and September 3rd groundwater elevations in the Upper Aquifer wells. This difference reflects the approximate water level change resulting from shutting down the groundwater recovery wells in late July. Because of dry, summer conditions, natural, seasonal water level changes over this period are likely negligible. As shown on Figure 4-21, the water level change was +1 foot at all monitored locations except for PW9 and CW13. This suggests that most, if not all, of the FPA is within the recovery well hydraulic capture zone (RPW2, RPW4, RPW5, PW8, E-02, and E-06, which were active on July 25). It should be noted that this radius of influence evaluation is applicable to the low water levels consistent with summer - dry season conditions. The hydraulic effects of groundwater extraction may differ for winter - wet season conditions.

Historical tidal efficiency factors representing conditions prior to installation of the sheet pile wall are available for a limited number of site monitoring wells. For Upper Aquifer wells CW13 and MW14, pre-wall tidal efficiency factors were 54 percent and 21 percent, respectively (CH2MHILL, 1996). In 2012, tidal efficiency factors of 2 percent and 5 percent were found for these areas (CH2M HILL, 2013c). These results indicate that installation of the sheet pile wall has resulted in a substantial decrease in the hydraulic connection of the Upper Aquifer with Eagle Harbor in these two areas. It was concluded that tidal fluctuation plays a minor role in causing the short duration downward gradients observed within the FPA.

SECTION 5

Nature and Extent of Contamination

This section integrates existing information with the results of the recently completed TarGOST Phase 1/Phase 2 investigations to develop an improved understanding of NAPL distribution within the vadose zone and Upper Aquifer at the site.

5.1 Potential Contaminant Sources

Potential sources of NAPL in the FPA are divided into categories based on historical source documentation as primary and secondary sources (Figure 5-1). Primary sources were identified from Figures B, C, and D of the *Final Removal Report* (Ecology and Environment, 1995) for 1992 through 1994 removal activities at the site. Primary sources were identified as sumps, trenches, and other areas with observed contamination. The areas identified in addition to sumps and trenches include the following:

- Naphthalene disposal area – The site of the naphthalene block excavation activities that were performed in conjunction with the removal actions from 1992 through 1994. A block of solid phase naphthalene 4 to 5 feet thick and 15 feet long located to the southwest of Tank 4-A in the tank farm area was removed from this location.
- An area of excavated major pipes and leaks – This area is located in the Engine Room (the large building southeast of the retorts).
- Old sump – The old sump area contained sludge that were excavated during the removal actions from 1992 to 1994 (Ecology and Environment, 1995).

Wastewater, oil, and sludge remaining in site sumps and trenches were removed during the actions from 1992 through 1994 (Ecology and Environment, 1995).

Secondary sources have also been identified and prioritized based on a review of historical documentation. These secondary sources are typically in process areas, are sites of documented spills or contamination, and may have had previous removal actions. These areas include the following:

- West Dock – During the removal actions conducted from 1992 through 1994, an area between wooden bulkheads adjacent to the West Dock was found to contain buried sludge. EPA decided to amend the Removal Action scope to include the demolition of a section of the West Dock and the excavation of 120 cubic yards of sludge located under the dock.
- Former Lagoon/Tram Loading Area – Prior to the 1920s when the site was reconstructed, a lagoon area existed to the south of the retorts and transfer table pit. Logs were reportedly floated in and out of this lagoon prior to it being filled in (USACE, 2007). Later use of this area included the tram loading.
- Tank 6C – This one-million-gallon aboveground storage tank (AST) contained PCP and creosote-contaminated waste oil and sludge at the time of removal actions in 1992 to 1994 (Ecology and Environment, 1995). The materials within the tank were treated and the tank was demolished in 1993.
- Log Storage Area – This area was primarily used to store untreated wood (USACE, 2007).
- Former Seattle Steam Storage Tank – This location housed a steam storage tank.
- Area of reported pipeline leak – This site was the location of a reported leak in an underground creosote pipeline.
- Transfer Table Pit – Transport of treated logs occurred through the transfer table pit to the West Dock. Historically, chemical process fluids from the retorts were allowed to discharge directly to the ground surface in this area and seep into the soil and groundwater (USACE, 2007). During the 1992 to 1994 remedial actions, the transfer table pit was observed to contain drippings and buried creosote-

contaminated sludge (Ecology and Environment, 1995). Excavation activities were performed to remove all sludge, as well as contaminated concrete and wood debris to the depth of the groundwater/saltwater interface at approximately 10 to 15 feet bgs (Ecology and Environment, 1995).

5.2 Upper Aquifer – NAPL Characteristics and Distribution

This section discusses the nature and extent of creosote-related NAPL contamination present in the Upper Aquifer. For this draft, the discussion focuses on NAPL characteristics and distribution summarized from both historical site data and data collected from recent TarGOST field investigations and relevant information from the OU1 2012 field investigation. Existing information regarding the nature and extent of dissolved phased contamination has been reviewed and deemed non-representative of current conditions. The most recent groundwater quality data representing conditions in the Upper Aquifer were collected in the 1990s prior to installation of the perimeter sheet pile wall. Supplemental sampling of Upper Aquifer wells is planned. Following evaluation, the Upper Aquifer groundwater quality data set will be used to update the CSM.

5.2.1 NAPL Characteristics

Historical NAPL characteristic data are available from the USACE 1999 pre-remedial design field exploration for the Wyckoff/Eagle Harbor Superfund Site (USACE, 2000) and *Final Report: Wyckoff/Eagle Harbor Superfund Site*

Steam Injection Treatability Study (EPA, 2002). These historical data are compiled and described in *NAPL Characteristic Data and Aquitard Entry Pressure Calculations* provided in Appendix A. Available data include NAPL product chemical composition, density, oil-water interfacial tension, and solubility measurements from NAPL samples collected at upland monitoring wells in 1999.

5.2.1.1 Chemical Composition

The chemical composition of creosote NAPL influences its properties (density, interfacial tension, viscosity and solubility), which in turn affects migration and weathering in the subsurface environment and the partitioning of dissolved phase contaminants from the NAPL to groundwater. Historical chemical composition data are available from NAPL samples collected from site extraction wells and a composite sample taken from the GWTP. Figure 5-2 graphically presents percent chemical composition of historical upland NAPL samples.

The NAPL samples contained comparable proportions of naphthalene and other low molecular weight (less than 200 grams per mole) PAHs (LPAHs) including acenaphthene, fluorene, phenanthrene, and anthracene. Pyrene and fluoranthene were the most prominent high molecular weight (greater than 200 grams per mole) PAHs (HPAHs) detected. PCP was detected in several samples but was a minor component compared to the LPAH and HPAH constituents. In general, the chemical fingerprints of NAPL samples exhibit limited variability and establish a consistent compositional pattern of PAHs and PCP. PW9 and the composite sample show the greatest variability, with reduced naphthalene composition and a greater fraction of dibenzofuran.

5.2.1.2 Density

NAPL density is the measure of the NAPL mass per unit volume. Site data are available from 11 NAPL samples collected from recovery wells and a composite at the GWTP. Measured values ranged from 0.978 to 1.052 grams per milliliter (g/mL) at 10° centigrade (C). Compared to a water density of 0.9997 g/mL at 10° C, the specific gravity of NAPL is close to water.

Within the vadose zone under a two fluid system (air and NAPL), gravity forces dominate and creosote NAPL migrates primarily downward with some lateral spreading as a result of capillary forces and medium spatial variability (that is, layering). Once the water table is encountered, NAPL will tend to pool on the water surface until the pool height results in a gravity force that exceeds the pore entry pressure of the saturated soils below the water table.

Once within the saturated zone, because of the density ranges, NAPL will tend to partition into phases that are both lighter (LNAPL) and heavier (DNAPL) than water. LNAPL will tend to move laterally with the water table gradient. DNAPL will displace water and continue its migration under pressure and gravity forces. Preferential spreading will occur where DNAPL encounters relatively permeable layers or other pathways that present less capillary resistance to entry than underlying, less-permeable strata. The potential presence of salt water, because of the proximity with Eagle Harbor, with a density of approximately 1.03, will also influence DNAPL migration.

5.2.2 Extent of NAPL

This section presents the horizontal and vertical extent of NAPL at the FPA by site hydrogeologic unit, based on the most recent site investigation activities conducted in 2012 and 2013. The extent of NAPL in the Upper Aquifer is estimated from the recently collected TarGOST data as summarized in the Draft *2013 Wyckoff Upland NAPL Field Investigation Technical Memorandum Field Summary Report* (CH2M HILL, 2013b). The extent of NAPL in the Lower Aquifer is estimated from NAPL thickness measurements of Lower Aquifer monitoring wells during the June 2012 Lower Aquifer groundwater sampling event (CH2MHILL, 2013e). The extent of NAPL in the Aquitard is inferred through comparison of Lower Aquifer to Upper Aquifer NAPL extents and calculation of capillary entry pressures required to induce NAPL migration into the Aquitard.

5.2.2.1 Upper Aquifer NAPL Extent and Distribution

The extent and distribution of NAPL in the Upper Aquifer is evaluated through the TarGOST dataset and through NAPL thickness measurements in site monitoring wells screened in the Upper Aquifer.

Distribution via the TarGOST Dataset

During the 2013 Upland NAPL field investigation, 141 primary and 7 replicate TarGOST borings and 20 confirmation soil core borings were advanced to characterize the extent of NAPL in the Upper Aquifer. Because of the relative high density of vertical to horizontal readings, the final TarGOST dataset consists of 198,992 data points. In raw form, the TarGOST data do not explicitly indicate the presence or absence of NAPL. Interpretation is needed to select a %RE value that represents a transition or cutoff between the presence or absence of NAPL. To accomplish this, a robust analysis was completed to evaluate the cutoff between the presence or absence of NAPL using multiple lines of evidence. Details of the analysis are presented in the *2013 Wyckoff Upland NAPL Field Investigation Technical Memorandum Field Summary Report* (CH2M HILL, 2013b). Evaluation findings indicate that a TarGOST %RE response between 5%RE and 10%RE can be justifiably selected as representing the presence of NAPL. Based on stakeholder review and approval, TarGOST responses of 10%RE and greater are inferred to indicate that NAPL is present at measured locations.

Visualization and evaluation of the TarGOST dataset was conducted using multiple approaches including raw TarGOST logs as fence diagrams, geostatistical interpolation using mining visualization software (MVS), and data filtering and integrating with Excel in conjunction with 2-D visualizations. Results of each of the approaches are summarized below, because each is helpful for assessing NAPL extent and distribution in the Upper Aquifer.

Fence Diagrams including Analysis of Confirmation Boring Data

Plates 1 through 3 present the series of fence diagrams along 12 transects across the site, produced from the raw TarGOST logs to present the distribution of NAPL across the Upland Project Area. The primary transects (A through F) were chosen such that they radiate outward from a centrally located TarGOST probe location at the site (2013T-005). Three sub-transects stemming from transects D and F were added for greater spatial coverage and to aid in identifying potential flow paths. Transect G was added to evaluate NAPL effects along the interior perimeter of the sheet pile wall. All LIF response graphs are scaled the same, with vertical response grid lines at an interval of 25%RE and a maximum response of 150%RE.

Important relevant observations from the TarGOST log fence diagrams are as follows:

- In general, NAPL is thickest in the center of the site where higher TarGOST responses are located, then transitions to thinner lenses with lower response as the fence diagrams move radially away from the center of the FPA and potential source areas.
- Beyond the center of the FPA and potential sources, the NAPL lenses are vertically distributed but not in any obvious patterns with depth. This distribution is likely a result of multiple source areas, preferential pathways associated with interbedded lithologies, and interaction with variable fluid densities resulting from the Upper Aquifer's transition from freshwater to saltwater and operation of the hydraulic containment system.
- Deeper (near Aquitard) TarGOST responses at greater than 10 percent appear to terminate at or above the TarGOST boring refusal depths. In general, where comparable lithology is available, TarGOST refusal is coincident with or slightly below the transition from the Upper Aquifer to the glacial till (e.g., a layer within the Aquitard). These factors suggest that the glacial till is effectively restricting the migration of NAPL to deeper elevations.
- Along the FPA's west side and north end, elevated TarGOST readings were measured adjacent to the outer sheet pile wall at depths at and above the glacial till layer. In these areas the sheet pile wall driven depths are greater than the deepest elevated TarGOST responses.

As part of the TarGOST investigation, confirmation borings were advanced and logged for soil type and NAPL observations. The resulting datasets were compared to evaluate the association of NAPL with soil type. Figure 5-3 presents the confirmation boring lithology and NAPL-affected soil core lengths by historical geologic unit. The first graphic represents the confirmation boring footage by soil type and NAPL absence and presence. The second graphic to the right represents the lithology type as a percent of total recovered confirmation boring footage. The third graphic at the bottom represents the presence of NAPL as a percentage of total NAPL footage observed, segregated by lithologic unit. Of the 598.5 feet of recovered soil cores, NAPL was observed in 119 feet, or 20 percent of the sampled material. When compared with NAPL presence by geologic unit, there is a tendency for NAPL to preferentially inhabit coarser-grained soil as evidenced by the increased percentages of NAPL by soil type relative to the general prevalence of soil type in the Upper Aquifer. Eighty-two percent of the NAPL was observed in coarser-grained material consisting of marine sand or marine sand and gravel, and 15.5 percent of NAPL was observed in finer-grained material consisting of marine silt or marine sediment. This is compared with coarse- to fine-grained material distribution of 68 to 24 percent, respectively, from the confirmation soil logs.

MVS Visualizations and Volume Estimate of NAPL-affected Soil

MVS visualizations were conducted by Sundance Environmental and Energy Specialists LTD (Sundance).To manage the size of the TarGOST dataset, the site was separated into four subareas (2 through 5) and each was interpolated separately. Subareas overlapped along their boundaries to ensure complete coverage. Three-dimensional visualization files presenting the interpolated 10% RE TarGOST response shells were created for each subarea, thereby allowing a user to rotate the visualization and see the estimated NAPL extent from varying angles. Plates 4 through 7 present screen shots for the respective subarea visualizations from multiple angles. Upon review of these, it appears that the NAPL has partially separated vertically with some migration downward to the Aquitard with further migration downslope, some migration horizontally along the water table, and some in between these two zones but with a downward slope. Based on these observations, the Upper Aquifer was segregated into three vertical compartments: Compartment 1 – vadose zone to just below the water table (ground surface to -5 MLLW), Compartment 2 – the intermediate zone (-5 MLLW to 10 feet above the Aquitard), and Compartment 3 – above the Aquitard (10 feet above the Aquitard to boring refusal depth). Figure 5-4 displays how the compartments juxtapose with each other.

Volume estimates of NAPL-affected soil developed using these MVS interpolations are presented in Table 5-1. Approximately 68,500 cubic yards of NAPL-affected soil are estimated to be present in the FPA distributed as follows: 55 percent is in Compartment 1, 18 percent is in Compartment 2, and 28 percent is in

Compartment 3. This estimate is considered to represent a low-end estimate of NAPL-affected soil volume at the site. It is 27 percent lower than the previous USACE estimate of 94,400 cubic yards, and 37 percent lower than the high-end estimate developed using the Thiessen Polygon method, presented in the next section.

In addition to interpolating the TarGOST dataset, Sundance also interpolated soil layers (as defined by the Unified Soil Classification System) obtained from site historical soil borings. This was performed to provide an estimation of higher resolution stratigraphic detail within the Upper Aquifer, which will theoretically influence NAPL migration. At CH2M HILL's request the resulting "micro-stratigraphy" model was combined with the TarGOST NAPL model within MVS to provide a preliminary estimate of the combined distribution by geologic unit. Combined results are presented in Table 5-2 and Figure 5-5. Eighty percent of the NAPL was estimated to be contained in coarser-grained material consisting of gravel and sand, and 18 percent of NAPL was estimated to be contained in finer-grained material consisting of silt and clay. The relative distribution of these model results is consistent with NAPL/material distribution observed in the TarGOST confirmation borings – 82 to 15.5 percent of NAPL in coarse- to fine-grained material, respectively (see previous section).

Thiessen Polygon Distribution and Volume Estimate of NAPL-affected Soil

An evaluation to estimate the total volume of NAPL-affected soil in the FPA was conducted using the TarGOST response data coupled with a Thiessen polygon analysis.

- For the first step, the raw response data from each TarGOST location was first converted from discrete point data to thickness data. This was accomplished by applying each discrete response measurement to the interval represented by the midpoints between each discrete response depth. Once readings were paired with thicknesses instead of discrete depths, the total thickness of the ≥10%RE TarGOST response levels at each location was summed.
- For the second step, Thiessen polygons were created for the surveyed TarGOST locations within the sheet pile wall boundary, and the areas for each polygon were multiplied by the summed thickness for each TarGOST location (from Step 1). This provided a volumetric estimate for each polygon corresponding to a ≥10%RE response.
- For the third step, the volumes from the individual Thiessen polygons (from Step 2) were summed to provide the total volumetric estimate of NAPL-affected soil, as defined by the ≥10%RE TarGOST response.

Additional details on the application of this approach are presented in the *Wyckoff Upland NAPL Field Investigation Technical Memorandum* (CH2M HILL, 2013b).

For graphical presentation of the resulting NAPL-affected soil by Thiessen Polygon method, the Upper Aquifer is segregated into the same vertical compartments identified via the MVS visualizations presented in the previous section (Plate 8). In addition to the compartments, NAPL-affected soil distribution for the combined Upper Aquifer is also displayed. Within each polygon both the total summed thickness (≥10%RE) and the percent of NAPL-affected volume (NAPL-affected volume divided by total polygon volume) are posted. The polygons are color-coded by summed thickness. As an example, the Thiessen polygons with summed thickness greater than or equal to 10 feet are color-coded as red. For the combined Upper Aquifer (All Compartments), 34 of the 129 polygons have summed NAPL thicknesses greater than or equal to 10 feet and encompass a combined area of approximately 2.7 acres.

In comparison to potential sources detailed in Section 4.1, the thickest accumulations of NAPL-affected material (greater than 20 feet thick) appear to be concentrated in the center of the FPA near the Retort area, as well as to the east by the Naphthalene Block Excavation Area. Lesser but still significant accumulations of NAPL-affected material appear to be associated with other potential sources such as the Old Sump to the east; the shop building to the north; the sump associated with a concrete pit for an outhouse, also to the north; the discharge point from a buried drain to the west; and the former floating dock, also to the west.

Volume estimates of NAPL-affected soil developed using the Thiessen polygon approach are presented in Table 5-3. For this approach, Compartment 1 is further divided into both unsaturated (Compartment 1a) and saturated (Compartment 1b) zones. Approximately 109,069 cubic yards of NAPL-affected soil are estimated to be present in the FPA using the Thiessen polygon approach. Fifty-two percent is present in Compartment 1 (5 percent in Compartment 1a and 47 percent in Compartment 1b), 23 percent is present in Compartment 2, and 25 percent is present in Compartment 3. This estimate is considered a high-end estimate of NAPL-affected soil volume at the site. It is 16 percent higher than the previous USACE estimate of 94,400 cubic yards, and 59 percent higher than the low-end estimate developed using the MVS interpolations, presented in the previous section.

TarGOST Reading Integration with 2-D Interpolation to Estimate NAPL Volume

The method and results presented in this section provide a rough approximation of the NAPL volume by gallons present in the Upper Aquifer. This is important to the CSM and FFS development of remedial action alternatives, as it provides an estimate of NAPL phase contaminant volume in the Upper Aquifer. The results can be roughly compared with the previous USACE NAPL volume estimate of 1,200,000 gallons. This methodology provides the most benefit as a tool for estimating the relative mass reduction resulting from implementation of potential alternatives. This tool would be useful for evaluating the relative remedy protectiveness and to support the estimation of relative duration to reach the remedial action objectives for the potential alternatives.

The NAPL volume was prepared by applying the dilution series for TarGOST signal calibration completed under OU1 Field Investigation activities in 2012 (CH2M HILL, 2012). The dilution series was developed by adding different weight percentages of LNAPL collected from Wyckoff upland recovery wells to a composite sample of OU1 beach sand. The upland LNAPL sample consisted of equal proportions of LNAPL from individual samples collected by CH2M HILL from wells PW-1 and PW-4. The composite sediment sample was created by combining approximately equal proportions of gravelly sand material with minor shell fragments from three near-surface locations on the East Beach and North Shoal in the OU1 project area. Visible wood, algae, and other organic materials were excluded from the sample. The signal calibration curve comparing the TarGOST LIF response to weight percentages of LNAPL is presented on Figure 5-6. Historical soil and NAPL density data were used to convert from weight percentage to volumetric percentage, then a linear interpolation was applied to the dilution series to allow conversion of the TarGOST readings to the volumetric percent concentration in parts per million (ppm).

NAPL volumes were estimated using techniques similar to the Thiessen polygon approach described above.

- For the first step, each TarGOST reading ≥10%RE is converted to an estimated ppm concentration (TarGOST concentration) using the dilution series linear interpolation.
- For the second step, the estimated TarGOST concentration is converted to a percentage of volume and multiplied by the associated discrete response volume. The discrete response volume is simply the discrete response depth (developed through Step 1 of the Thiessen polygon approach) multiplied by a 5x5-foot area. This results in an estimate of NAPL volume within each discrete response volume. When summed together, this represents the volume of NAPL within a 5x5-foot column coincident with the TarGOST location.
- For the third step, the NAPL volumes from each TarGOST location column are interpolated to a grid with 5x5-foot cell spacing. The interpolated values from each grid cell are summed to provide an estimate of total NAPL volume.

Plate 9 presents the estimated distribution by NAPL volume developed using this method. This includes NAPL distribution for the combined Upper Aquifer and the compartments identified via the MVS visualizations. Volume estimates of NAPL developed through this TarGOST integration approach are presented in Table 5-4. Rounding to the appropriate significant digit using this method, approximately 650,000 gallons of NAPL are estimated to be present in the Upper Aquifer. Forty-five percent is estimated to be in Compartment 1 (5 percent in Compartment 1a and 40 percent in Compartment 1b), 19 percent in Compartment 2, and 36 percent in Compartment 3. The NAPL volume estimates provided should not be considered as absolute, but are provided for relative comparison with application of potential remedial technologies.

5.3 Lower Aquifer Nature and Extent

OU2 groundwater quality sampling is conducted on an annual basis, with samples primarily collected from monitoring wells screened in the Lower Aquifer. Under the current sampling program, a total of 25 wells and piezometers are sampled and analyzed for SVOC, PAH, PCP, and TPH constituents. Twenty-four of the 25 wells sampled are screened in the Lower Aquifer. In June 2012 NAPL measurements from the wells were obtained to evaluate the presence of NAPL in the Lower Aquifer. This is not typically done during sampling events. The last water quality sampling event was conducted in May 2013.

For the May 2013 sampling event, of the 24 Lower Aquifer samples, 19 were reported by the laboratory to have non-detect or very low detects of analyzed constituents with no exceedances of the groundwater cleanup levels (CULs). The remaining five Lower Aquifer samples at monitoring wells CW05, CW15, P-3L, PZ-11, and VG-2L were reported to have at least one constituent concentration that exceeds a CUL.

Based on the varying PAH constituents detected above their corresponding CULs in May 2013, acenaphthene was selected as an indicator constituent to present the spatial distribution of PAH constituents in the Lower Aquifer. It was selected as the most appropriate indicator constituent because it was detected above its CUL of 3 mg/L in the most monitoring wells. Figure 5-8 presents the resulting concentration isopleths for acenaphthene. The results show two areas at the site where acenaphthene (and other PAH constituent concentrations) are consistently detected near or above cleanup levels. One area is in the northern portion of the FPA and encompasses monitoring wells CW05, CW15, P-3L and VG-2L; the other area is in the southwest portion of the FPA, surrounding piezometer PZ-11. In general concentrations of acenaphthene appear to be relatively stable above the CUL in wells CW15, P3L, and VG2L, and are increasing in CW05 in the northern area of the site. In the southwest area of the site, concentrations are relatively stable, with slight fluctuation, above the CUL since May 2010.

June 2012 NAPL measurements indicate the presence of NAPL in three Lower Aquifer wells (CW15, P-3L, and VG-2L) in the northern area of the FPA. This corresponds with the northern portion of the FPA where acenaphthene and other PAH constituent concentrations are consistently detected near or above cleanup levels. In 2012, NAPL measurements were not attempted at monitoring well PZ-11; however, based on PZ-11 water quality results, the presence of NAPL in this well is possible.

5.4 Aquitard Nature and Extent

There are no monitoring wells or piezometers within the Aquitard, and only limited borings have been advanced through the Aquitard. Consequently, creosote as NAPL or as dissolved constituents in Aquitard pore water cannot be directly measured. Instead, indirect observations and estimates must be relied on to evaluate the extent of NAPL contamination in the Aquitard. The following observations are informative in evaluating NAPL extent in the Aquitard:

- NAPL is present at the base of the Upper Aquifer at varying thicknesses and volumes in certain areas of the FPA, as depicted in the TarGOST logs and the 2- and 3-D visualization methods presented in Section 5.2.2. This provides the potential for downward NAPL migration into the Aquitard across a broad expanse of the site.

- NAPL is present in the Lower Aquifer in an area to the north in three Lower Aquifer wells (VG-2L, P-3L, and CW15). NAPL has migrated to this area from the Upper Aquifer, but the migration pathway is unclear.
- Lower Aquifer water quality conditions indicate two areas with PAH constituents greater than CULs; one to the north encompassing monitoring wells CW05, CW15, P-3L, and VG-2L; the other to the southwest surrounding piezometer PZ-11.
- The Aquitard is thin to absent in the vicinity of PZ-11 (See Figure 4-18). Consequently, the potential migration of dissolved phased constituents from surface contamination to the Lower Aquifer is not inhibited in this area. It is unclear whether NAPL is present in the Lower Aquifer in this area.
- The Aquitard thickness varies over areas of the site where NAPL is present at the base of the Upper Aquifer. The Aquitard's slope and thickness, its capillary forces, and NAPL pool height control the potential for NAPL penetration and migration through the Aquitard to the Lower Aquifer.

Figure 5-9 presents a compilation of the observations and estimates for assessing the potential for NAPL migration through the Aquitard. This includes potential depressions in the Aquitard surface as indicated for the Aquitard surface interpolation; a color-flood of the Aquitard thickness; water quality impacts to the Lower Aquifer, including isopleth contours indicating Lower Aquifer concentrations of acenaphthene exceeding the CUL, and wells with observed NAPL; and TarGOST boring locations that indicate a NAPL pool height greater than required for NAPL entry into the Aquitard. Estimated values of pool height in saturated sediment required for NAPL to enter the Aquitard underlying the FPA were calculated using an air entry pressure scaling method and site data obtained from previous site investigations, and are presented in Appendix A.

Interpretation of these lines of evidence suggests that the presence of NAPL and dissolved constituents in the Aquitard is likely in the northern portion of the FPA and possible in the center of the FPA. At the north end of the site, Lower Aquifer water quality effects align with NAPL thicknesses observed in the Upper Aquifer that exceed the required height for NAPL entry into the Aquitard (as observed at TarGOST location 2013T-043). Furthermore, the Aquitard thickness is estimated to be thinner in this vicinity at approximately 8 to 25 feet, and the Aquitard surface itself is thought to have several depressions where NAPL could pool.

SECTION 6

CSM Summary and Conclusions

The distribution of contaminants in soil and groundwater at the Wyckoff Site is related to the types of chemicals released at the site (that is, creosote, PCP, and aromatic carrier oils as NAPL) and to the geology and hydrogeology underlying the site. The primary sources of contamination are located along the eastern portion of the FPA and include sumps, trenches, and other areas (naphthalene disposal area, areas with pipes and leaks) with observed contamination. Wastewater, oil, and sludge remaining in site sumps and trenches were removed during removal actions conducted from 1992 through 1994. Secondary sources are located throughout the FPA, typically in process areas or at sites of documented spills or contamination, which may have also been addressed by previous removal actions.

6.1 2007 FPA CSM Update Summary

The conceptual model for contaminant migration at the site from the 2007 CSM Update is summarized below:

- As the spills and leaks occurred, the contaminants moved as mobile NAPL into the vadose zone, adsorbing onto soil, volatilizing into soil gas, and dissolving into pore water.
- The mobile NAPL migrated downward through the vadose zone until it reached the water table and separated into light and dense phases:
  - The LNAPL spread out along the water table surface and migrated laterally with the groundwater.
  - Downward migration of DNAPL was slowed or halted as it encountered higher-density brackish groundwater and lower-permeability zones within the Upper Aquifer. Some DNAPL continued migrating downward until it reached the Aquitard.
  - Lateral movement of DNAPL has occurred through high-permeability gravel and cobble zones, or through spreading when the DNAPL reached low-permeability zones within the Upper Aquifer or at the top of the Aquitard.
  - NAPL underwent dissolution as it encountered groundwater in the Upper Aquifer, resulting in dissolved contamination. The aqueous-phase contaminants were then transported with the groundwater flow, laterally toward Eagle Harbor.

Potential mechanisms for transport of contaminants into the Lower Aquifer include:

- Leakage of DNAPL or dissolved contaminants through “holes” and sand zones in the Aquitard. Downward advective transport of dissolved contaminants through the Aquitard is considered unlikely under natural conditions or containment pumping, because the hydraulic head is higher in the Lower Aquifer than in the Upper Aquifer creating a net upward flow potential.
- Transport of DNAPL across the Aquitard by water displacement/”wicking” mechanisms.
- Leakage of DNAPL or dissolved contamination as a result of early drilling activities on the Site, which may have provided conduits through the Aquitard. In 1995, EPA decommissioned 12 old wells. These were industrial water supply wells, monitoring wells, groundwater/contaminant extraction wells, and two deep drinking water supply wells.
- Transport of dissolved contaminants by molecular diffusion across the Aquitard from DNAPL on top of the Aquitard.

Any dissolved contaminants reaching the Lower Aquifer would be carried by regional groundwater flow toward discharge areas deep in Eagle Harbor and Puget Sound. However, due to the long transport distances involved, it is likely that any contaminants reaching the Lower Aquifer would likely be removed by sorption and decay before discharge to the surface waters.

6.2 Summary of Conclusions from the 2014 FPA CSM Update

The conclusions from the FPA CSM Update for contaminant migration at the Site are summarized below:

- Results from recent NAPL thickness measurements and the 2013 TarGOST investigations indicate that NAPL is thickest in the vadose zone and Upper Aquifer in the center of the Site.
- The thickest accumulations of affected material (greater than 20 feet thick) appear to be concentrated in the center of the site near the Retort Area as well as to the east by the Naphthalene Block Excavation Area.
- Lesser but still significant thickness of NAPL-affected material appears to be associated with other potential sources such as the Old Sump to the east; the shop building to the north; the sump associated with a concrete pit for an outhouse, also to the north; the discharge point from a buried drain to the west; and the former floating dock, also to the west.
- Moving radially away from the center of the Site and potential source areas, NAPL occurs in thinner lenses that are vertically distributed but not in any obvious pattern with depth.
- TarGOST results suggest that the glacial till layer at the base of the Upper Aquifer is restricting the migration of NAPL to deeper elevations at most locations underlying the FPA.

The volume of NAPL in the Upper Aquifer was estimated using results from the 2012 and 2013 investigations.

Based on the Thiessen polygon approach, approximately 109,069 cubic yards of NAPL-affected soil is present, with 52 percent present in Compartment 1 (the vadose zone to just below the water table [ground surface to -5 MLLW]), 23 percent in Compartment 2 (the intermediate zone [-5 MLLW to 10 feet above the Aquitard underlying the Upper Aquifer]), and 25 percent in Compartment 3 (the material 10 feet above the Aquitard to approximately the top of the Aquitard). Approximately 650,000 gallons of NAPL are estimated to be present in the Upper Aquifer, with 45 percent in Compartment 1, 19 percent in Compartment 2, and 36 percent in Compartment 3. The NAPL volume estimates provided should not be considered as absolute, but are provided for relative comparison with application of potential remedial technologies.

Confirmation sampling results indicate an association of NAPL with soil type/geologic unit. Of the 598.5 feet of recovered soil cores, NAPL was observed in 20 percent of the sampled material. NAPL was found to preferentially inhabit coarser-grained soil, with 82 percent of the NAPL observed in coarser-grained material consisting of marine sand or marine sand and gravel in the vadose zone and Upper Aquifer. Approximately 16 percent of NAPL was observed in finer-grained material consisting of marine silt or clay.

NAPL and dissolved NAPL constituents have been detected in the Lower Aquifer wells monitored at the site. June 2012 NAPL measurements indicate the presence of NAPL in three Lower Aquifer wells (VG-2L, P-3L, and CW15) in the northern area of the site. This is consistent with the groundwater monitoring results, which indicate the presence of acenaphthene and other PAH constituent concentrations near or above cleanup levels in wells located in the northern portion of the site. Elevated PAHs are also detected in the southwest portion of the site, surrounding piezometer PZ-11.

Although none of the many onsite subsurface explorations before 2004 directly identified “holes” in the Aquitard, existing data indirectly support hydraulic connection between the aquifers. The Aquitard thickness varies over areas of the site where NAPL is present at the base of the Upper Aquifer. The Aquitard’s slope and thickness, its capillary forces, and NAPL pool height control the potential for NAPL penetration into and through the Aquitard to the Lower Aquifer. Based on multiple lines of evidence, including Aquitard NAPL entry pressures, Aquitard thickness, and depressions on the Aquitard surface where NAPL could pool, the presence of NAPL and dissolved constituents in the Aquitard are likely in the northern extent of the site and are possible in the center of the site (areas near CW12, VG-4L, and VG-5L).

Available information (TarGOST results, geologic information, sheet pile wall construction information) indicates that the sheet pile wall has been driven to sufficient depths, and that it is keyed into the Aquitard. Multiple lines of evidence were evaluated to assess the sheet pile wall's effectiveness as a NAPL and dissolved phase plume migration barrier (CH2M HILL, 2013c). The various lines of evidence indicate that the sheet pile wall has a relatively moderate to high degree of effectiveness in hydraulically isolating the upland side of the Upper Aquifer from the Eagle Harbor side. Currently, while there is some hydraulic flux through the sheet pile wall via the seams, a comparison of current to historical tidal efficiency factor measurements combined with the sheet pile wall construction information indicates that the current hydraulic flux through the sheet pile wall is significantly less than during pre-wall conditions. NAPL observations within the five channels welded to the sheet pile wall seams suggest that NAPL migration through the sheet pile wall seams is possible. As with the hydraulic flux, current NAPL flux through the wall would be significantly less than pre-wall conditions. This is borne out by the observed reduction in NAPL seeps from pre-sheet pile wall conditions.

SECTION 7

References

Berkeley Hydrotechnique, 1989 *Final Pump Test Report For Eagle Harbor Site – Analyses*. June.

CH2M HILL. 1996. *Groundwater Extraction System Assessment, Report 1, Wyckoff Groundwater Operable Unit, Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Washington.* Report prepared for EPA. August.

CH2M HILL. 1997. *Remedial Investigation Report, Wyckoff Soil and Groundwater Operable Units, Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Washington.* Report prepared for EPA. June.

CH2M HILL. 2004a. *Wyckoff Site & Sheet Pile Wall Summary, Technical Memorandum*. April.

CH2M HILL. 2004b. *Geotechnical Data Report, Borings and Piezometer Installation-Upgradient Cut-off Wall, Wyckoff/Eagle Harbor Superfund Site.* Report prepared for EPA. September.

CH2M HILL. 2007a. *Sheet Pile Installation Summary Technical Memorandum, Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Washington.* June.

CH2M HILL, 2007b. *Groundwater Conceptual Site Model Update Report for the Former Process Area, Wyckoff/Eagle Harbor Superfund Site, Soil and Groundwater Operable Units.* April.

CH2M HILL, 2009. Soil Boring and Monitoring Well Construction Summary – Wyckoff/Eagle Harbor Superfund Site. January.

CH2M HILL. 2012. *2012 Field Investigation Technical Memorandum Wyckoff OU-1 Focused Feasibility Study*. September.

CH2M HILL. 2013a. *Quality Assurance Project Plan Wyckoff Upland NAPL Investigation*. January.

CH2M HILL. 2013b. *2013 Wyckoff Upland NAPL Field Investigation Technical Memorandum Field Summary Report*. June.

CH2M HILL. 2013c. *Wyckoff Sheet Pile Wall Evaluation*. August.

CH2M HILL. 2013d. *Evaluation of Wyckoff Groundwater Level Data June 24, 2012 through September 21, 2012*. January.

CH2M HILL. 2013e. *Technical Memorandum - Groundwater Quality Sampling Results for Wyckoff/Eagle Harbor Superfund Site—June 2012.* January.

Ecology and Environment, 1995. *On-Scene Coordinator's Report, Wyckoff Facility Operable Unit, Wyckoff/Eagle Harbor Superfund Site.* July.

Frans, L.M., Bachmann, M.P., Sumioka, S.S., and Olsen, T.D., 2011, *Conceptual model and numerical simulation of the groundwater-flow system of Bainbridge Island*, Washington: U.S. Geological Survey Scientific Investigations Report 2011–5021, 96 p.

Haugerud, Ralph, 2005, *Preliminary Geologic Map of Bainbridge Island*. Washington: U.S. Geological Survey Open-File Report 2005-1387, 1 pl.

Kato and Warren and Robinson and Nobel. 2000. *City of Bainbridge Island Level II Assessment--An Element of the Water Resource Study.* Report prepared for the City of Bainbridge Island. December.

Tetra Tech, 1988, *Assessment of Expedited Response Actions,* February.

U.S. Army Corps of Engineers (USACE). 1998. *Onshore Field Investigation Report for the Barrier Wall Design Project, Wyckoff Groundwater Operable Unit.* Report prepared for EPA. January.

———. 1998. *Offshore Field Investigation Report for the Barrier Wall Design Project, Wyckoff Groundwater Operable Unit.* Report prepared for EPA. April.

———. 2000. *Comprehensive Report, Wyckoff NAPL Field Exploration, Soil and Groundwater Operable Units, Wyckoff/Eagle Harbor Superfund Site, Bainbridge, Island, WA*. May.

———. 2006. *Thermal Remediation Pilot Study Summary Report, Revision 3.0, Wyckoff/Eagle Harbor Superfund Site, Soil and Groundwater Operable Units.* Report prepared for EPA. October.

———. 2007. *Wyckoff Second Five-Year Review Report for the Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Washington*. September 26, 2007.

U.S. Environmental Protection Agency (EPA), 2000. *Record of Decision, Wyckoff/Eagle Harbor Superfund Site, Soil and Groundwater Operable Units, Bainbridge Island, Washington.* February.

———. 2002. *Final Report: Wyckoff/Eagle Harbor Superfund Site Steam Injection Treatability Study.* U.S. Environmental Protection Agency, Robert S. Kerr Environmental Research Center, Ada, Oklahoma. July 11.

Appendix A
NAPL Characteristic Data and Aquitard Entry Pressure Calculation

NAPL Characteristic Data and Aquitard Entry Pressure Calculations – Wyckoff/Eagle Harbor Superfund Site Upland Area

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1.0 Introduction

This memorandum to file presents available NAPL characteristics data historically collected from site production wells. Using the historical NAPL properties data, the potential for NAPL to migrate into the Aquitard from the Upper Aquifer is assessed.

2.0 NAPL Characteristics Data

Historical NAPL characteristic data are available from the USACE 1999 pre-remedial design field exploration for the Wyckoff/Eagle Harbor Superfund Site (USACE, 2000). No new samples were collected during the spring 2013 field event for physical or chemical NAPL characterization.

Available data include NAPL product chemical composition, density, oil-water interfacial tension, and solubility measurements. Because the 1999 NAPL samples were collected from upland site wells with accumulated NAPL, these samples represent mobile phase product. These samples provide comparative information for assessing properties of Wyckoff NAPL originating from upland sources, although NAPL properties may change with subsurface transport to down-gradient areas. Changes to NAPL properties can occur through potential chromatographic-like separation, geochemical interaction with substrate, and constituent weathering. As a result, the NAPL samples collected from upland extraction wells may not fully represent the range of characteristics of all NAPL present in the upland area.

2.1 Chemical Composition

Table 2-1 presents the chemical composition of historical upland NAPL samples collected as part of the USACE 2000 field exploration activities. NAPL composition results are available for seven upland wells and one composited sample, with analyzed constituents including benzene, toluene, ethylbenzene, and xylenes (BTEX), low and high molecular weight polycyclic aromatic hydrocarbons (LPAHs and HPAHs), and pentachlorophenol (PCP). This data set was evaluated using the EPA Fingerprint Analysis of Leachate Contaminants (FALCON) analysis (EPA 2004) to identify the chemical signature of the NAPL samples. Figure 2-1 presents the graphical fingerprints of the PAH and PCP constituents for individual samples. The NAPL samples contained comparable proportions of naphthalene and other LPAHs including acenaphthene, fluorene, phenanthrene, and anthracene. Pyrene and fluoranthene were the most prominent HPAHs detected. PCP was detected in several samples but was a minor component compared to the LPAH and HPAH constituents. In general the chemical fingerprints of NAPL samples presented on Figure 2-1 exhibit limited variability and establish a consistent compositional pattern of PAHs and PCP. PW9 and the composite sample show the greatest variability with reduced naphthalene composition and enhanced dibenzofuran.

A 2001 investigation conducted by Battelle indicated that the fingerprint of total petroleum hydrocarbons (TPH) in Wyckoff sediment samples was characterized as consisting of various two-ring low-molecular weight PAH (LPAHs) (i.e. Carbon [C] 0 to C4 naphthalenes) and three- and four-ring LPAH and high-molecular weight PAH (HPAH) compounds (phenanthrene, anthracene, fluoranthene, and pyrene). No significant petroleum-derived components or contributions from plant waxes were identified. This investigation concluded the characteristics of TPH in the Wyckoff sediment samples are typical of various coal-derived liquid products formed during the heating/conversion of coal, most consistent with creosote (Battelle 2001).

2.2 Physical Characteristics

For the NAPL samples collected from the upland wells, Table 2-2a and 2-2b present density measurements of both groundwater and NAPL, Table 2-3 presents the interfacial tension measurements, and Table 2-4 presents the viscosity measurements. Measurements are presented for a temperature of 10°C, but measurements at other temperatures are also available (USEPA, 2002). These data can be used for assessing the potential for NAPL migration and estimate potential NAPL flux rates.

2.3 Data Quality Concerns

The quality of the NAPL physical property data obtained from previous investigations is of concern. The range of interfacial tension values obtained for NAPL-groundwater from the site are very low compared to published values for petroleum distillates (50 dynes/cm at 20° C) (API, 2002).

It was noted in the interfacial tension table notes from the USACE data set that one of the NAPL samples appeared to be an emulsion (USACE, 2000). To obtain accurate interfacial tension measurements, two distinct phases (NAPL and water) must be present. An additional sample appeared to contain two different NAPL products, one lighter than water and one denser than water. Finally, multiple samples were reported as having very little difference in density between the two fluids, making an accurate reading very difficult to obtain. USEPA also noted that the range of NAPL/water IFT values measured were close to the practical limits of measurability with the instrument used to conduct the measurements (USEPA, 2002).

3.0 Aquitard Entry Pressure Calculations

A range of anticipated values of non aqueous-phase liquid (NAPL) pool height in saturated sediment required for NAPL to enter the aquitard underlying the Wyckoff/Eagle Harbor Superfund Site was calculated using an air entry pressure scaling method and site data obtained from previous site investigations.

3.1 Methodology

Particle size data was obtained for 5 aquitard samples previously obtained and analyzed from the site. These data are included in Table 3-1. The percentages of sand, silt, and clay for each sample was entered into the USDA's pedotransfer function (PTF) Rosetta software package to obtain the van Genuchten parameters for each sample, including the air entry pressure (See Table 3-2). The average air entry pressure for the site was calculated as 65.90 cm water (2.16 feet water). This average air entry pressure value was carried forward in the evaluation to encompass the range of soil types observed in the aquitard across the site (USEPA, 2002).

The ratio of NAPL-water interfacial tension (IFT) to water-air interfacial tension was calculated based on previously measured site IFT data to scale the air entry pressure obtained from Rosetta (Table 1) to a NAPL entry pressure. The IFT values and scaling factors are shown in Table 3-3. These IFT values were reported in the *Final Report: Wyckoff/Eagle Harbor Superfund Site Steam Injection Treatability Study* (USEPA, 2002). Only the IFT measurements taken in the downward direction were used in this evaluation, as USEPA reported the downward reading values to be more within the range where measurements can be reliably made than those measured in the upward direction (USEPA, 2002).

This scaling factor is multiplied by the air entry pressure to calculate the NAPL entry pressure. The scaling factor accounts for NAPL as the non-wetting fluid as opposed to air, as assumed in the Rosetta PTF (Miller and Miller, 1956). Additionally, the published average NAPL-water IFT value for creosote NAPL (50 dynes/cm at 20°C) was used with the average measured site water-air IFT value (70.9 dynes/cm at 10°C) to obtain an "average" scaling factor, as the published value was thought to be more accurate than previously measured NAPL-water IFT values (API, 2002).

The resulting NAPL entry pressures, expressed in feet of water pressure head are shown in Table 3-4. Table 3-4 also displays the NAPL entry pressures converted from water pressure head to the height of NAPL saturated sediment in feet, based on the difference in density between the site NAPL and groundwater. In the saturated zone, the difference in density between the DNAPL and water is what induces pressure on the aquitard. The average measured density values for groundwater and DNAPL samples at each temperature were used in the unit conversions (Table 2-2a). These average density values were 1.006 g/mL and 1.033 g/mL for groundwater and DNAPL, respectively. Since the difference in densities between groundwater and DNAPL are relatively small, a large DNAPL pool height is required to produce the required entry pressure, as demonstrated by the much larger NAPL pool heights than water pressure head (Table 3-4).

Based on the available data for aquitard grain size distribution, interfacial tension, and groundwater and NAPL densities, a minimum NAPL pool height of 9.40 feet is required under current field conditions (~10 °C) for NAPL to enter the aquitard. However, there are some concerns about the quality of the available physical property data, as described in the following section.

3.2 Data Quality Concerns

The quality of the data obtained from previous investigations and used in this calculation is of concern. It was noted in the interfacial tension table notes from the USACE data set that one of the NAPL samples appeared to be an emulsion. To obtain accurate interfacial tension measurements, two distinct phases (NAPL and water) must be present. An additional sample appeared to contain two different NAPL products, one lighter than water and one more dense than water. Finally, multiple samples were reported as having very little difference in density between the two fluids, making an accurate reading very difficult to obtain. USEPA also notes that the range of NAPL/water IFT values measured were close to the practical limits of measurability with the instrument used to conduct the measurements (USEPA, 2002).

The range of interfacial tension values obtained for NAPL-groundwater from the site are very low compared to published values for creosote NAPLs. The lower end of the range of anticipated NAPL head values is based upon site-specific measured interfacial tension values (5.3 dynes/cm at 10 °C). Based on the possible inaccuracy of the very low measured IFT values and the reported difficulties obtaining measurements for some of the NAPL-groundwater sample pairs at the site (USEPA, 2002), a literature value for anticipated NAPL head values was calculated using the average published IFT for creosote (50 dynes/cm). However, the API guidance notes that field values of interfacial tension are normally much lower than laboratory-measured literature values, and therefore field values are generally preferred.

The density values used for NAPL also affect the final NAPL pool height value calculated, and there is uncertainty regarding the final pool height values reported based on using the average measured DNAPL density at the site rather than analyzing the NAPL entry pressures on a location by location basis with location-specific NAPL density data. Additionally, there is uncertainty in the average measured DNAPL density value, as it is significantly lower than the reported literature density values of creosote (1.050 g/mL) (Environment Agency, 2003).

Because of these uncertainties, it is recommended that new samples of NAPL and groundwater be obtained from the site and analyzed for IFT and density in order to better refine these results.

4.0 References

API, 2002. *Evaluating Hydrocarbon Removal from Source Zones and its Effect on Dissolved Plume Longevity and Magnitude*, September 2002, API Pub No 4715.

Environment Agency. 2003. *An Illustrated Handbook of DNAPL Transport and Fate in the Subsurface*. R&D Publication 133. United Kingdom Environment Agency. June.

Miller, E.E., Miller, R.D., 1956. Physical theory of capillary flow phenomena. J. Appl. Phys. 27, 324–332.

U.S. Environmental Protection Agency (USEPA), 2002. *Final Report: Wyckoff/Eagle Harbor Superfund Site Steam Injection Treatability Study.* USA Environmental Protection Agency. Ada, Oklahoma. July 11, 2002.

———. 2004. *Fingerprint Analysis of Contaminant Data: A Forensic Tool for Evaluating Environmental Contamination*. EPA/600/5-04/054, Office of Research and Development, Office of Solid Waste and Emergency Response, U.S. EPA. Russell H. Plumb, Jr., Lockheed Martin Environmental Services. May 2004.

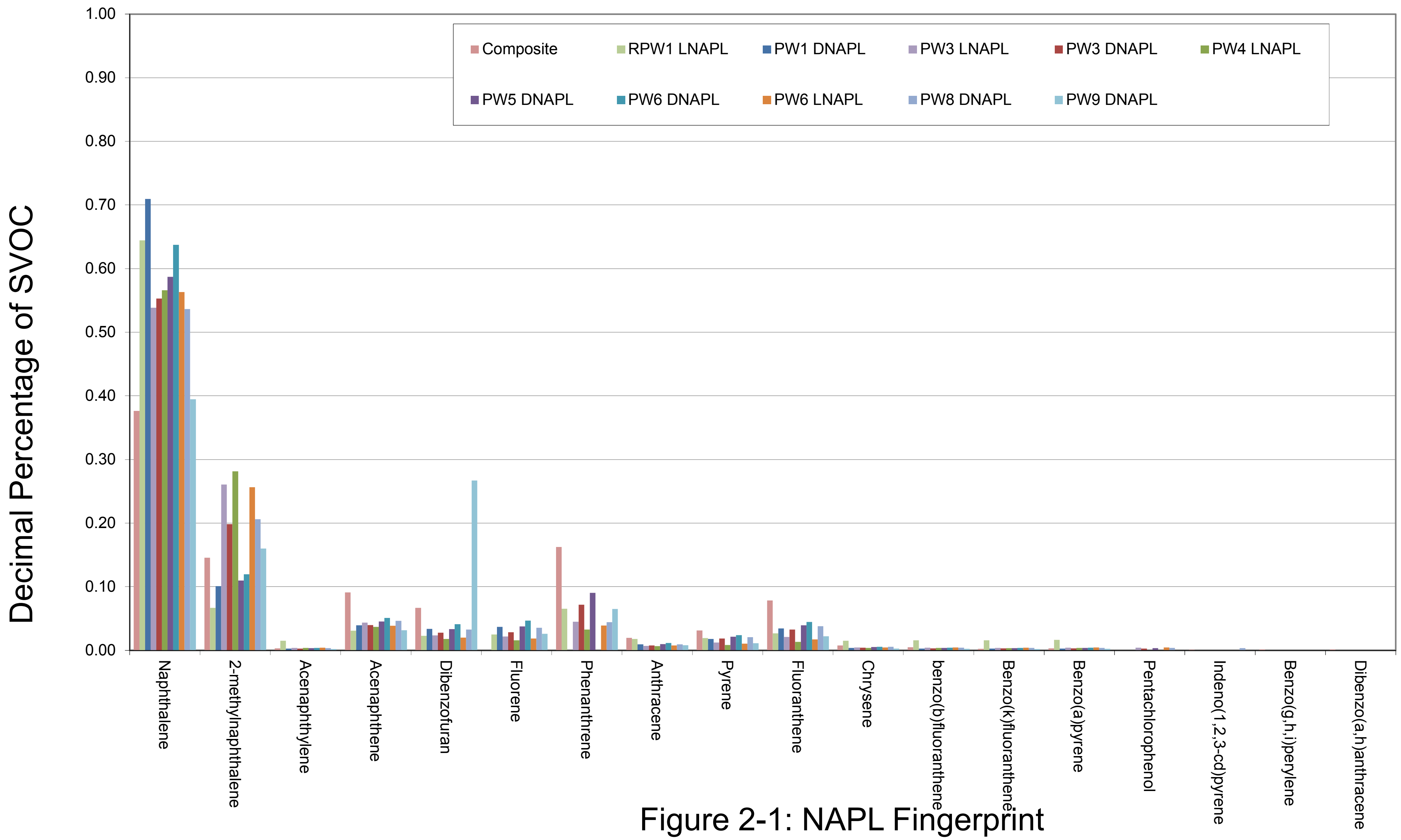

Figure 2-1: NAPL Fingerprint

Table 2-1

EPA Fingerprint Analysis of Leachate Contaminants (FALCON) for Wyckoff Superfund Site Historical Upland Samples

Wyckoff/Eagle Harbor Superfund Site

	Composite	RPW1 - LNAPL	RPW1-DNAPL								
Compound/Sample Name:	**Composite**	**RPW1 LNAPL**	**PW1 DNAPL**	**PW3 LNAPL**	**PW3 DNAPL**	**PW4 LNAPL**	**PW5 DNAPL**	**PW6 DNAPL**	**PW6 LNAPL**	**PW8 DNAPL**	**PW9 DNAPL**
Toluene	NA	NA	NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ethylbenzene	NA	NA	NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
m,p-Xylene	NA	NA	NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
o-Xylene	NA	NA	NA	0.0	0.0	2.2	0.0	0.0	0.0	0.0	2.4
Phenol	NA	NA	NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naphthalene	168.4	89.3	526.8	305.7	408.8	335.3	400.6	376.3	298	333.7	385.7
2-Methylnaphthalene	65.1	9.3	75	148.1	146.7	166.9	74.9	70.7	135.8	128.2	156.4
Acenaphthylene	1.4	2.1	2.2	2.2	2.2	2.3	2.4	2.3	2.3	2.3	2.3
Acenaphthene	40.8	4.3	29.4	24.8	29.5	22	31	30.1	20.6	29	31.1
Dibenzofuran	30.0	3.2	25.2	13.4	20.7	10.7	23	24.4	10.7	20.5	261
Fluorene	0.18	3.5	27.6	12.4	21.2	9.4	25.7	27.6	10	22.1	25.6
Pentachlorophenol	0.18	0	0	2.4	2.3	0	2.5	0	2.4	2.4	0
Phenanthrene	72.7	9.1	0	25.7	53.1	19.4	61.8	0	20.7	27.6	63.7
Anthracene	8.9	2.5	7.1	4.1	5.8	4	6.8	7	4.2	5.9	8.2
Carbazole	16.7	*	5.4	0	3.2	0	4.9	4.7	2.7	4.2	6.6
Fluoranthene	35.1	3.7	25.8	12	24.2	8.1	26.9	26.4	9.1	23.7	21.7
Pyrene	14.1	2.7	13.5	7.1	13.9	5.1	14.8	14.3	5.6	13	11.3
Benz(a)anthracene	4.6	*	3.4	2.6	3.8	2.3	4.1	3.7	2.4	3.9	2.9
Chrysene	3.5	2.1	3	2.6	3.3	2.4	3.8	3.5	2.5	3.6	2.8
Benzo(b)fluoranthene	2.3	2.2	2.3	2.4	2.5	2.3	2.8	2.6	2.4	2.7	2.4
Benzo(k)fluoranthene	1.1	2.2	2.2	2.3	2.4	2.2	2.6	2.4	2.3	2.5	2.3
Benzo(a)pyrene	1.5	2.3	2.3	2.4	2.5	2.3	2.7	2.5	2.4	2.6	2.4
Indeno(1,2,3-cd)pyrene	0.6	0	0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0
Dibenzo(a,h)anthracene	0.7	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Benzo(g,h,i)perylene	0.7	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Notes: Upland NAPL samples were collected as part of the USACE 2000 field exploration activities (USACE, 2000).

This dataset was evaluated using the EPA Fingerprint Analysis of Leachate Contaminants (FALCON, EPA 2004) analysis to identify the chemical signature of the NAPL samples.

*Peak area was below quantification limits

NA - not available, not presented in historical documentation

Table 2-2a

Groundwater Density at 10 C

Wyckoff/Eagle Harbor Superfund Site

Sample	Location	GW density at 10° C (g/mL)
99293528	EWC3	1
99293533	EW7	1.007
99293534	EW7	1.014
99293535	MW14	1.02
99293536	P03	1.006
99293537	P09	1.003
99293538	P011	0.999
99293539	P017	1.001
99293540	EW03	1.008
GW Statistics	Minimum	0.999
	Maximum	1.02
	Average	1.006
	Standard Deviation	0.007

Table 2-2b

NAPL Density at 10 C

Wyckoff/Eagle Harbor Superfund Site

Sample	**Location**	**NAPL density at 10° C (g/mL)**
9929352 P001 DNAPL Average density	P001	1.027
9929365-1 RPW-1 DNAPL Average density	RPW-1	1.052
9929365-2 RPW-3 DNAPL Average density	RPW-3	1.024
9929365-3 RPW-6 DNAPL Average density	RPW-6	1.045
9929365-4 RPW-5 DNAPL Average density	RPW-	1.036
9929365-6 RPW-8 DNAPL Average density	RPW-8	1.029
9929365-7 RPW-9 DNAPL Average density	RPW-9	1.044

Table 2-3

Interfacial Tension Measurements at 10 C

Wyckoff/Eagle Harbor Superfund Site

Fluid Pair	IFT (dynes/cm) at 10 C
Average Air/Water IFT	70.9
Maximum Air/Water IFT	76.8
Minimum Air/Water IFT	45.4
Literature Value NAPL/Water IFT	50
Average NAPL/Water IFT	12.5
Maximum NAPL/Water IFT	19.5
Minimum NAPL/Water IFT	5.3
Average NAPL/Air IFT	36.1
Maximum NAPL/Air IFT	41.4
Minimum NAPL/Air IFT	32.8
Notes: Literature value is for petroleum distillate (API, 2002)	

Table 2-4

NAPL Viscosity at 10 C

Wyckoff/Eagle Harbor Superfund Site

Sample	Location	Viscosity (Cp)
99293527	P001	12.4
99293650	RPW-1	17.4
99293652	RPW-3	11.3
99293653	RPW-6	15.8
99293654	RPW-5	14.9
99293656	RPW-8	15.8
99293657	RPW-9	9.9
99293658	RPW-4	4.9
99293651	RPW-1	17.4
99293655	RPW-3	9.1
99293659	RPW-6	5.7

Table 3-1
Particle Size Data - Aquitard Samples
Wyckoff/Eagle Harbor Superfund Site

	99CD01 45.5-46.5 ft	99CD02 48-49.5 ft	99CD03 31-33 ft	99CD04 41-43 ft	99CD05 57-59 ft
Bulk Density (g/cc)	1.37	1.85	1.63	1.33	1.95
Cation Exchance Capacity (meq/100g)	6.2	5.0	2.8	21	5.4
TOC (mg/kg)	1120	270	3850	3150	ND (<100)
Particle Size					
Description	Silt	Fine Sand	Silt	Silt	Medium Sand
Median grain size (mm)	0.007	0.237	0.007	0.006	0.339
Particle Size Distribution:					
Gravel	0	11.13	0	0	18.75
Coarse Sand	0	5.67	0	0	6.32
Medium Sand	0	16.24	0	0	19.62
Fine Sand	5.6	38.68	7.28	5.58	32.07
Silt	56.16	na	52.4	50.64	<2
Clay	38.22	na	40.33	43.51	<2
Silt and Clay	94.4	28.31	92.72	94.15	23.24

Notes:
na = not analyzed

Table 3-2

van Genuchten Parameters from Soil Type

Wyckoff/Eagle Harbor Superfund Site

Sample Name	Soil Type	van Genuchten Parameters from Rosetta				Calculated Air entry pressure (cm water)	Calculated air entry pressure (ft water)
		θr	Θs	N	α (cm water)		
99CD01	Silty Clay Loam	0.0966	0.4921	1.4545	0.0102	97.66	3.2
99CD02	Sand	0.0507	0.376	4.4249	0.0344	29.11	0.96
99CD03	Silty Clay	0.0979	0.4913	1.4302	0.0108	92.62	3.04
00CD04	Silty Clay	0.1015	0.5056	1.3932	0.0125	79.89	2.62
99CD05	Sand	0.0523	0.3766	3.1769	0.0331	30.21	0.99
Average						65.9	2.16

Table 3-3

Interfacial Tension Values and Scaling Factors

Wyckoff/Eagle Harbor Superfund Site

Temperature (°C)	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**
Average Air/Water IFT (dynes/cm)	70.9	67.7	71.2	69.8	68.5	67.4	66.9	65.9	63.5
Maximum Air/Water IFT (dynes/cm)	76.8	76.6	74.1	72.3	72.1	69.1	69.3	66.8	69.5
Minimum Air/Water IFT (dynes/cm)	45.4	62.4	61.6	66.2	60.5	65.5	59.7	65	51.4
Literature NAPL/Water IFT (dynes/cm)	50	50	50	50	50	50	50	50	50
Average NAPL/Water IFT (dynes/cm)*	12.5	13.3	13.3	13.1	11.9	13.8	11	12.5	12.4
Maximum NAPL/Water IFT (dynes/cm)*	19.5	22.6	19.7	18.8	21	16.9	15.6	12.9	19.8
Minimum NAPL/Water IFT (dynes/cm)*	5.3	4.4	6.3	7.7	5	12.4	5	12.1	6.6
Scaling Factor – Literature NAPL value	0.71	0.74	0.7	0.72	0.73	0.74	0.75	0.76	0.79
Scaling Factor – Average site NAPL value	0.18	0.2	0.19	0.19	0.17	0.21	0.16	0.19	0.2
Scaling Factor – Maximum site NAPL value	0.25	0.3	0.27	0.26	0.29	0.24	0.23	0.19	0.28
Scaling Factor – Minimum site NAPL value	0.12	0.07	0.1	0.12	0.08	0.19	0.08	0.19	0.13

Notes: *IFT data for NAPL/water is average, maximum, and minimum of DOWN direction data only. Noted in USACE dataset as being thought to be more within the reliably measurable range than those in the UP direction.

Scaling factors are based on similar parameters – Average IFT/Average IFT; Maximum IFT/maximum IFT, etc. Literature scaling factor is Literature value NAPL/water IFT over average water/air IFT

Table 3-4

Anticipated NAPL Entry Pressures

Wyckoff/Eagle Harbor Superfund Site

Temperature (°C)	10	20	30	40	50	60	70	80	90
Lower End Value (ft water)[a]	0.25	0.15	0.22	0.25	0.18	0.41	0.18	0.4	0.28
Average Value (ft water)[a]	0.38	0.42	0.4	0.41	0.38	0.44	0.35	0.41	0.42
Upper End Value (ft water)[a]	0.55	0.64	0.57	0.56	0.63	0.53	0.49	0.42	0.62
Literature Value (ft water)[a]	1.52	1.6	1.52	1.55	1.58	1.6	1.61	1.64	1.7
Lower End Value (NAPL Pool Height in Saturated Sediment [ft])[a]	9.4	5.67	8.23	9.36	6.65	15.24	6.74	14.98	10.33
Average Value (NAPL Pool Height in Saturated Sediment [ft])[a]	14.17	15.8	15	15.09	13.98	16.52	13.22	15.27	15.71
Upper End Value (NAPL Pool Height in Saturated Sediment [ft])[a]	20.43	23.74	21.4	20.93	23.44	19.68	18.12	15.54	22.93
Literature Value (NAPL Pool Height in Saturated Sediment [ft])[a]	56.76	59.44	56.52	57.65	58.74	59.7	60.15	61.06	63.37

[a] Lower end value based on minimum measured interfacial tension data. Upper value based on maximum measured interfacial tension data. Average value based on average measured interfacial tension data. Literature value based on published interfacial tension data for petroleum distillates (API, 2002).

Tables

TABLE 2-1
Historical Groundwater Investigation Chronology
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff / Eagle Harbor Superfund Site

Year	Investigation Activities	Reference(s)
1972	Investigations began due to reports of oil observed on the beach. Drilling of shallow soil borings and installation of slotted casings in the borings. Data from these “wells” were used to determine general hydrogeologic conditions at the site in order to evaluate possible strategies for eliminating oil seepage from the site to Puget Sound.	Harbinger. May 2, 1972. *Reports on Wood Preservative Seepage at the Eagle Harbor Plant.* Prepared for the Wyckoff Company, Seattle, Washington. Harbinger. June 12, 1972. *Report on Wood Preservative Seepage at the Eagle Harbor Plant.* Prepared for the Wyckoff Company, Seattle, Washington. CH2M HILL. September 29, 1972. *Abatement of Creosote Seeps at Eagle Harbor Plant.* Letter from W.T. Dehn to D. Johnson/Wyckoff Company, Seattle, Washington.Harbinger. October 20, 1972. *Report on Wood Preservative Seepage at the Eagle Harbor Plant.* Prepared for the Wyckoff Company, Seattle, Washington.
1986	Nine shallow monitoring wells (EW03 through EW08 and EW10 through EW12, 10.8 to 29 feet below ground surface [ft bgs]) and three deeper wells (EWC1 through EWC3, 59.7 to 64.5 ft bgs) were installed within the FPA. Water-level measurements and analytical data obtained from samples collected from the wells were used to evaluate hydrogeologic conditions and contaminant concentrations in groundwater at the FPA.	Entrix. December 9, 1986. *Data Report for the RCRA 3013 Investigation*. Prepared for the Wyckoff Company, Eagle Harbor, Washington.
1988	12 monitoring wells (MW13 through MW23, and MWC20) were installed at the Wyckoff Site. Well depths were between 20 and 60 ft bgs. Water-level measurements and analytical data collected from these wells and those installed in 1986 were used to evaluate hydrogeologic conditions and contaminant concentrations in groundwater, to assess potential risk, and to develop possible remedial actions. An aquifer pumping test was also conducted in 1988. Four pumping wells (PW1 through PW4) and 10 observation wells (OB1 through OB10) were installed for the test.	Tetra Tech. February 2, 1988. Final Report. *Assessment of Expedited Response Actions, Wyckoff Company*. Prepared for Jacobs Engineering Group, Bellevue, Washington. Applied Geotechnology Inc. (AGI). December 16, 1988. *Aquifer Pumping Tests, Data Package, Wyckoff Company, Eagle Harbor, Washington*. Bellevue, Washington.

TABLE 2-1
Historical Groundwater Investigation Chronology
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff / Eagle Harbor Superfund Site

Year	Investigation Activities	Reference(s)
1989	Seventeen shallow observation wells (PO1 through PO17, 19 to 20 ft bgs) and one deeper observation well (PO18, 47 ft bgs) were installed to gauge NAPL thickness in the FPA. Water-level data, NAPL thickness measurements, and analytical results obtained from samples collected at these wells were used to evaluate the extent of light NAPL (LNAPL) and characterize contaminant concentrations in the upper aquifer. Three extraction wells (PW5, PW6, and PW7) were also installed to depths of 39 to 40 ft bgs.	Applied Geotechnology Inc. (AGI). June 2, 1989. Data Report, *Further Product Exploration, Wyckoff Company, Eagle Harbor Site. Bellevue, Washington*.
1994	Focused Remedial Investigation/Feasibility Study (RI/FS) for groundwater. Five additional monitoring wells were installed in the FPA, two in the upper aquifer (CW03 and CW04) and three in the lower aquifer (CW01, CW02, and CW05). Water-level measurements and groundwater samples were collected from these wells and from 29 previously installed monitoring, observation, and extraction wells. The samples were analyzed for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides, and polychlorinated biphenyls (PCBs). In addition, a sample of dense NAPL (DNAPL) was collected from one well (CW05) and analyzed for physical properties.	CH2M HILL. July 13, 1994. *Final Focused RI/FS for the Groundwater Operable Unit for the Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Washington*. Prepared for U.S. Environmental Protection Agency Region 10, Seattle, Washington.
1995	Supplemental Remedial Investigation. Nine new monitoring wells were installed. Six wells were completed in the upper aquifer: three to monitor LNAPL (CW07, CW08, and CW13) and three to monitor DNAPL (CW06, CW10, and CW14). Three wells were completed in the lower aquifer (CW09, CW12, and CW15) to evaluate the interconnection between the lower and upper aquifers and to monitor water quality in the lower aquifer. The new wells, as well as 10 existing wells, were sampled as part of the investigation. The groundwater samples were analyzed for PAHs, polychlorinated phenols, VOCs, base/neutral and acid extractables (BNAs), pesticides, and PCBs.	CH2M HILL, June 1997. *Remedial Investigation Report for the Wyckoff Soil and Groundwater Operable Units*. Prepared for U.S. Environmental Protection Agency Region 10, Seattle, Washington.

TABLE 2-1

Historical Groundwater Investigation Chronology

2014 Conceptual Site Model Update for the Former Process Area

Wyckoff / Eagle Harbor Superfund Site

Year	Investigation Activities	Reference(s)
1995	Groundwater Extraction System Assessment Report. A large scale step rate pumping test was conducted at the Wyckoff Groundwater Operable Unit to evaluate fluid-level, NAPL recovery, and water quality data collected from individual extraction wells. The assessment was conducted to determine the effectiveness of the extraction system in containing contaminants beneath the facility and determine the most effective pumping rate for optimizing NAPL recovery.	CH2M HILL, June 1996. *Groundwater Extraction System Assessment Report No. 1 & No. 2.* Prepared for U.S. Environmental Protection Agency Region 10, Seattle, Washington.
1999	NAPL field Investigation. USACE conducted an intensive field investigation in the FPA to more clearly define the extent of NAPL in the subsurface and to characterize the continuity and topography of the upper aquitard. The investigation focused primarily on soil conditions above and below the water table. Two monitoring wells (99CD-MW02 and 99CD-MW04) were installed in the lower portion of the aquitard where sand lenses and DNAPL had been observed.	U.S. Army Corps of Engineers [USACE], May 2000. *Comprehensive Report, Wyckoff NAPL Field Exploration*.
2001	Construction of the perimeter sheet pile wall completed. The wall is approximately 1,880 feet long and extends approximately 20 to 90 feet below grade. It was constructed with the intention to embed the bottom of the wall into the aquitard layer. Construction of a 536-foot-long sheet pile surrounding the steam injection pilot text area was also completed.	CH2M HILL. 2004. *Wyckoff Site & Sheet Pile Wall Summary, Technical Memorandum*. April. CH2M HILL, 2007. *Sheet Pile Installation Summary Technical Memorandum*. June.
2002	Thermal Pilot Study Baseline Investigation. USACE conducted a baseline investigation of groundwater conditions in the vicinity of the thermal treatment pilot study area in the central portion of the FPA. Groundwater samples were obtained from seven extraction wells (E-01 through E-07, five lower-aquifer monitoring wells (99CD-MW02, 99CD-MW04, CW05, CW09, and CW15), and three upper-aquifer monitoring wells (MW17, MW18, and MW19). The samples were analyzed for PAHs and PCP.	USACE, 2006. *Thermal Remediation Pilot Study Summary Report.*

TABLE 2-1
Historical Groundwater Investigation Chronology
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff / Eagle Harbor Superfund Site

Year	Investigation Activities	Reference(s)
2004 to 2013	Groundwater monitoring to demonstrate hydraulic containment and monitor changes in contaminant levels in the upper and lower aquifers was initiated in 2004. The current hydraulic containment monitoring program involves continuous water-level monitoring using data loggers installed in 17 upper-aquifer wells and eight lower-aquifer wells. Contaminant concentrations in the lower aquifer and select upper aquifer wells are monitored on an annual basis.	CH2M HILL, various Technical Memoranda from September 2004b through March 2013. *Evaluation of Groundwater Level Data*.
2013	Upland NAPL Field investigation. Field investigation using Tar-specific Green Optical Scanning Tool (TarGOST) to semi-quantitatively determine the relative distribution of NAPL in the subsurface at the Wyckoff Site upland area. The investigation included the advancement of 141 TarGOST probes and 20 confirmation borings over two investigation phases in January through March 2013.	CH2M HILL, 2013. 2013 Wyckoff Upland Non-Aqueous Phase Liquid (NAPL) Technical Memorandum
2013	Evaluation of the integrity of the sheet pile wall and identify possible pathways for migration of NAPL and/or contaminated groundwater to Eagle Harbor. Field measurements (salinity profiles under pumping and non-pumping conditions, groundwater level data, NAPL measurements) and evaluation of existing data (sheet pile wall as-built specifications, boring logs and well construction diagrams).	CH2M HILL, 2013. Wyckoff Sheet Pile Wall Evaluation.

Table 3-1
Wyckoff Well Data
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff / Eagle Harbor Superfund Site

Monitoring Well Identification	Type of Well	Aquifer	Surveyed Ground Elevation (ft MLLW)	Surveyed Outer Casing Elevation (ft MLLW)	Surveyed Inner Casing Elevation (ft MLLW)	Top of Screen (ft bgs)	Bottom Of Screen (ft bgs)	Sump Length (ft)	Total Well Depth (ft bgs)	Well Diameter (inches)
02CD-MW01	Monitoring Well	Lower	16.13	18.34	18.01	53.0	63.0	0	63.0	2
99CD-MW02A	Monitoring Well	Lower	14.82	17.29	16.72	72.5	82.5	0	82.5	2
99CD-MW04A	Monitoring Well	Lower	16.18	18.54	18.17	66.0	76.0	0	76.0	2
CW01	Monitoring Well	Lower	59.04	61.82	61.12	52.0	62.0	3	65.0	4
CW02	Monitoring Well	Lower	17.17	20.10	19.60	67.0	77.0	3	80.0	4
CW03	Monitoring Well	Upper	17.06	19.91	19.43	39.0	49.0	3	52.0	4
CW04	Monitoring Well	Upper	15.11	18.02	17.59	49.0	67.0	3	70.0	4
CW05	Monitoring Well	Lower	15.93	18.96	18.45	58.0	99.0	3	102.0	4
CW06	Monitoring Well	Upper	14.82	16.97	16.77	54.5	64.5	3	67.5	4
CW07	Monitoring Well	Upper	14.74	17.46	16.84	5.0	20.0	3	23.0	4
CW08	Monitoring Well	Upper	15.59	18.35	18.00	5.0	20.0	3	23.0	4
CW09	Monitoring Well	Lower	15.56	18.49	17.94	95.0	105.0	3	108.0	4
CW10	Monitoring Well	Upper	15.32	18.03	17.53	49.0	59.0	3	62.0	4
CW12	Monitoring Well	Lower	16.39	19.25	18.79	55.0	65.0	3	68.0	4
CW13	Monitoring Well	Upper	15.03	18.20	17.52	5.0	20.0	3	23.0	4
CW14	Monitoring Well	Upper	15.09	17.85	17.18	26.0	36.0	3	39.0	4
CW15	Monitoring Well	Lower	14.46	17.06	16.48	85.0	95.0	3	98.0	4
E-01	Steam Pilot Well	Upper	14.51	21.66	N/A	4.5	31.4	5	36.4	10
E-02	Steam Pilot Well	Upper	18.61	21.64	N/A	6.6	35.5	5	40.5	10
E-03	Steam Pilot Well	Upper	19.04	21.05	N/A	7.6	28.8	5	33.8	10
E-04	Steam Pilot Well	Upper	19.21	21.73	N/A	7.0	31.5	5	36.5	10
E-05	Steam Pilot Well	Upper	19.31	21.57	N/A	6.6	30.0	5	35.0	10
E-06	Steam Pilot Well	Upper	18.69	20.63	N/A	7.4	38.0	5	43.0	10
EW03	Monitoring Well	Upper	17.25	17.51	17.38	17.5	22.5	1	23.5	2
EW04	Monitoring Well	Upper	N/A	N/A	N/A	17.0	22.0	1	23.0	2
EW07	Monitoring Well	Upper	15.15	17.41	17.01	15.0	20.0	1	21.0	2
EW08	Monitoring Well	Upper	15.25	18.46	17.52	4.8	9.8	1	10.8	2
EWC3	Monitoring Well	Upper	15.55	15.55	15.26	58.5	63.5	1	64.5	2
MW14	Monitoring Well	Upper	15.86	18.59	18.05	7.0	17.0	5	22.0	2
MW15	Monitoring Well	Upper	15.95	15.97	15.62	5.0	15.0	7	22.0	2
MW16	Monitoring Well	Upper	14.35	14.53	14.03	5.0	15.0	7.5	22.5	2
MW17	Monitoring Well	Upper	16.39	19.27	19.21	5.0	15.0	15	30.0	2
MW18	Monitoring Well	Upper	15.95	16.22	16.18	5.0	15.0	7	22.0	2
MW19	Monitoring Well	Upper	18.74	18.94	18.60	5.0	15.0	5	20.0	2
MW21	Monitoring Well	Upper	18.75	18.82	18.41	8.5	18.5	5	23.5	2
MW23	Monitoring Well	Upper	18.35	18.15	17.60	5.0	15.0	5	20.0	2
P-1L	Monitoring Well	Lower	N/A	N/A	N/A	85.0	95.0	2	97.0	2
P-2L	Monitoring Well	Lower	N/A	N/A	N/A	102.6	112.6	2	114.6	2
P-3L	Monitoring Well	Lower	N/A	N/A	N/A	110.4	120.4	2	122.4	2
P-4L	Monitoring Well	Lower	N/A	N/A	N/A	78.8	88.8	2	90.8	2
P-5L	Monitoring Well	Lower	N/A	N/A	N/A	68.0	78.0	2	80.0	2
P-6L	Monitoring Well	Lower	N/A	N/A	N/A	75.0	85.0	2	87.0	2
PO01	Monitoring Well	Upper	15.75	18.85	18.09	4.0	14.0	3	17.0	2
PO03	Monitoring Well	Upper	14.37	17.01	16.51	4.0	14.0	3	17.0	2
PO04	Monitoring Well	Upper	15.10	17.16	16.83	4.5	14.5	3	17.5	2
PO05	Monitoring Well	Upper	14.67	17.35	16.87	4.5	14.5	3	17.5	2
PO09	Monitoring Well	Upper	16.52	19.04	18.69	5.0	15.0	3	18.0	2
PO13	Monitoring Well	Upper	15.05	17.35	16.93	5.0	15.0	3	18.0	2
PO18	Monitoring Well	Upper	16.40	18.01	17.75	5.0	15.0	1	16.0	2
PW8	Extraction Well	Upper	14.42	16.11	16.22	5.0	48.0	4	52.0	2
PW9	Extraction Well	Upper	N/A	N/A	N/A	4.0	34.0	6	40.0	8
PZ-03	Monitoring Well	Lower	18.14	20.43	20.01	20.0	30.0	2	32.0	2
PZ-05	Monitoring Well	Lower	20.60	22.82	22.24	3.0	8.0	2	10.0	2
PZ-06	Monitoring Well	Upper	19.47	22.38	21.98	1.0	6.0	2	8.0	2
PZ-07	Monitoring Well	Upper	20.22	21.31	20.88	2.0	12.0	2	14.0	2
PZ-08	Monitoring Well	Lower	17.99	20.25	19.92	15.0	25.0	2	27.0	2
PZ-09	Monitoring Well	Lower	18.16	20.23	19.89	15.0	25.0	2	27.0	2
PZ-10	Monitoring Well	Lower	18.25	20.37	20.10	15.0	25.0	2	27.0	2
PZ-11	Monitoring Well	Lower	18.23	20.48	20.13	15.0	25.0	2	27.0	2
PZ-12	Monitoring Well	Lower	18.00	20.14	19.88	15.0	25.0	2	27.0	2
RPW1	Extraction Well	Upper	15.95	16.82	16.66	5.0	38.0	4	42.0	8
RPW2	Extraction Well	Upper	14.87	15.45	15.27	5.0	55.0	4	59.0	8
RPW3	Extraction Well	Upper	15.57	16.27	**16.08**	4.2	57.0	4	61.0	8
RPW4	Extraction Well	Upper	15.61	15.97	16.30	5.0	49.4	4	53.4	8
RPW5	Extraction Well	Upper	14.34	15.20	15.02	5.0	54.0	4	58.0	8
RPW6	Extraction Well	Upper	15.69	16.07	16.45	4.1	35.6	4	39.6	8
RPW7	Monitoring Well	Upper	16.54	16.87	17.30	5.0	46.0	4	50.0	8
SE-01	Monitoring Well	Upper	N/A	N/A	N/A	37.9	47.9	2	49.9	2
SE-02	Monitoring Well	Lower	N/A	N/A	N/A	38.1	48.1	2	50.1	2
VG-1L	Monitoring Well	Lower	N/A	N/A	N/A	88.5	98.5	2	100.5	2
VG-2L	Monitoring Well	Lower	N/A	N/A	N/A	114.7	124.7	2	126.7	2
VG-2U	Monitoring Well	Upper	N/A	N/A	N/A	78.7	88.7	2	90.7	2
VG-3L	Monitoring Well	Lower	N/A	N/A	N/A	85.4	95.4	2	97.4	2
VG-3U	Monitoring Well	Upper	N/A	N/A	N/A	49.9	59.3	2	61.3	2
VG-4L	Monitoring Well	Lower	N/A	N/A	N/A	75.0	85.0	2	87.0	2
VG-5L	Monitoring Well	Lower	N/A	N/A	N/A	60.6	70.6	2	72.6	2
VG-5U	Monitoring Well	Upper	N/A	N/A	N/A	15.4	25.4	2	27.4	2

Notes
bgs = below ground surface
ft = feet
MLLW = mean low low water

Table 3-2

Groundwater Extraction Volumes by Well - April 2012 through March 2013

2014 Conceptual Site Model Update for the Former Process Area

Wyckoff / Eagle Harbor Superfund Site

Month-Year	RPW1	RPW2	RPW3	RPW4	RPW5	RPW6	RPW7	RPW8	E-02	E-06	All WELLS (gallons per month)	All WELLS (gallons per minute)
Apr-12	178,424	611,287	0	412,687	392,961	152,531	358,862	104,209	155,131	221,681	2,587,773	59.0
May-12	0	466,212	0	369,560	359,225	0	341,710	21,226	0	243,041	1,800,974	41.1
Jun-12	0	370,019	0	270,843	303,368	0	299,951	9,294	0	216,482	1,469,957	33.5
Jul-12	0	251,638	0	178,006	219,366	0	162,043	0	47,770	128,403	987,226	22.5
Aug-12	0	0	0	0	0	0	0	0	0	0	0	0.0
Sep-12	68,083	214,909	0	173,030	189,252	78,565	177,359	22,698	83,300	107,431	1,114,627	25.4
Oct-12	84,355	299,780	0	260,180	270,841	90,955	262,597	48,775	0	149,738	1,467,221	33.5
Nov-12	238,749	523,216	0	370,109	466,525	244,943	337,190	203,013	178,826	189,121	2,751,692	62.8
Dec-12	352,981	663,175	0	495,308	601,883	302,264	355,610	210,368	203,679	196,489	3,381,757	77.2
Jan-13	268,947	566,437	0	318,153	489,888	223,016	271,431	159,718	145,059	145,157	2,587,806	59.0
Feb-13	68,089	537,702	0	352,233	429,909	81,317	295,042	63,149	45,032	167,194	2,039,667	46.5
Mar-13	0	516,014	0	378,775	417,206	0	298,954	0	0	180,098	1,791,047	40.9
TOTAL Extracted April 2012 through March 2013 (gallons)	1,259,628	5,020,389	0	3,578,884	4,140,424	1,173,591	3,160,749	842,450	858,797	1,944,835	21,979,747	
Average (gallons per month)	104,969	418,366	0	298,240	345,035	97,799	263,396	70,204	71,566	162,070	1,831,646	
Average (gallons per minute)	2.4	9.5	0.0	6.8	7.9	2.2	6.0	1.6	1.6	3.7	41.8	
Minimum (gallons per month)	0	0	0	0	0	0	0	0	0	0	0	
Maximum (gallons per month)	352,981	663,175	0	495,308	601,883	302,264	358,862	210,368	203,679	243,041	3,381,757	

Table 3-3

LNAPL and DNAPL Removed from Extraction Wells and Plant Tanks - March 26, 2012 through March 25, 2013

2014 Conceptual Site Model Update for the Former Process Area

Wyckoff / Eagle Harbor Superfund Site

	RPW1		RPW2		RPW4		RPW5		RPW6		RPW8		RPW9		Plant
Date	LNAPL Pumped (gal)	DNAPL Pumped (gal)	LNAPL Pumped (gal)	DNAPL Pumped (gal)	LNAPL Pumped (gal)	DNAPL Pumped (gal)	LNAPL Pumped (gal)	DNAPL Pumped (gal)	LNAPL Pumped (gal)	DNAPL Pumped (gal)	LNAPL Pumped (gal)	DNAPL Pumped (gal)	LNAPL Pumped (gal)	DNAPL Pumped (gal)	NAPL (gal)
March-12	11	30	15	34				28		11		14		11	
April-12		41		32				44				18			
May-12															
June-12				43	23			41				26			
July-12															
August-12															
September-12	17	41		37				34				15			
October-12															
November-12		34		21				32				31			
December-12		43		17				23				18		28	
January-13		38	23	38	31			54				23		23	
February-13		24		44				44				21			
March-13				37				43				31			
Total Gallons Pumped March 23, 2012 through March 25, 2013	28	251	38	303	54	0	0	343	0	11	0	197	0	62	2,945
Number Times Pumped	2	7	2	9	2	0	0	9	0	1	0	9	0	3	0

Total LNAPL Recovered - Wells	120	Gallons	988	pounds	
Total DNAPL Recovered - Wells	1,167	Gallons	10,060	pounds	
Total Product Recovered - Wells	1,287	Gallons	11,048	pounds	
Total NAPL Removed - Plant Tanks	2,945	Gallons	25,278	pounds*	(note: for purpose of this estimate, assumed to be 90 percent DNAPL and 10 percent LNAPL)
Total Product Removed - Wells and Plant	4,232	Gallons	36,326	pounds	

Table 3-4

Estimated Mass of Dissolved Contaminants Removed and Treated - March 27, 2012 to March 26, 2013

2014 Conceptual Site Model Update for the Former Process Area

Wyckoff / Eagle Harbor Superfund Site

Date	SP-0: Plant Influent				Estimated Mass Removed			Removal Efficiency		
	Weekly Influent (gal)	Total PAH (ug/L)	PCP (ug/L)	O&G (mg/L)	PAHs (lbs)	PCP (lbs)	O&G (lbs)	PAHs (lbs/gal)	PCP (lbs/gal)	O&G (lbs/gal)
3/27/2012	641,932	11,000	170	5.6 J	58.9	0.91	30.0	9.2E-05	1.4E-06	4.7E-05
4/3/2012	544,671	14,000	180	29.2 J	63.6	0.82	132.7	1.2E-04	1.5E-06	2.4E-04
4/10/2012	641,139	27,000	180	20.6 J	144.4	0.96	110.2	2.3E-04	1.5E-06	1.7E-04
4/17/2012	611,865	42,000	150	28.5 J	214.4	0.77	145.5	3.5E-04	1.3E-06	2.4E-04
4/24/2012	632,719	21,000	170	23.3 J	110.9	0.90	123.0	1.8E-04	1.4E-06	1.9E-04
5/1/2012	493,614	11,000	140	7.8 J	45.3	0.58	32.1	9.2E-05	1.2E-06	6.5E-05
5/8/2012	431,411	11,000	120	7.8 J	39.6	0.43	28.1	9.2E-05	1.0E-06	6.5E-05
5/15/2012	425,315	24,000	120	15.2 J	85.2	0.43	53.9	2.0E-04	1.0E-06	1.3E-04
5/22/2012	384,443	12,000	130	14.9 J	38.5	0.42	47.8	1.0E-04	1.1E-06	1.2E-04
5/29/2012	385,266	22,000	130	30.5 J	70.7	0.42	98.1	1.8E-04	1.1E-06	2.5E-04
6/5/2012	391,080	10,000	140	9.3 J	32.6	0.46	30.3	8.3E-05	1.2E-06	7.8E-05
6/12/2012	389,687	19,000	130	11.9 J	61.8	0.42	38.7	1.6E-04	1.1E-06	9.9E-05
6/19/2012	398,518	11,000	140	8.6 J	36.6	0.47	28.6	9.2E-05	1.2E-06	7.2E-05
6/26/2012	243,485	19,000	180	11.6 J	38.6	0.37	23.6	1.6E-04	1.5E-06	9.7E-05
7/3/2012	229,124	13,000	140	13.6 J	24.9	0.27	26.0	1.1E-04	1.2E-06	1.1E-04
7/10/2012	235,068	13,000	180	7.6 J	25.5	0.35	14.9	1.1E-04	1.5E-06	6.3E-05
7/17/2012	237,542	13,000	180	9.6 J	25.8	0.36	19.0	1.1E-04	1.5E-06	8.0E-05
7/24/2012	270,328	16,000	160	7 J	36.1	0.36	15.3	1.3E-04	1.3E-06	5.7E-05
7/31/2012	236,401	NC	NC	NC	31.6	0.32	13.4	1.3E-04	1.3E-06	5.7E-05
8/7/2012	0									
8/14/2012	0									
8/21/2012	0									
8/28/2012	0									
9/4/2012	0									
9/11/2012	340,282	13,000	260	8.6 J	36.9	0.74	24.4	1.1E-04	2.2E-06	7.2E-05
9/18/2012	308,854	9,700	170	9.9 J	25.0	0.44	25.5	8.1E-05	1.4E-06	8.3E-05
9/25/2012	294,548	14,000	150	8.4 J	34.4	0.37	20.6	1.2E-04	1.3E-06	7.0E-05
10/2/2012	247,559	13,000	190	8.6 J	26.9	0.39	17.8	1.1E-04	1.6E-06	7.2E-05
10/9/2012	241,505	17,000	210	12.1 J	34.3	0.42	24.4	1.4E-04	1.8E-06	1.0E-04
10/16/2012	245,180	15,000	190	10 J	30.7	0.39	20.5	1.3E-04	1.6E-06	8.3E-05
10/23/2012	329,486	12,000	240	7 J	33.0	0.66	19.2	1.0E-04	2.0E-06	5.8E-05
10/30/2012	497,219	13,000	220	6.6 J	53.9	0.91	27.4	1.1E-04	1.8E-06	5.5E-05
11/6/2012	607,874	14,000	200	8.2 J	71.0	1.01	41.6	1.2E-04	1.7E-06	6.8E-05
11/13/2012	623,710	13,000	190	7.6 J	67.7	0.99	39.6	1.1E-04	1.6E-06	6.3E-05
11/20/2012	547,176	44,000	230	77.8 J	200.9	1.05	355.2	3.7E-04	1.9E-06	6.5E-04
11/27/2012	722,695	23,000	230	8.0 J	138.7	1.39	48.2	1.9E-04	1.9E-06	6.7E-05
12/4/2012	769,215	27,000	200	13.5 J	173.3	1.28	86.7	2.3E-04	1.7E-06	1.1E-04
12/11/2012	781,306	13,000	220	13.4 J	84.8	1.43	87.4	1.1E-04	1.8E-06	1.1E-04
12/18/2012	753,508	18,000	230	8.4 J	113.2	1.45	52.8	1.5E-04	1.9E-06	7.0E-05
12/25/2012	762,719	15,000	270	6.5 J	95.5	1.72	41.4	1.3E-04	2.3E-06	5.4E-05
1/3/2013	641,019	16,000	260	14.1 J	85.6	1.39	75.4	1.3E-04	2.2E-06	1.2E-04
1/8/2013	529,771	15,000	270	11.7 J	66.3	1.19	51.7	1.3E-04	2.3E-06	9.8E-05
1/15/2013	306,335	28,000	310	304 J	71.6	0.79	777.1	2.3E-04	2.6E-06	2.5E-03
1/22/2013	681,335	18,000	280	37.0 J	102.3	1.59	210.4	1.5E-04	2.3E-06	3.1E-04
1/29/2013	681,328	39,000	240	68.9 J	221.7	1.36	391.7	3.3E-04	2.0E-06	5.7E-04
2/5/2013	628,520	15,000	220	10 J	78.7	1.15	52.4	1.3E-04	1.8E-06	8.3E-05
2/12/2013	423,824	30,000	190	48 J	106.1	0.67	170.5	2.5E-04	1.6E-06	4.0E-04
2/19/2013	435,078	42,000	180	24.3 J	152.5	0.65	88.2	3.5E-04	1.5E-06	2.0E-04
2/26/2013	442,731	13,000	180	16.2 J	48.0	0.66	59.8	1.1E-04	1.5E-06	1.4E-04
3/5/2013	406,190	11,000	170	8.5 J	37.3	0.58	28.8	9.2E-05	1.4E-06	7.1E-05
3/12/2013	385,142	26,000	190	47.1 J	83.6	0.61	151.4	2.2E-04	1.6E-06	3.9E-04
3/19/2013	407,101	16,000	180	19.4 J	54.4	0.61	65.9	1.3E-04	1.5E-06	1.6E-04
3/26/2013	384,238	13,000	170	9.2 J	41.7	0.55	29.5	1.1E-04	1.4E-06	7.7E-05
Total	**22,249,056**				**3,555**	**36**	**4,097**	**0.0073**	**0.00008**	**0.0092**

NC = not collected

J = estimated concentration

Table 4-1

Regional Hydrogeologic Units, Thicknesses, Depths, and Hydraulic Conductivities

2014 Conceptual Site Model Update for the Former Process Area

Wyckoff / Eagle Harbor Superfund Site

Regional Hydrostratigraphic Unit		Thickness Range (feet)	Top Elevation Range (feet above sea level)	Hydraulic Conductivity Range and Median (feet/day)	Present Beneath Wyckoff Site?	Approximate Depth Interval (feet above sea level)
Qvt	Vashon Till Confining Unit	10 to 100	---	---	No	---
Qva	Vashon Till Advance Aquifer	20 to 200	0 to 300	0.70 to 13,000 [37]	No	---
QC1	Upper Confining Unit	50 to 300	-80 to 300	3.8 to 7.7 [4.9]	Yes	-100 to 0
QC1pi	Permeable interbeds	10 to 50	0 to 200	7.4 to 750 [13]	No	---
QA1	Sea Level Aquifer	25 to 200	-200 to 200	0.20 to 8,100 [22]	Yes	-150 to -100
QC2	Middle Confining Unit	150 to 600	-200 to 0	3.8 to 7.7 [4.9]	Yes	-230 to -150
QA2	Glaciomarine aquifer	20 to 300	-500 to -300	0.18 to 87 [5.4]	Yes	-350 to -230
QC3	Lower confining unit	50 to 300	-800 to -400	3.8 to 7.7 [4.9]	Yes	-680 to -350
QA3	Deep aquifer	50 to 300	-900 to -600	5.2 to 60 [26]	Yes	-800 to -680
QC4	Basal confining unit	unknown	-800 to -400	3.8 to 7.7 [4.9]	Yes	-1150 to -800
BR	Bedrock	unknown	-900 to 0	0.0043 to 5.7 [2.8]	Yes	below -1150

Information Source: Frans, Bachmann, Sumioka, and Olsen (2011)

--- not reported or not applicable

Table 5-1

Volume Estimates of NAPL-Impacted Soil Developed Using MVS

2014 Conceptual Site Model Update for the Former Process Area

Wyckoff / Eagle Harbor Superfund Site

	Volume >10%RE (CY)	Precent of total volume ≥10%RE by Compartment
Total	68,526	100%
Compartment 1	37,396	55%
Compartment 2	12,130	18%
Compartment 3	19,001	28%

Notes:

CY = cubic yards

Table 5-2

Compartmental Volumes of Soil Types with TarGOST Response ≥10% RE

2014 Conceptual Site Model Update for the Former Process Area

Wyckoff / Eagle Harbor Superfund Site

Soil Type	SubArea 2 (CY)	SubArea 3 (CY)	SubArea 4 (CY)	SubArea 5 (CY)	Total (CY)
Compartment 1: Ground Surface to -5 ft MLLW					
Gravel	345	4,076	207	4,692	9,320
Sand	852	10,530	2,582	8,275	22,239
Silt	1,077	1,889	19	1	2,986
Clay	692	909	18	0	1,619
Fill	6	1,118	32	75	1,231
Total	2,972	18,522	2,859	13,043	37,396
Compartment 2: -5 ft MLLW to 10 ft above Aquitard					
Gravel	38	1,765	319	1,528	3,650
Sand	1,290	3,793	282	2,334	7,699
Silt	170	576	21	0	767
Clay	5	7	0	0	12
Fill	0	0	0	0	0
Total	1,504	6,142	622	3,862	12,130
Compartment 3: 10 ft above Aquitard to Bottom of Boring					
Gravel	688	363	169	63	1,283
Sand	6,335	4,004	301	218	10,858
Silt	2,248	2,121	383	39	4,791
Clay	1,592	444	33	0	2,069
Fill	0	0	0	0	0
Total	10,863	6,932	887	319	19,001
Compartment Sums					
Gravel	1,071	6,204	696	6,283	14,254
Sand	8,477	18,328	3,165	10,826	40,796
Silt	3,495	4,586	424	40	8,545
Clay	2,290	1,359	51	0	3,700
Fill	6	1,118	32	75	1,231
Total	15,339	31,595	4,368	17,224	68,526

Notes:

CY = cubic yards

Table 5-3

Volume Estimates of NAPL-Impacted Soil Developed Using the Thiessen Polygon Approach

2014 Conceptual Site Model Update for the Former Process Area

Wyckoff / Eagle Harbor Superfund Site

	Volume >10%RE (CY)	Precent of total volume ≥10%RE by Compartment
Total ≥10%RE	109,069	100%
Compartment 1A	5,121	5%
Compartment 1B	51,512	47%
Compartment 2	24,779	23%
Compartment 3	27,657	25%

Notes:

CY = cubic yards

Table 5-4

TarGOST Integration NAPL Volume Estimate by Compartment

2014 Conceptual Site Model Update for the Former Process Area

Wyckoff / Eagle Harbor Superfund Site

	Gallons	Percent of Total NAPL Volume
Total	678,872	100%
Compartment 1a	30,740	5%
Compartment 1b	271,206	40%
Compartment 2	127,751	19%
Compartment 3	249,174	37%

Figures

316783.DE.01_ES042007003SEA . 1-1 site location.ai . 4/9/07 . dk

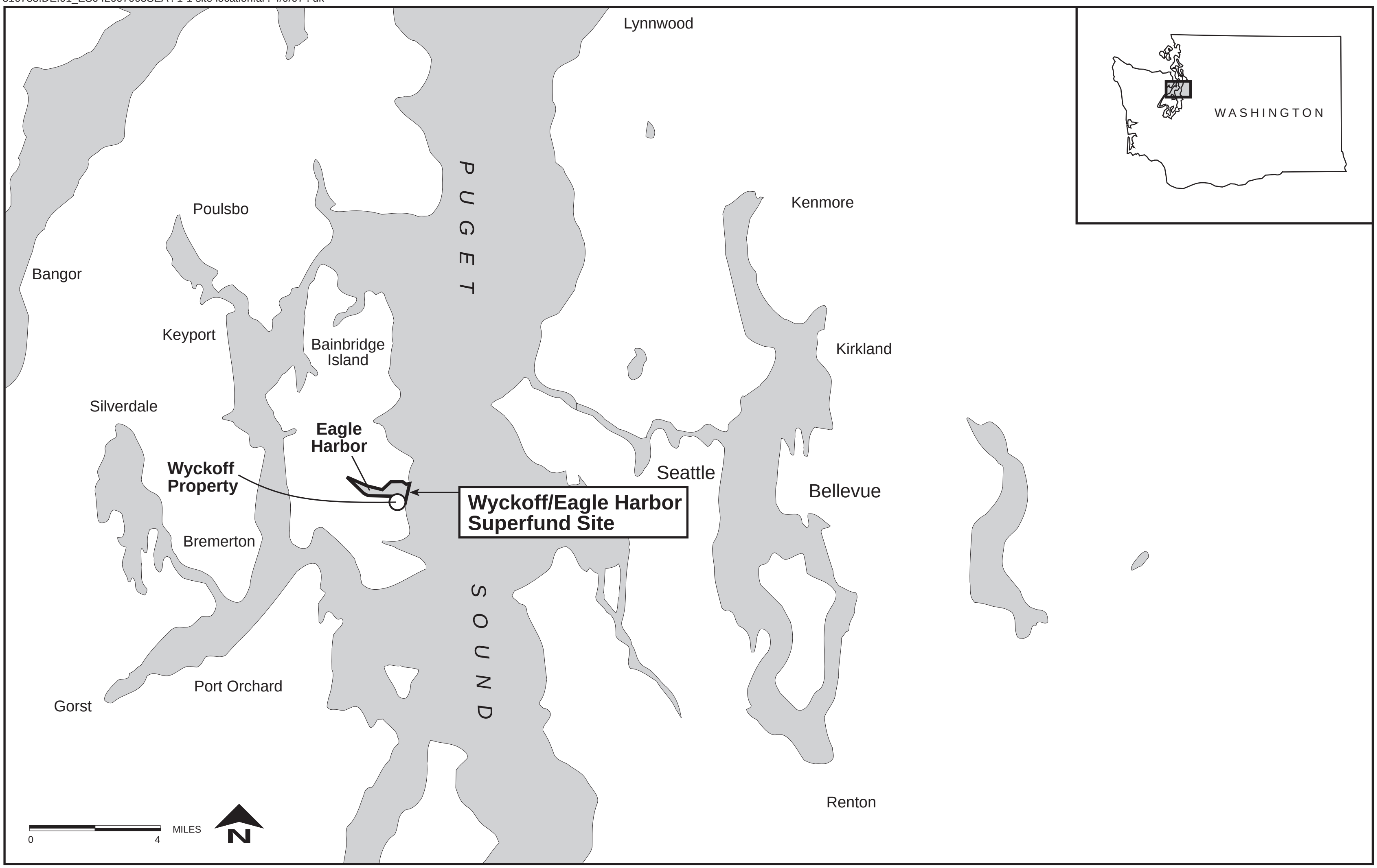

Figure 1-1

Site Location

2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

Figure 1-2
Location of Operable Units and Site Features
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

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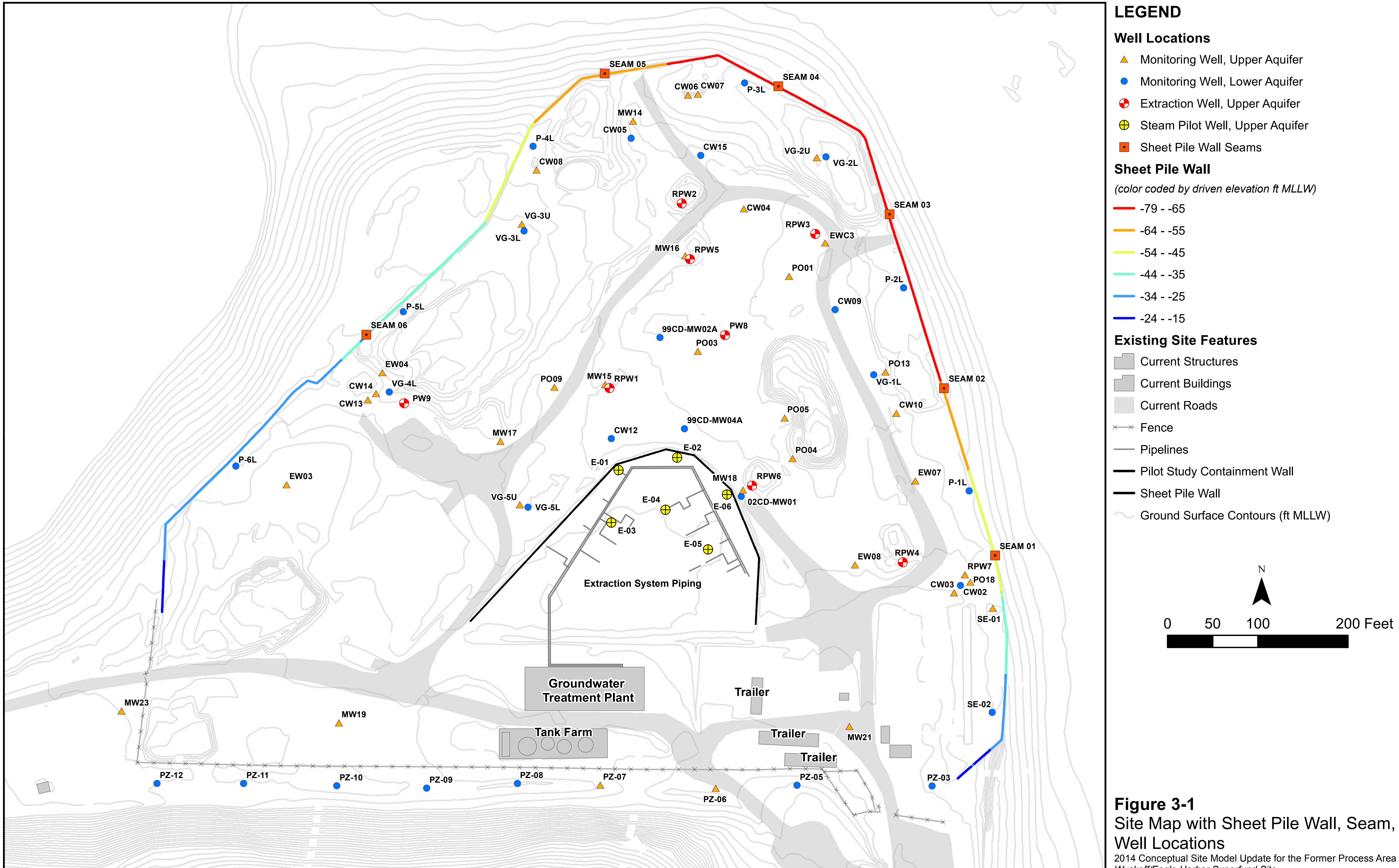

Figure 3-1
Site Map with Sheet Pile Wall, Seam, and Well Locations
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

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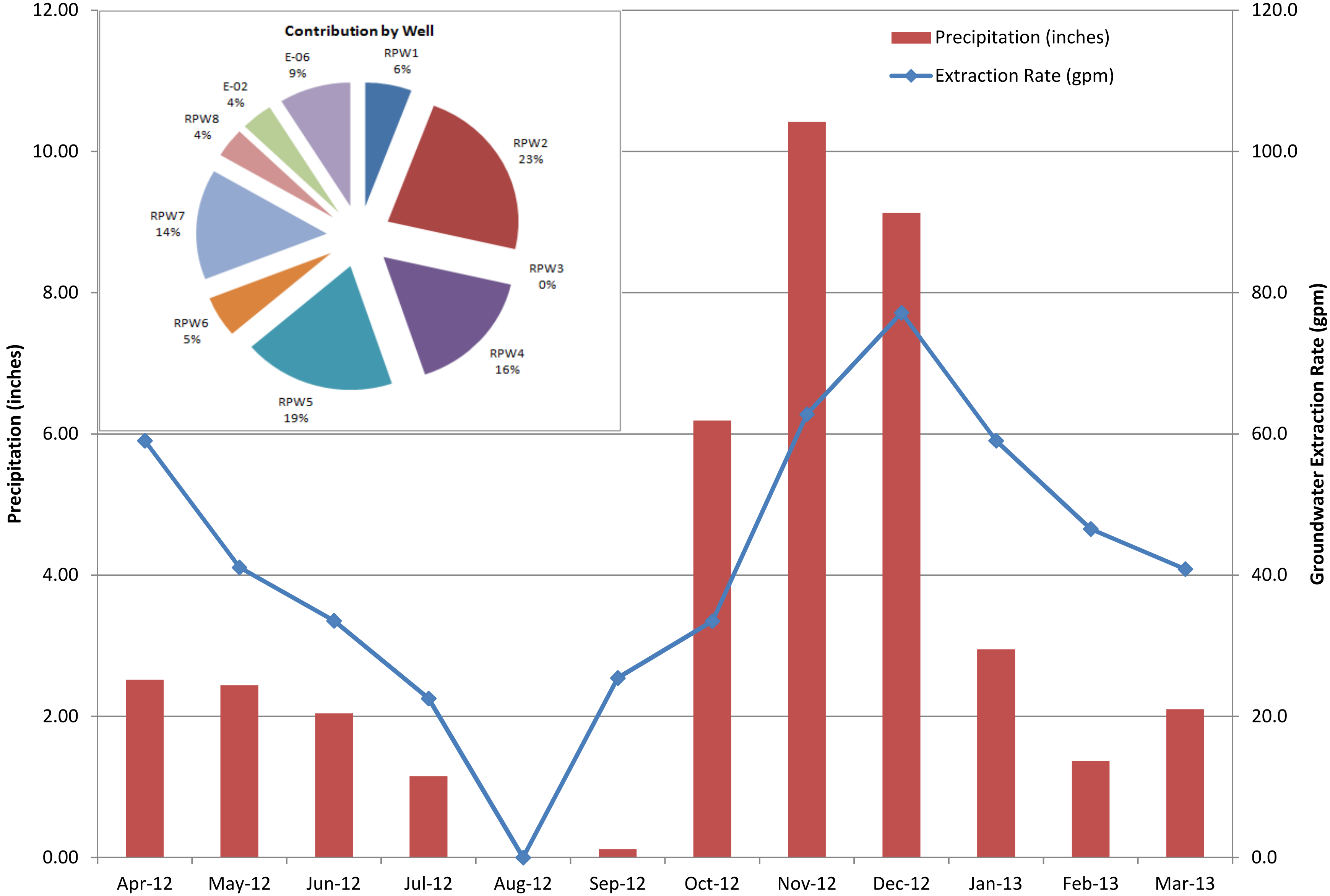


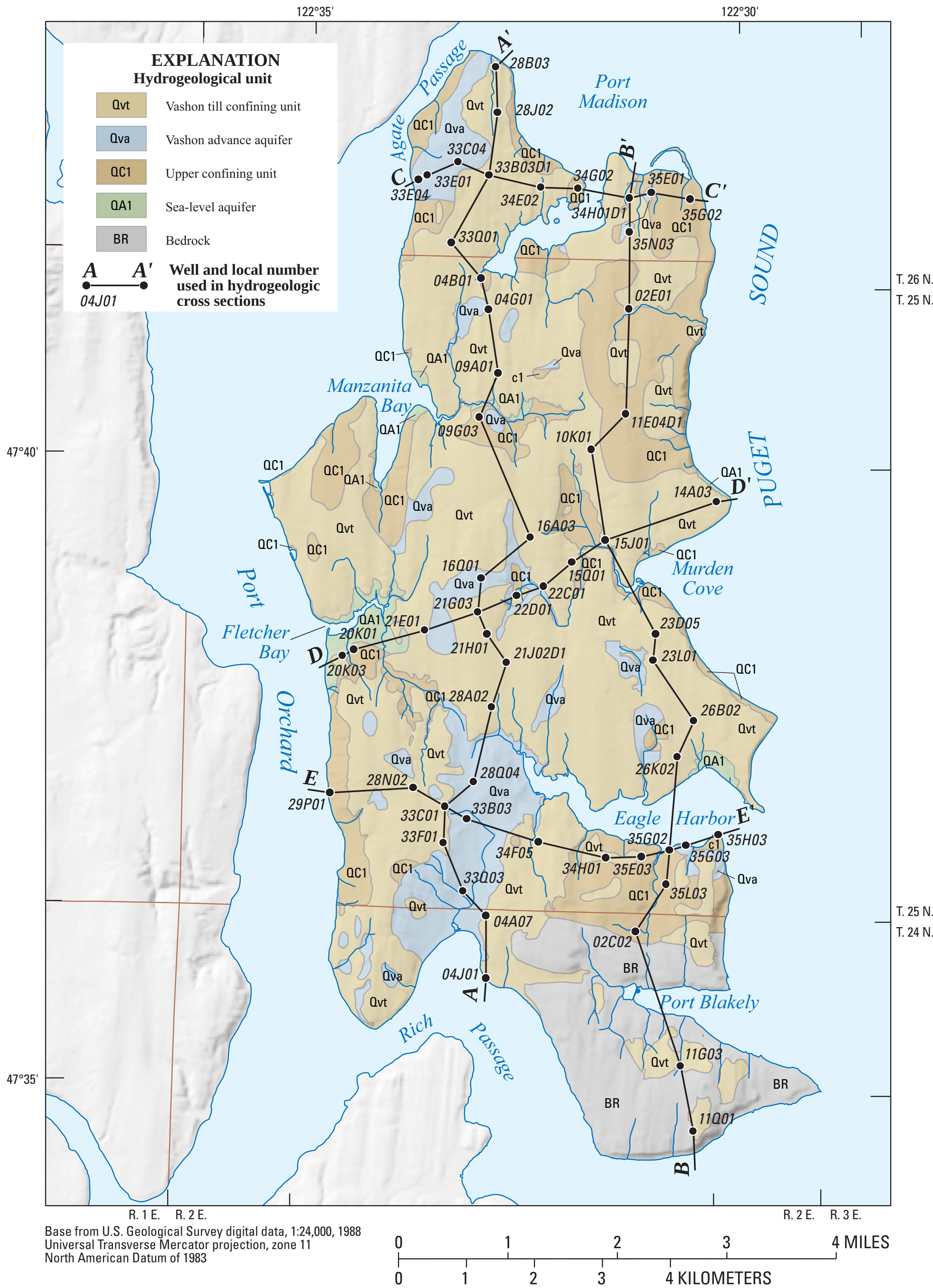
Figure 3-2

Monthly Precipitation and Groundwater Extraction Rates

April 2012 through March 2013

2014 Conceptual Site Model Update for the Former Process Area

Wyckoff /Eagle Harbor Superfund Site



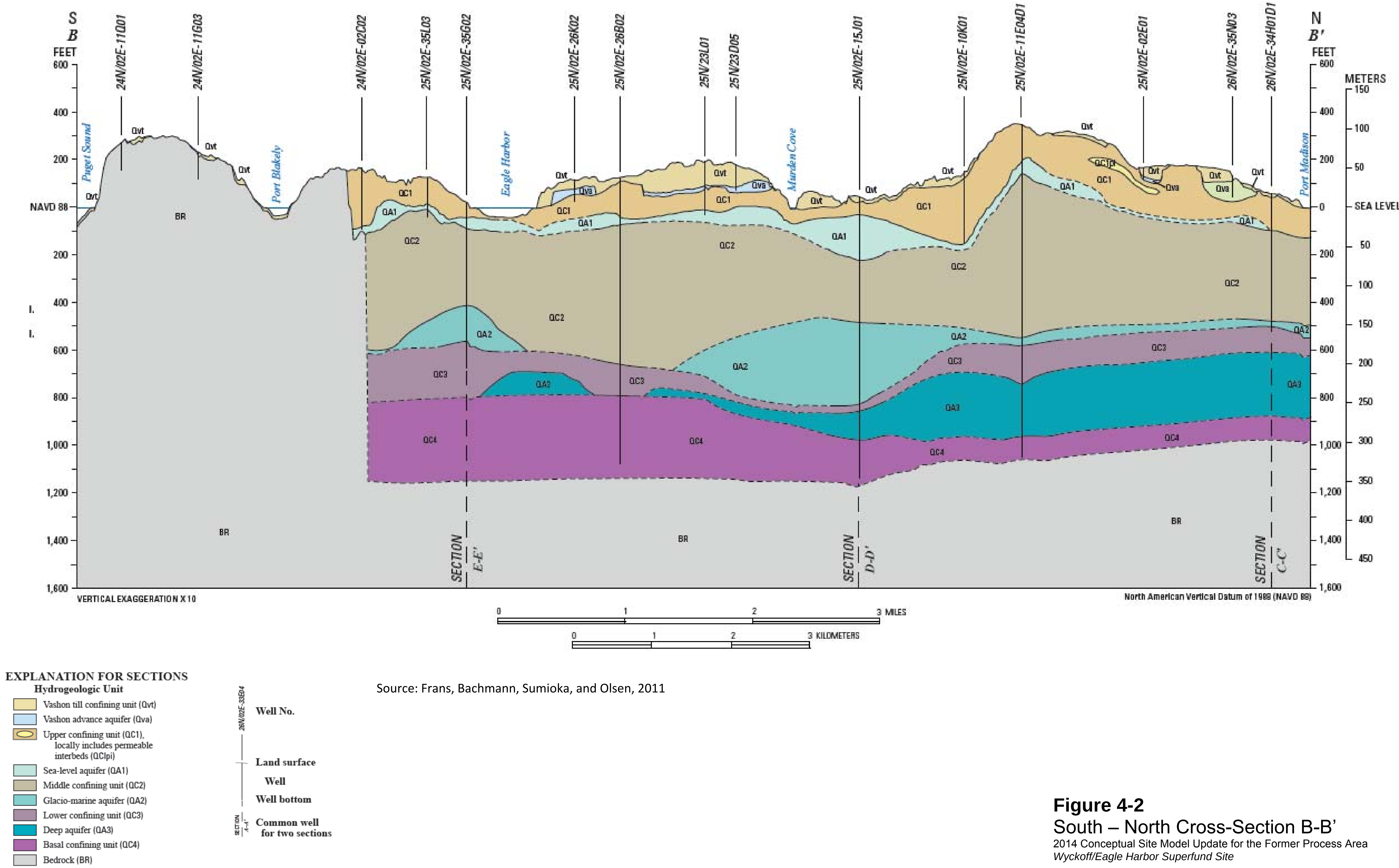
Data Source: Frans, Bachmann, Sumioka, and Olsen, 2011.

Figure 4-1

Surficial Hydrogeologic Units at Bainbridge Island

2014 Conceptual Site Model Update for the Former Process Area

Wyckoff/Eagle Harbor Superfund Site



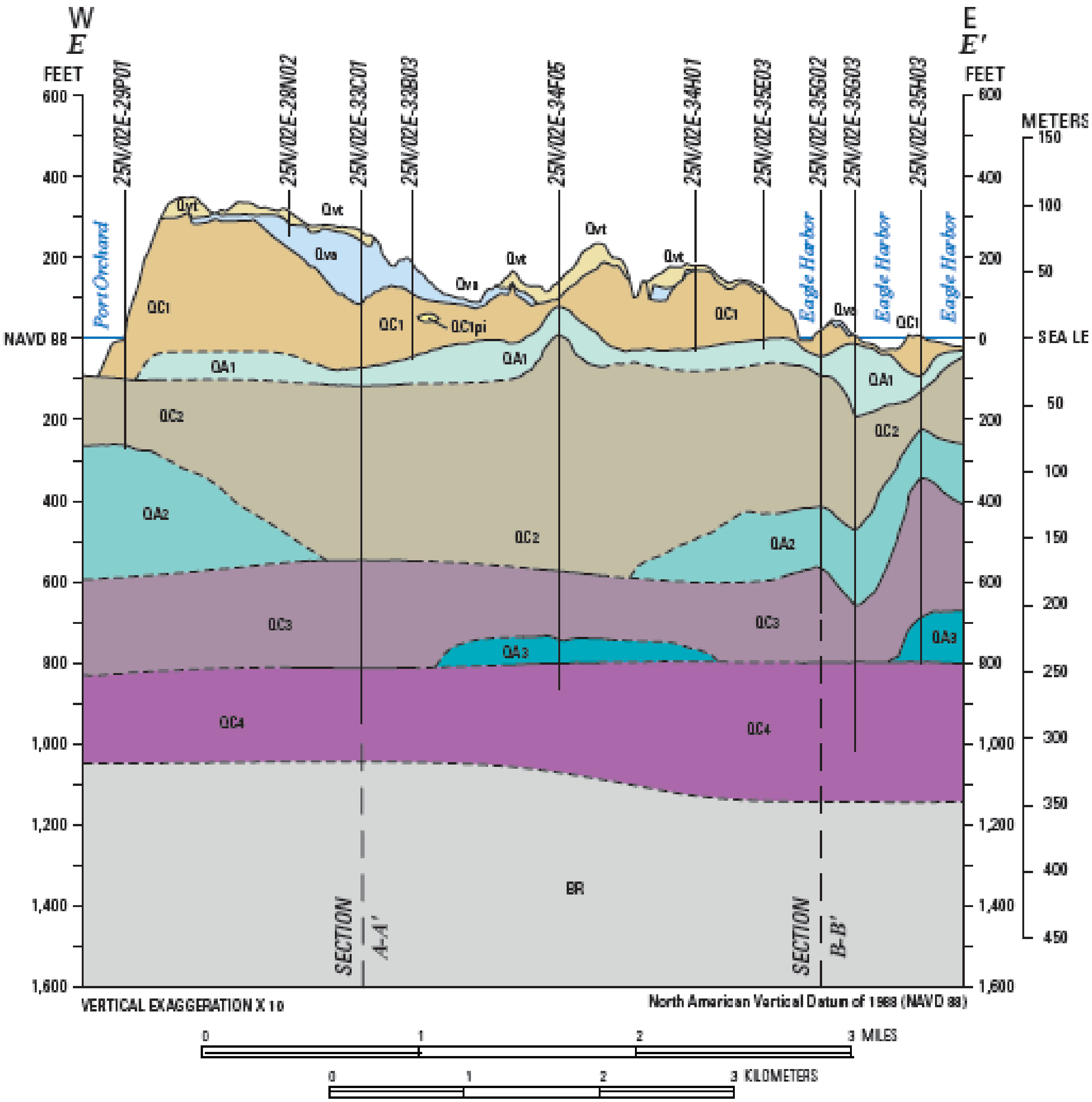
Source: Frans, Bachmann, Sumioka, and Olsen, 2011

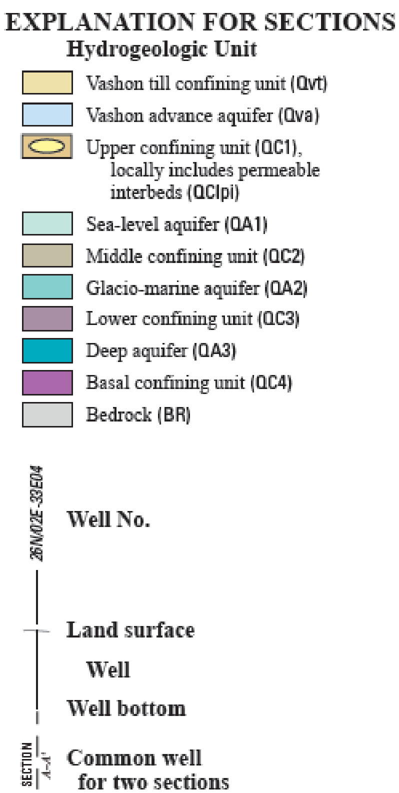
Figure 4-2

South – North Cross-Section B-B'

2014 Conceptual Site Model Update for the Former Process Area

Wyckoff/Eagle Harbor Superfund Site





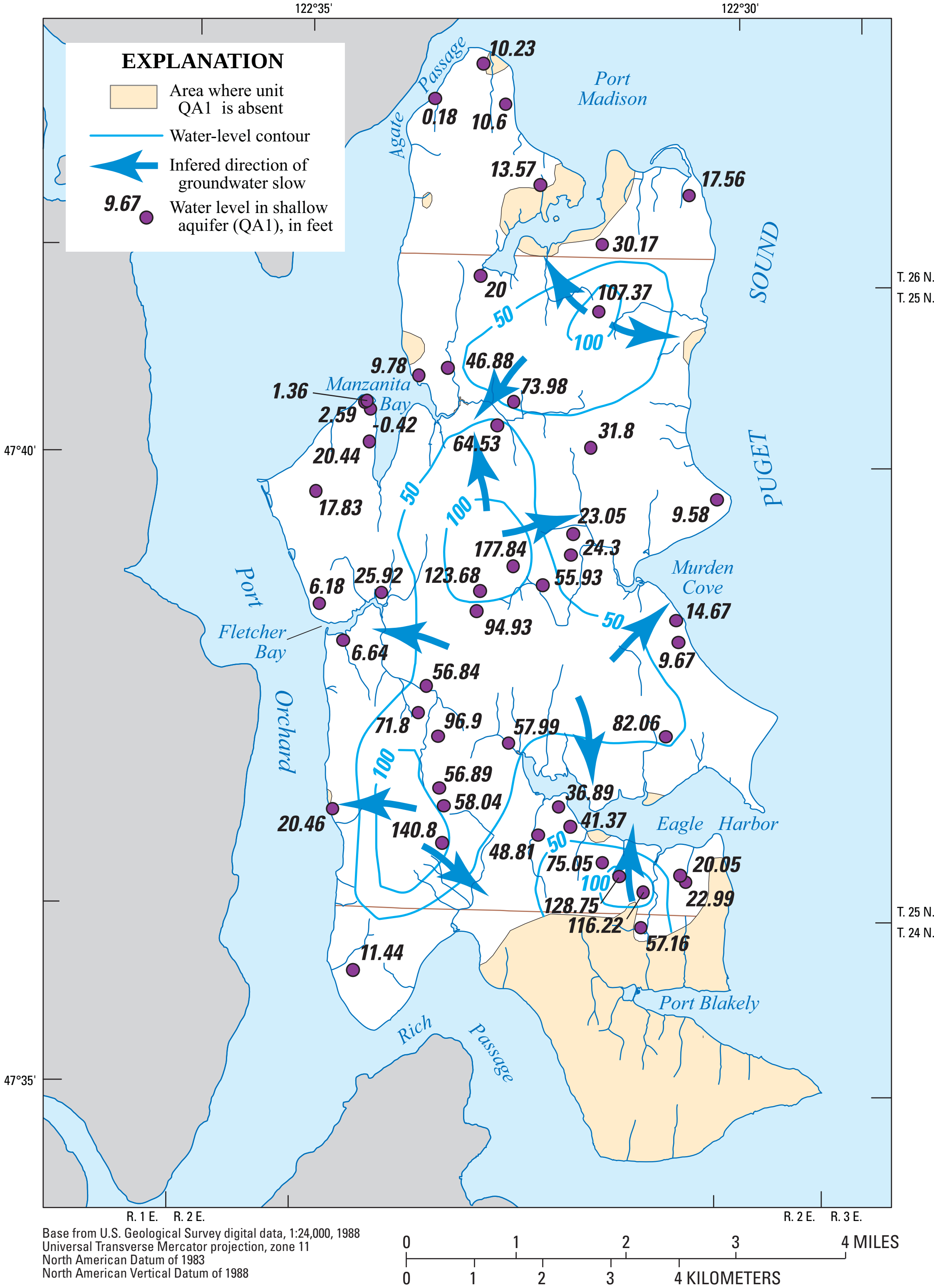
Source: Frans, Bachmann, Sumioka, and Olsen, 2011.

Figure 4-3

West-East Cross-Section E-E'

2014 Conceptual Site Model Update for the Former Process Area

Wyckoff/Eagle Harbor Superfund Site



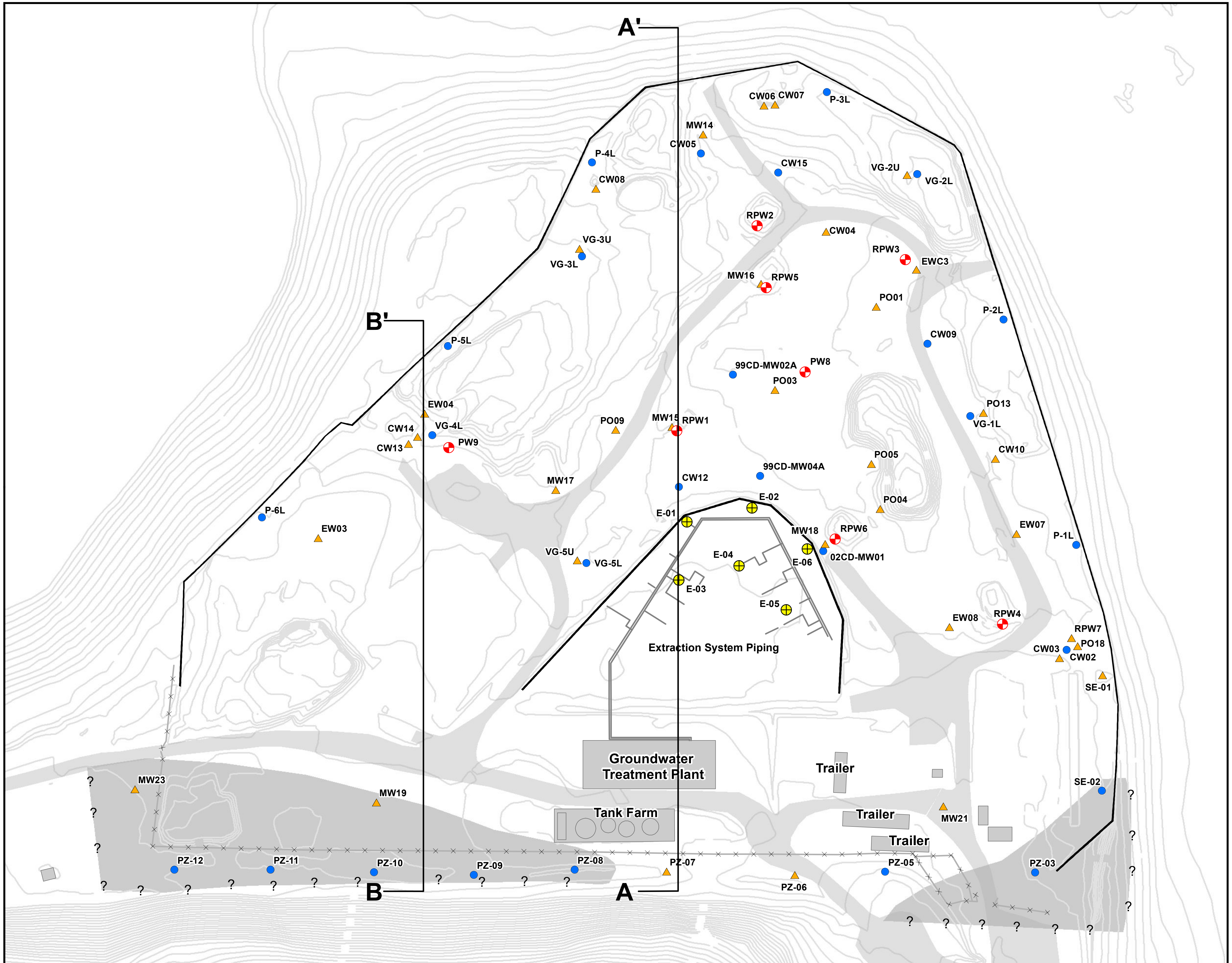
Source: Frans, Bachmann, Sumioka, and Olsen, 2011.

Figure 4-4

Regional Groundwater Elevations and Flow Directions in the QA1 Aquifer

2014 Conceptual Site Model Update for the Former Process Area

Wyckoff/Eagle Harbor Superfund Site



LEGEND

Well Locations

- Monitoring Well, Upper Aquifer
- Monitoring Well, Lower Aquifer
- Extraction Well, Upper Aquifer
- Steam Pilot Well, Upper Aquifer

Existing Site Features

- Current Structures
- Current Buildings
- Current Roads
- Fence
- Pipelines
- Pilot Study Containment Wall
- Sheet Pile Wall
- Ground Surface Contours (ft MLLW)
- Aquitard Thin (<4 ft) to Absent

N

0 50 100 200 Feet

Figure 4-5

Cross-Section Locations

2014 Conceptual Site Model Update for the Former Process Area

Wyckoff/Eagle Harbor Superfund Site

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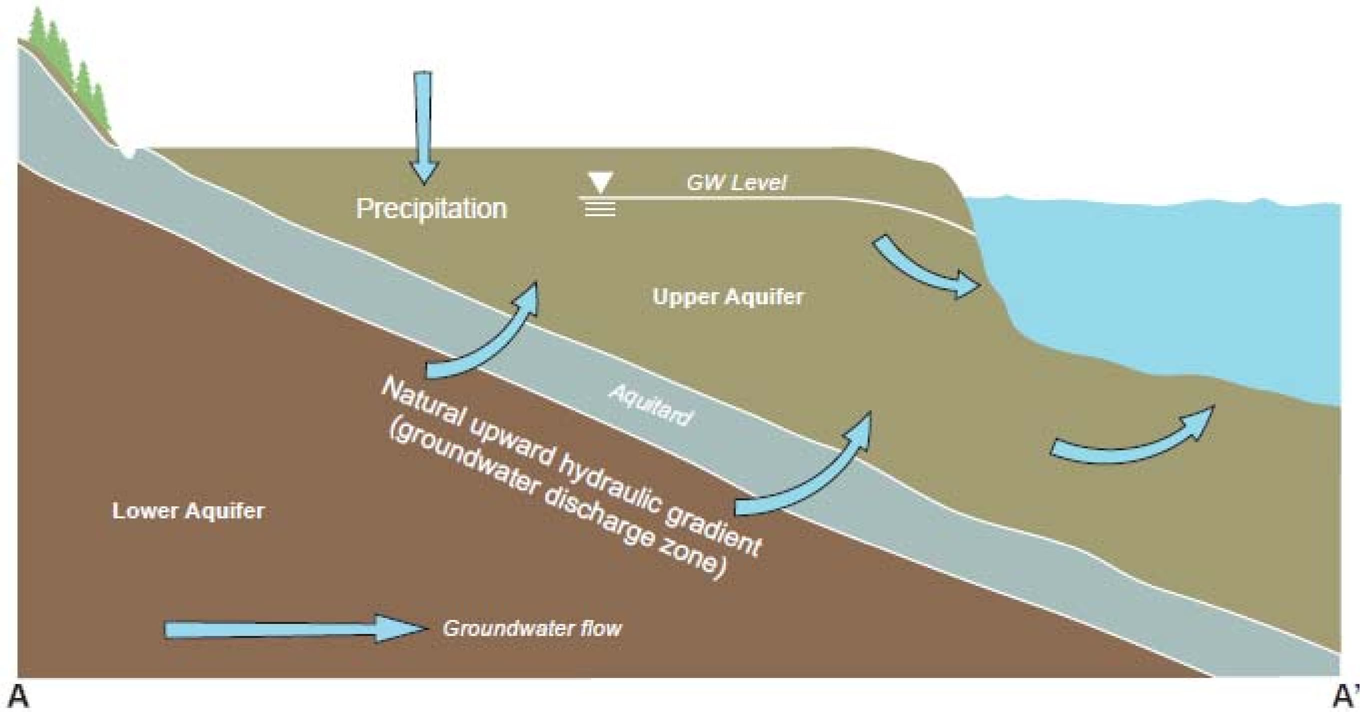
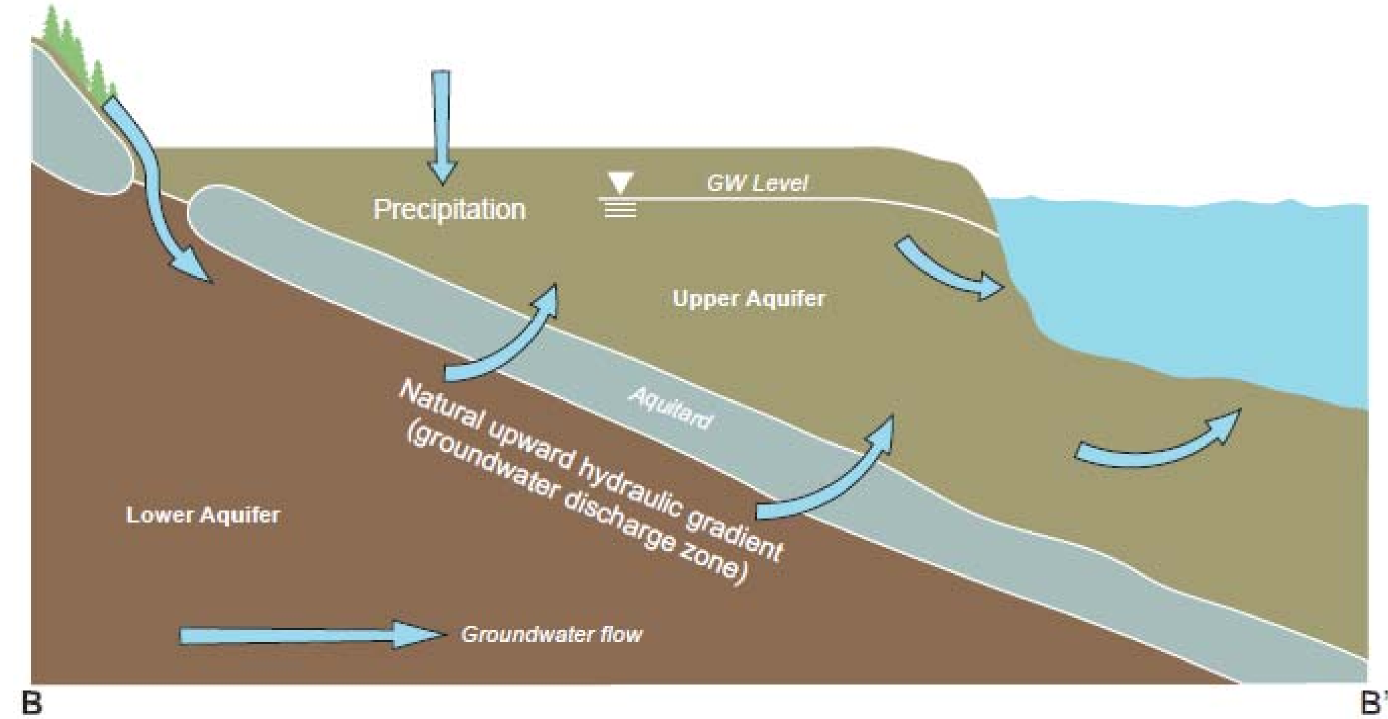
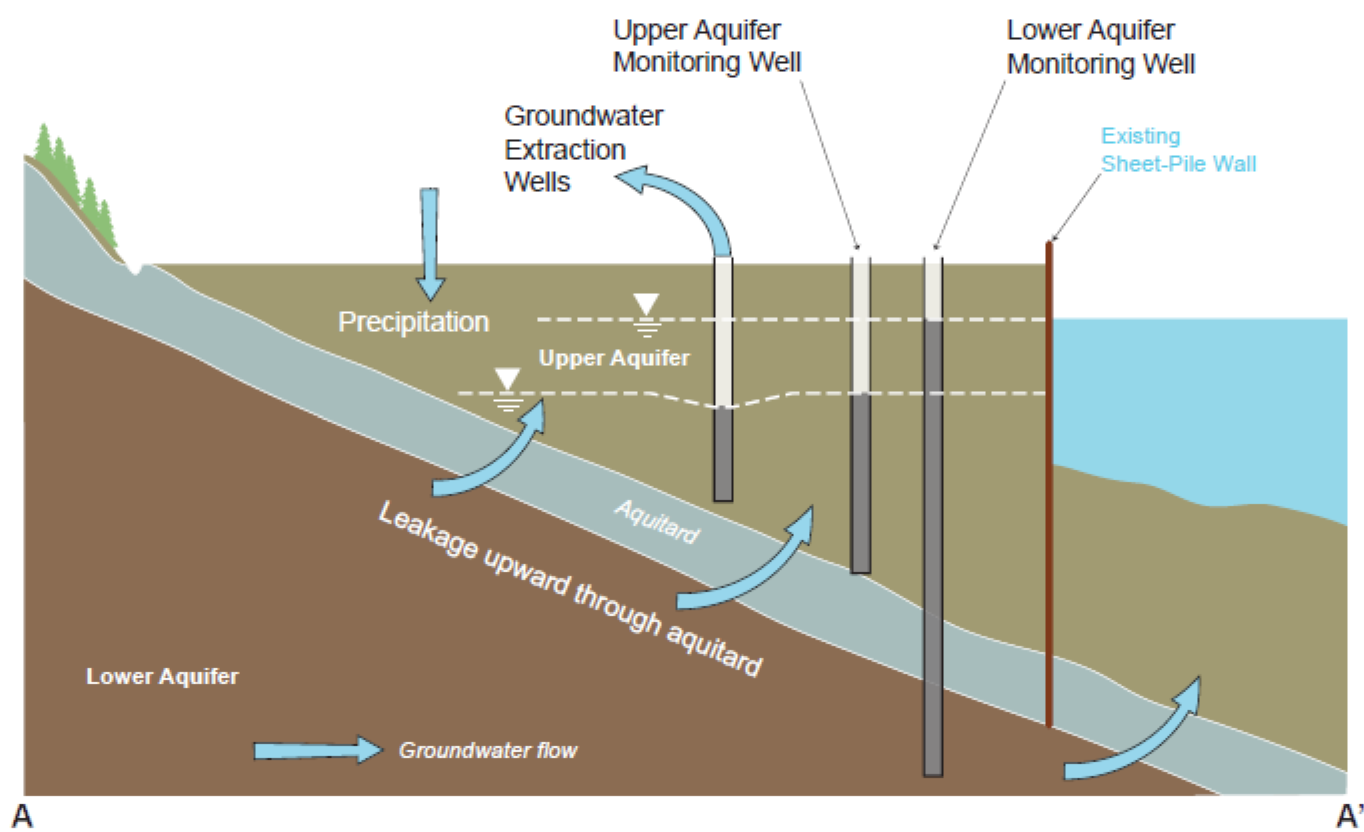


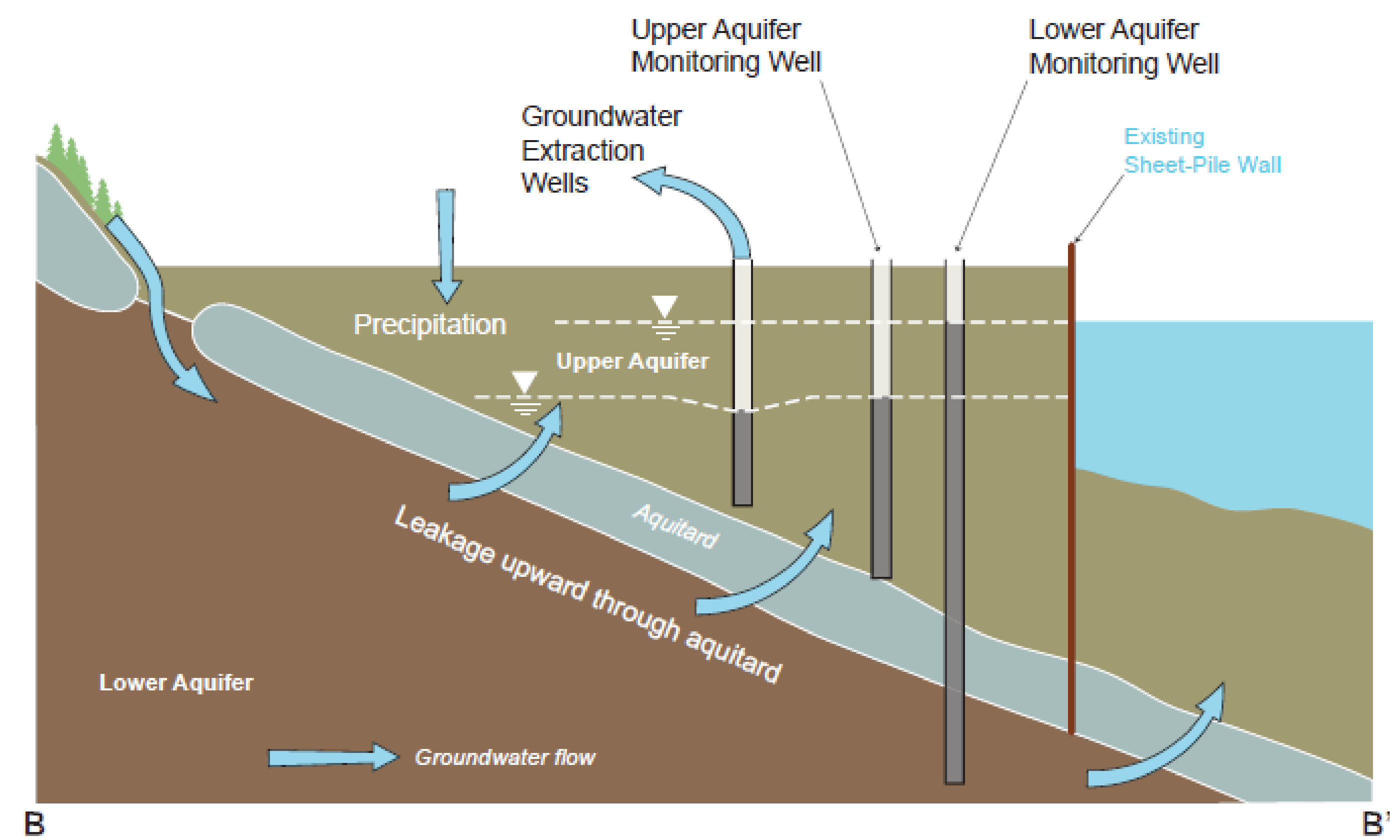
Original Groundwater Conditions at A-A'



Original Groundwater Conditions at B-B'



Current Groundwater Conditions at A-A'



Current Groundwater Conditions at B-B'

Figure 4-6
Schematic of Original and Current Groundwater Conditions
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff / Eagle Harbor Superfund Site.

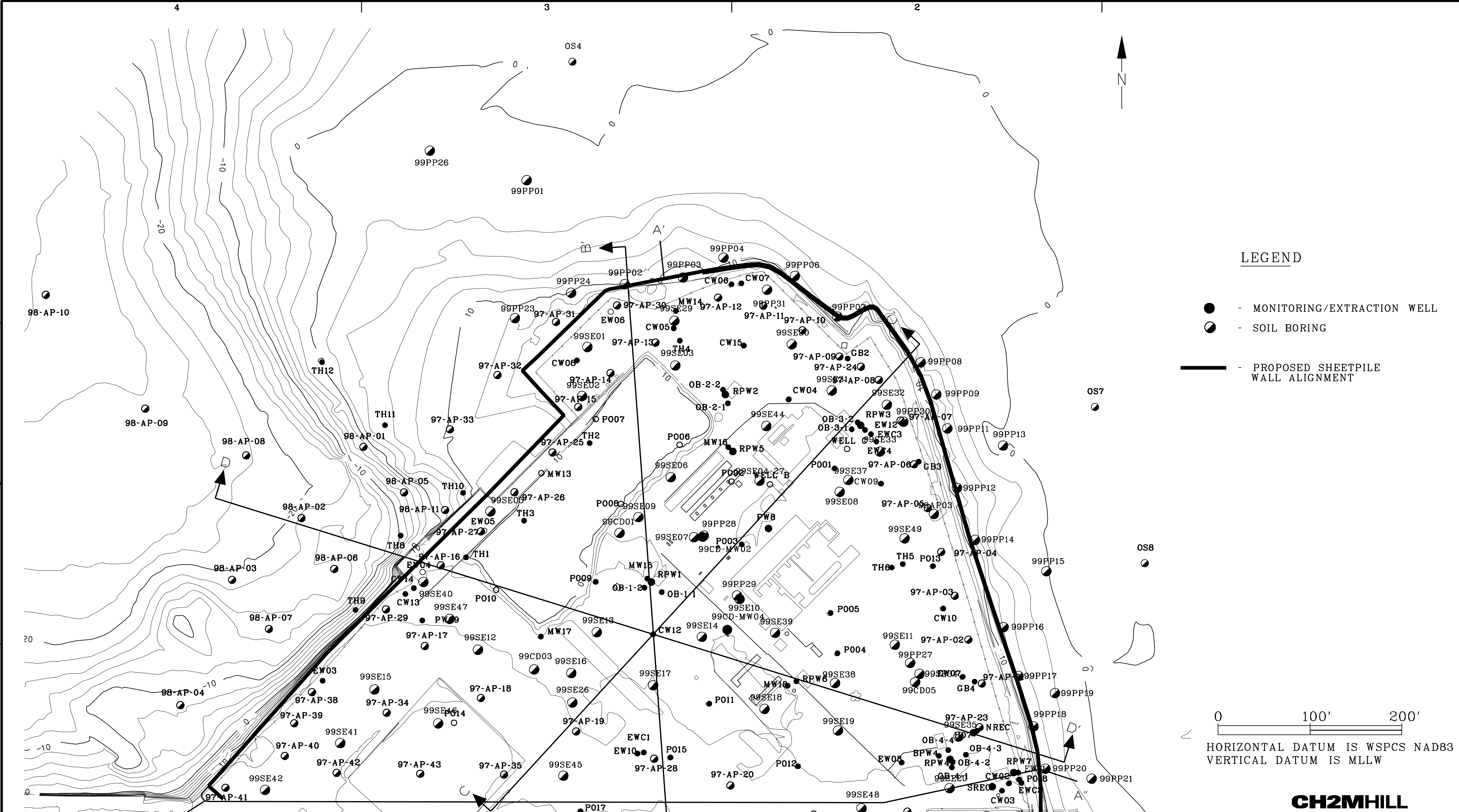


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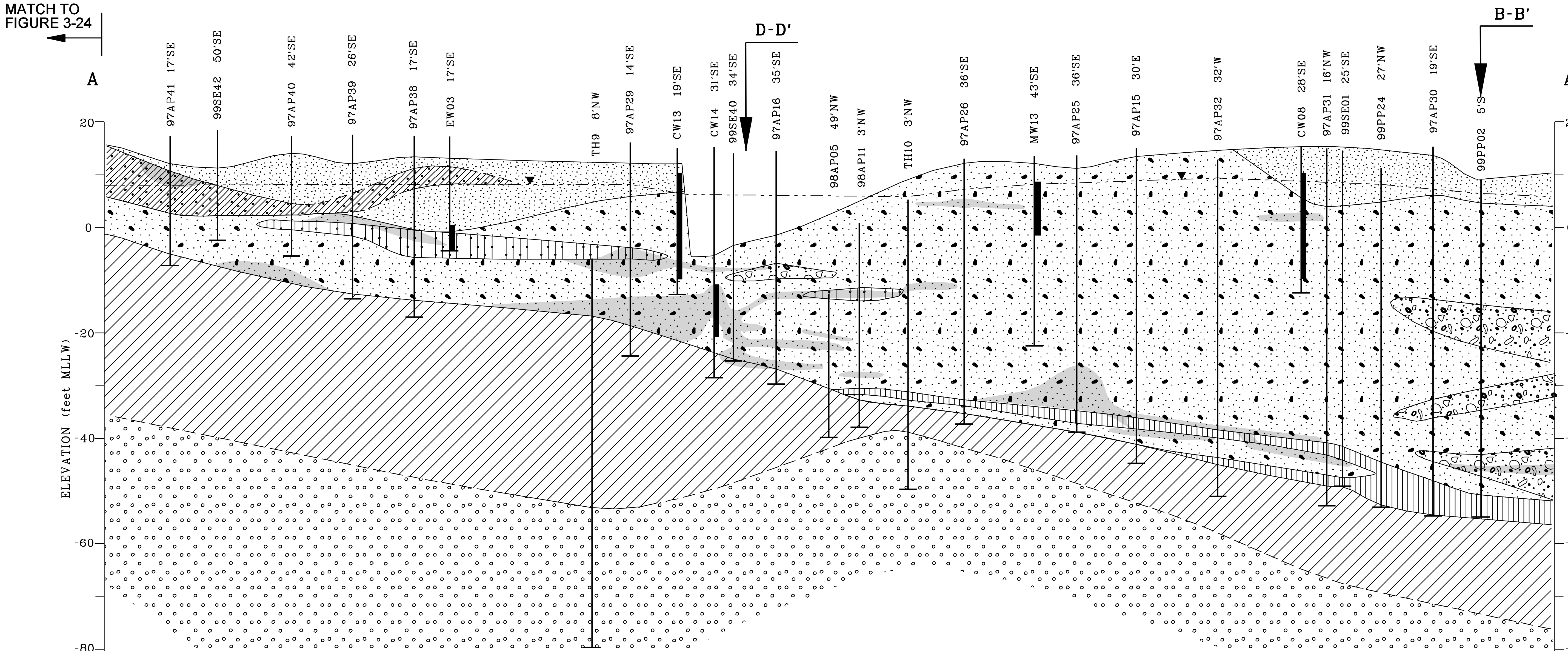
Figure 4-7
Geologic Profile Locations
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D				3
DSGN. BROOKSHIER		CHK. EASTERLY	FIGURE	

DATE AND TIME PLOTTED: $$$DATE$$$$ $TIME
DESIGN FILE: $$$DGN$$



NOTE:

PROFILE IS DRAWN ON A CURVED ALIGNMENT AND DOES NOT REPRESENT A PLANAR SURFACE.

GEOLOGIC UNITS

FILL: BROWN, FINE SAND. RARE SHELL FRAGMENTS, WOOD DEBRIS AND MAN-MADE DEBRIS.

NON-MARINE CLAY: GRAY TO BROWN, SOFT TO MEDIUM CLAY WITH PLANT FIBERS, WOOD AND ROOTS, AND BROWN CLAYEY FINE SAND.

MARINE SAND AND GRAVEL: GRAY TO DARK GRAY, LOOSE TO DENSE SAND AND GRAVEL WITH OCCASIONAL COBBLES (COBBLE-RICH AND GRAVEL ZONE SHOWN SEPARATELY). LOW SILT CONTENT AND ABUNDANT SHELL FRAGMENTS.

MARINE SILT: OLIVE-GRAY SILTY SAND (WITH THIN LAYERS OF SAND AND GRAVEL) TO SILT OR CLAY. ABUNDANT SHELL FRAGMENTS.

GLACIAL CLAY, SILT AND SAND: GRAY BROWN SILTY SAND WITH GRAVEL, BLUE-GRAY SILT/CLAY, AND GRAY-BROWN SILT/CLAY; DENSE, NO ORGANIC MATTER.

FLUVIAL SAND: DENSE TO VERY DENSE, GRAY-BROWN TO BROWN, WELL GRADED TO POORLY GRADED SAND WITH VARIABLE GRAVEL AND COBBLES.

SURFICIAL MARINE SEDIMENT: OFFSHORE HARBOR-BOTTOM SILT AND CLAY, DARK OLIVE TO BLACK, OFTEN WITH ABUNDANT WOOD CHIPS AND WOOD AND PLANT DEBRIS.

MOBILE NAPL (SEE DEFINITION IN TEXT)

PW8 - 14′SE — BORING ID NUMBER AND DISTANCE OF OFFSET FROM ALIGNMENT

WELL SCREEN

APPROX WATER TABLE

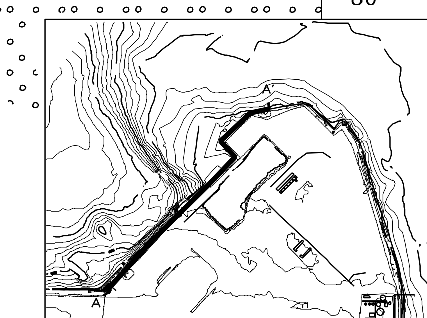


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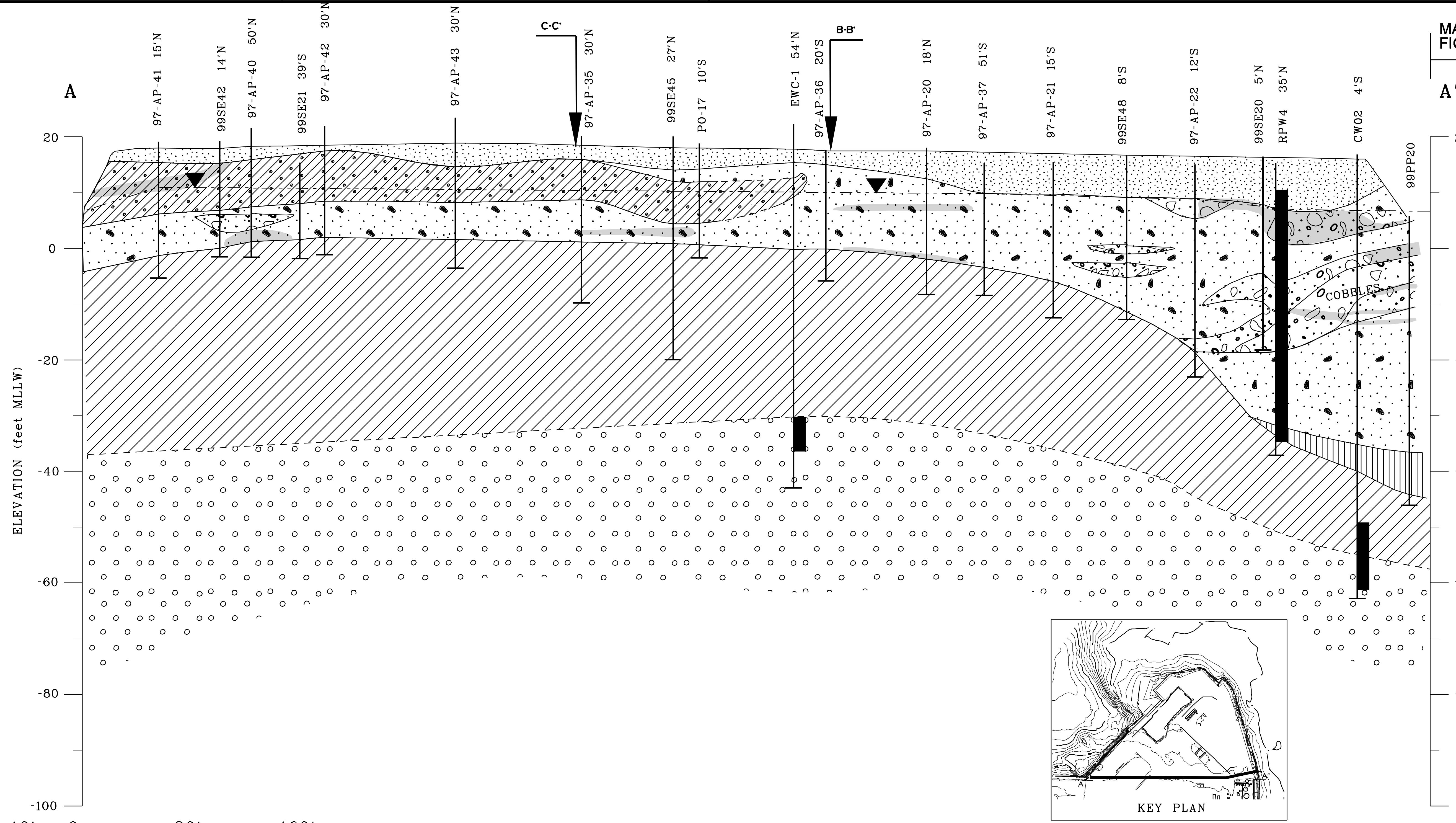
Figure 4-8
Geologic Profile A-A′
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D				4
DSGN. DIMBIRS		CHK. EASTERLY	FIGURE	



1'' = 80'   40' 0 80' 160'

VERTICAL EXAGGERATION = 4x
HORIZONTAL SCALE IN FEET

NOTE:

PROFILE IS DRAWN ON A CURVED ALIGNMENT AND DOES NOT REPRESENT A PLANAR SURFACE.

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FILL: BROWN, FINE SAND. RARE SHELL FRAGMENTS, WOOD DEBRIS AND MAN-MADE DEBRIS.

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MOBILE NAPL (SEE DEFINITION IN TEXT)

PW8 - 14'SE — BORING ID NUMBER AND DISTANCE OF OFFSET FROM ALIGNMENT

WELL SCREEN

APPROX WATER TABLE

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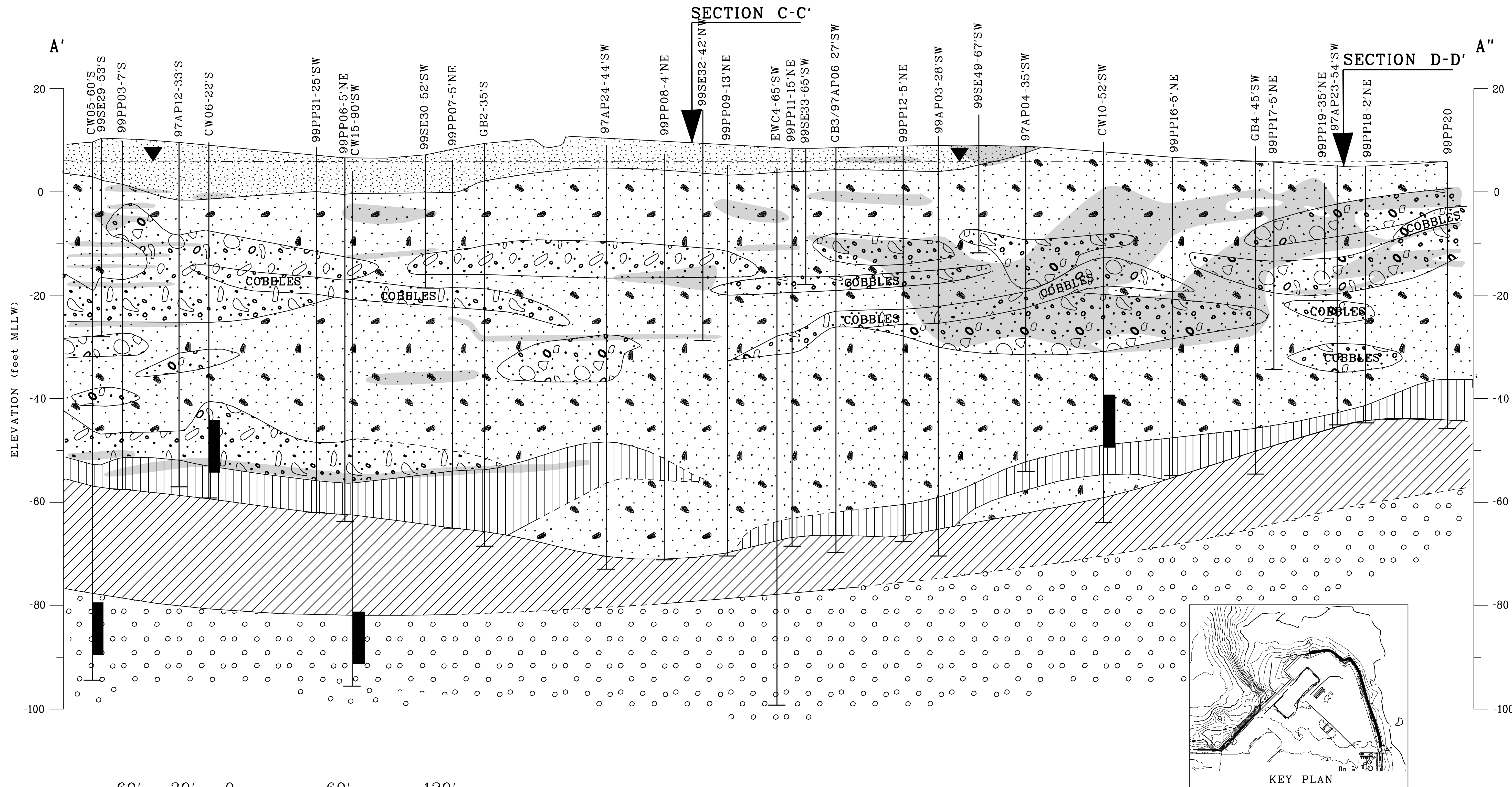
Figure 4-9
Geologic Profile A-A''
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

SIZE	INVITATION NO.	FILE NO.	DATE	PLATE
D				5
DSGN. DIMBIRS		CHK. EASTERLY	FIGURE	

DATE AND TIME PLOTTED: $$$DATE$$$$ $TIME
DESIGN FILE: $$$DGN$$



1" = 60'

60' 30' 0 60' 120'

HORIZONTAL SCALE IN FEET
VERTICAL EXAGGERATION = 3x

NOTE:

PROFILE IS DRAWN ON A CURVED ALIGNMENT AND DOES NOT REPRESENT A PLANAR SURFACE.

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MOBILE NAPL (SEE DEFINITION IN TEXT)

PW8 - 14'SE — BORING ID NUMBER AND DISTANCE OF OFFSET FROM ALIGNMENT

WELL SCREEN

APPROX WATER TABLE

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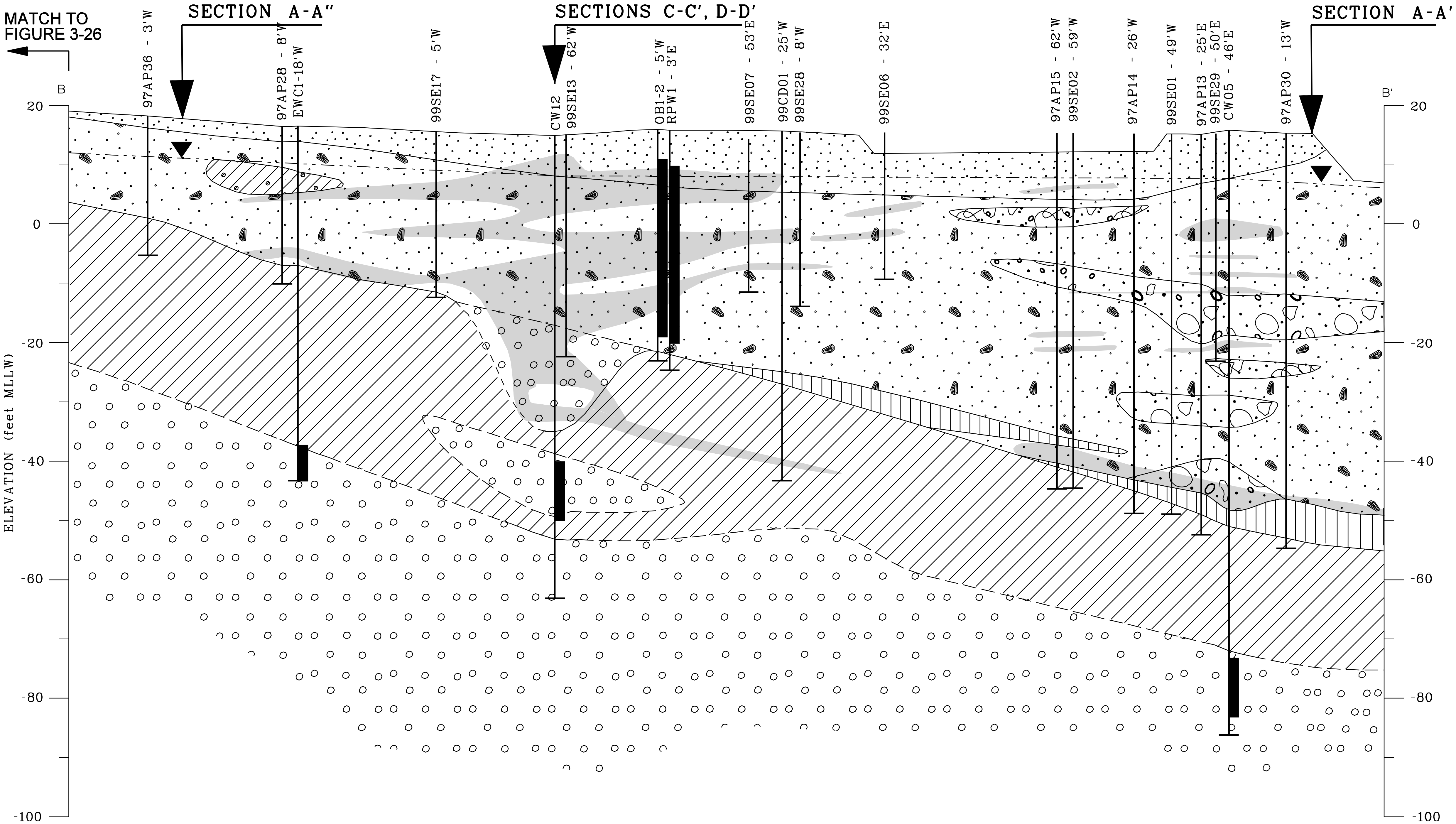
Figure 4-10
Geologic Profile A'-A"
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D				6
DGN DIMBIRS		CHK. EASTERLY	FIGURE	

DATE AND TIME PLOTTED: $$$DATE$$$$ $TIME
DESIGN FILE: $$$DGN$$$



1" = 60'

60' 30' 0 60' 120'

HORIZONTAL SCALE IN FEET
VERTICAL EXAGGERATION = 3x

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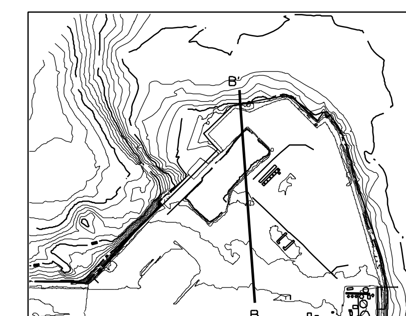
MOBILE NAPL (SEE DEFINITION IN TEXT)

PW8 - 14'SE — BORING ID NUMBER AND DISTANCE OF OFFSET FROM ALIGNMENT

WELL SCREEN

APPROX WATER TABLE



KEY PLAN

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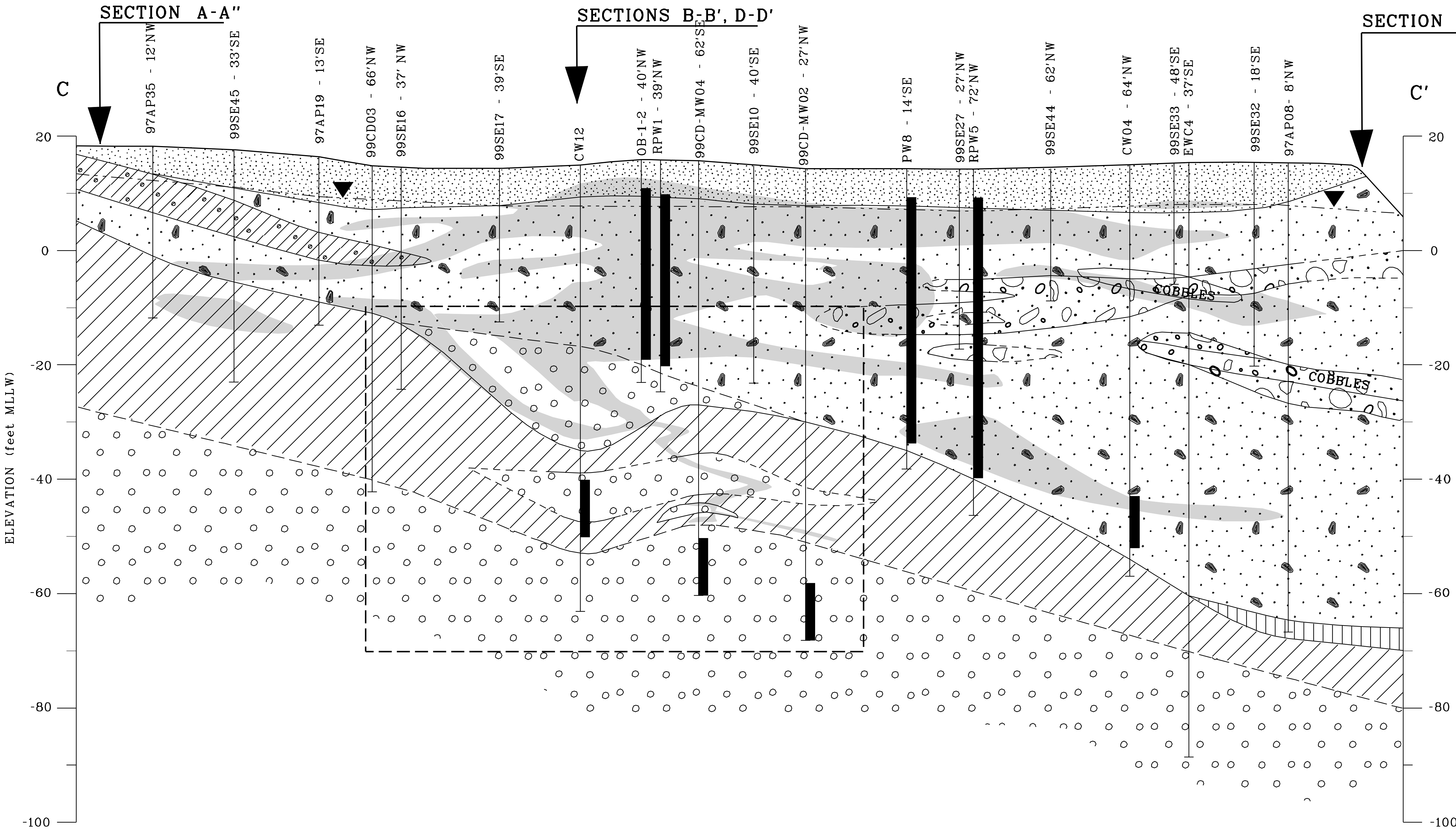
SEATTLE, WASHINGTON

Figure 4-11
Geologic Profile B-B'
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D				7

DGN	CHK	FIGURE
BROOKSHIER	EASTERLY	



1" = 60'

60' 30' 0 60' 120'

HORIZONTAL SCALE IN FEET

VERTICAL EXAGGERATION = 3x

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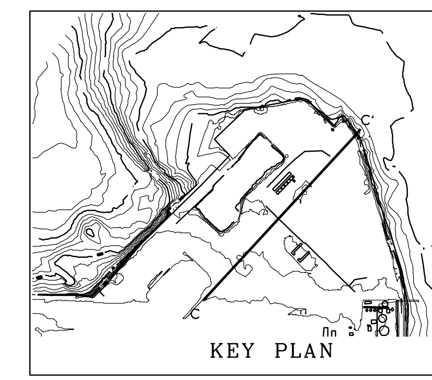
MOBILE NAPL
(SEE DEFINITION IN TEXT)

PW8 - 14'SE — BORING ID NUMBER AND DISTANCE OF OFFSET FROM ALIGNMENT

WELL SCREEN

APPROX WATER TABLE

AREA OF AQUITARD DETAIL, FIGURE 3-18



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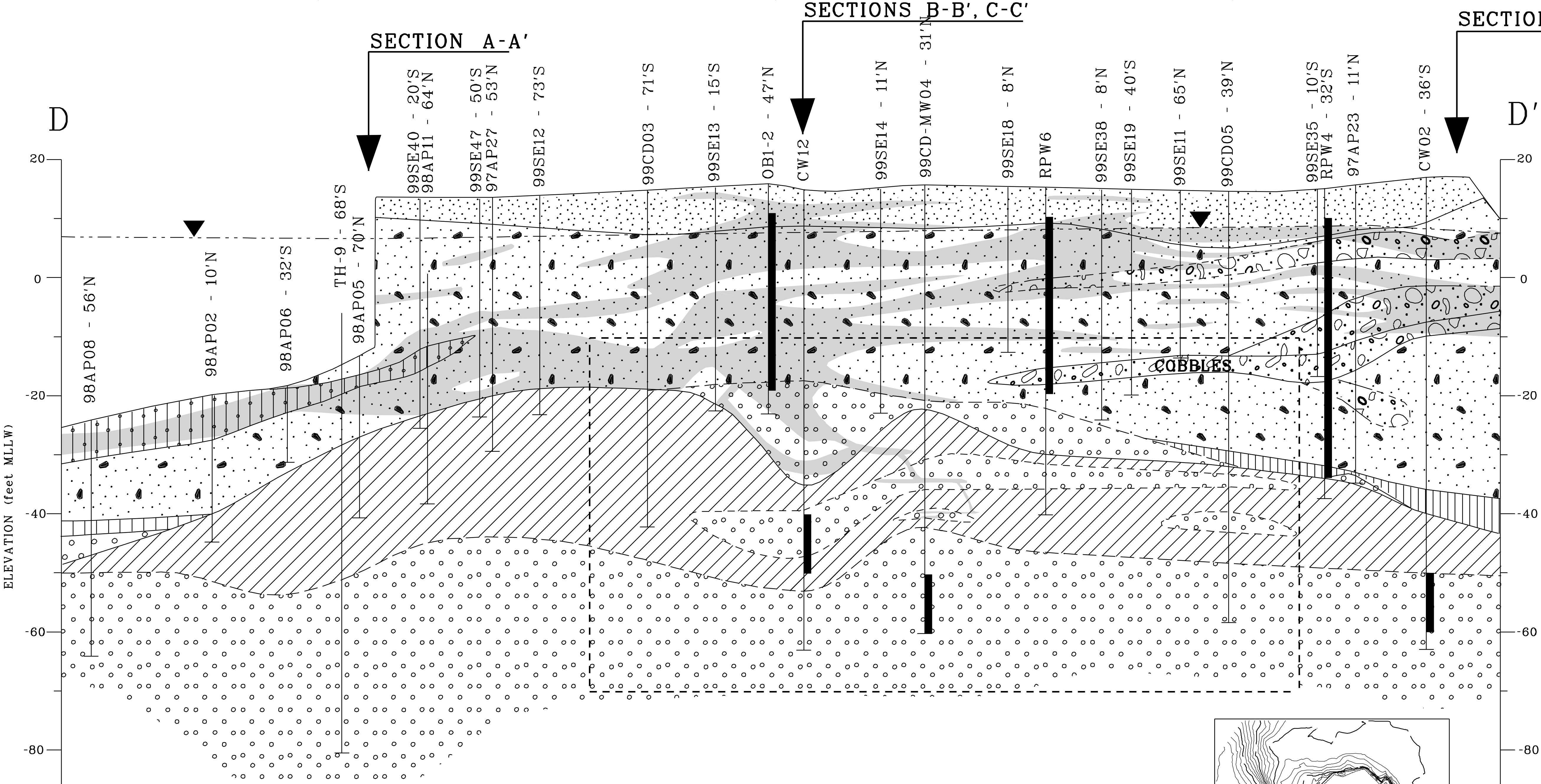
SEATTLE, WASHINGTON

Figure 4-12
Geologic Profile C-C'
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D				8
DGN BROOKSHIER	CHK. EASTERLY		FIGURE	

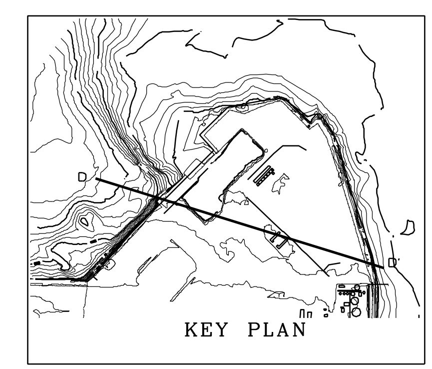


1" = 80'

80' 40' 0 80' 160'

HORIZONTAL SCALE IN FEET
VERTICAL EXAGGERATION = 4x

AREA OF AQUITARD DETAIL, FIGURE 3-19



GEOLOGIC UNITS

FILL:
BROWN, FINE SAND. RARE SHELL FRAGMENTS, WOOD DEBRIS AND MAN-MADE DEBRIS.

MARINE SAND AND GRAVEL:
GRAY TO DARK GRAY, LOOSE TO DENSE SAND AND GRAVEL WITH OCCASIONAL COBBLES (COBBLE-RICH AND GRAVEL ZONE SHOWN SEPARATELY). LOW SILT CONTENT AND ABUNDANT SHELL FRAGMENTS.

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FLUVIAL SAND:
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MOBILE NAPL (SEE DEFINITION IN TEXT)

PW8 - 14'SE — BORING ID NUMBER AND DISTANCE OF OFFSET FROM ALIGNMENT

WELL SCREEN

APPROX WATER TABLE

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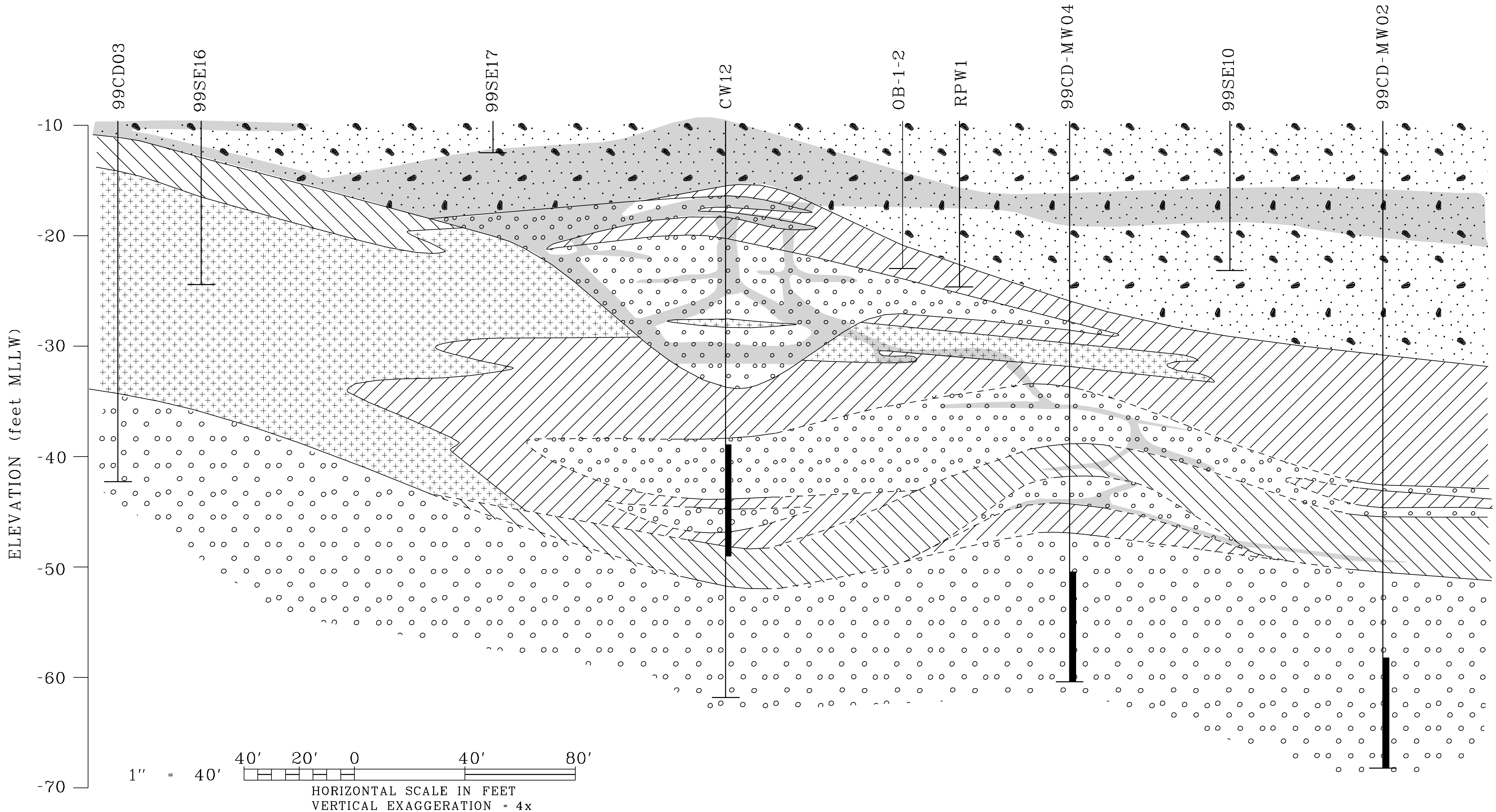
Figure 4-13
Geologic Profile D-D'
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D				9
DGN BROOKSHIER	CHK EASTERLY		FIGURE	

DATE AND TIME PLOTTED: $$$DATE$$$$ $TIME
DESIGN FILE: $$$DGN$$$



GEOLOGIC UNITS

MARINE SAND AND GRAVEL:
GRAY TO DARK GRAY, LOOSE TO DENSE SAND AND GRAVEL WITH OCCASIONAL COBBLES (COBBLE-RICH ZONE SHOWN SEPARATELY). LOW SILT CONTENT AND ABUNDANT SHELL FRAGMENTS.

MARINE SILT:
OLIVE-GRAY SILTY SAND (WITH THIN LAYERS OF SAND AND GRAVEL) TO SILT OR CLAY. ABUNDANT SHELL FRAGMENTS.

GLACIAL CLAY, SILT AND SAND:
BROWN SILTY SAND: BROWN TO GRAY SILTY SAND WITH GRAVEL AND GRAY-BROWN SILT/CLAY, COMMON OXIDATION, DENSE TO VERY DENSE.
GRAY CLAYEY SILT: GRAY TO BLUE-GRAY CLAYEY SILT WITH FINE SAND AND RARE GRAVEL, VERY STIFF.
DENSE SILTY GRAVEL: GRAY-BROWN TO GRAY-OLIVE SILTY GRAVEL AND SAND WITH OCCASIONAL OXIDIZED CLASTS, EXTREMELY DENSE.

FLUVIAL SAND:
DENSE TO VERY DENSE, GRAY-BROWN TO BROWN, WELL GRADED TO POORLY GRADED SAND WITH VARIABLE GRAVEL AND COBBLES.

MOBILE NAPL (SEE DEFINITION IN TEXT)

PW8 - 14'SE — BORING ID NUMBER AND DISTANCE OF OFFSET FROM ALIGNMENT

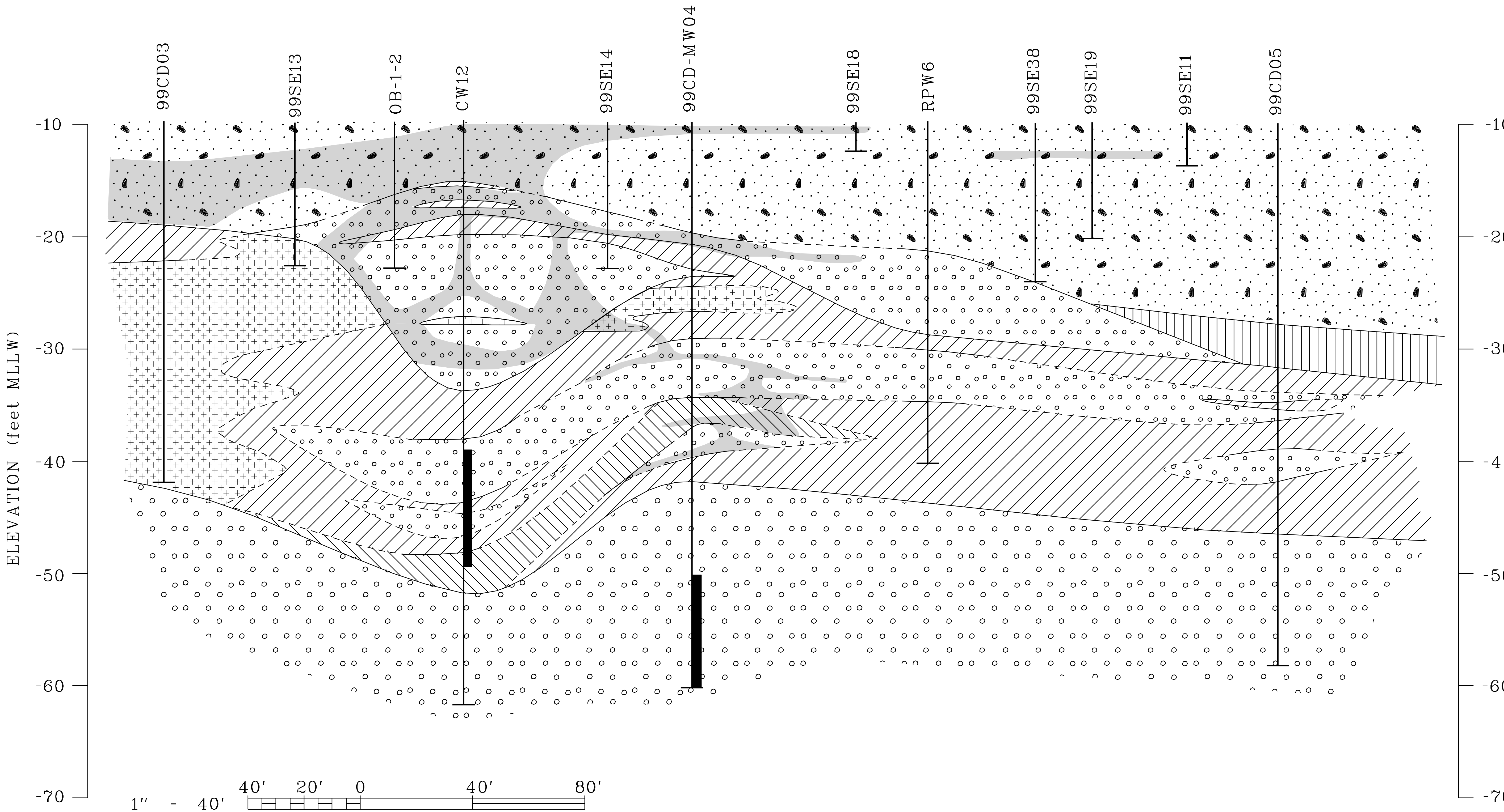
WELL SCREEN

CH2MHILL

U.S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

Figure 4-14
C-C' Inset - Aquitard
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D				12
DGN BROOKSHIER	CHK EASTERLY	FIGURE		



GEOLOGIC UNITS

MARINE SAND AND GRAVEL:
GRAY TO DARK GRAY, LOOSE TO DENSE SAND AND GRAVEL WITH OCCASIONAL COBBLES (COBBLE-RICH ZONE SHOWN SEPARATELY). LOW SILT CONTENT AND ABUNDANT SHELL FRAGMENTS.

MARINE SILT:
OLIVE-GRAY SILTY SAND (WITH THIN LAYERS OF SAND AND GRAVEL) TO SILT OR CLAY. ABUNDANT SHELL FRAGMENTS.

GLACIAL CLAY, SILT AND SAND:
BROWN SILTY SAND: BROWN TO GRAY SILTY SAND WITH GRAVEL AND GRAY-BROWN SILT/CLAY, COMMON OXIDATION, DENSE TO VERY DENSE

GRAY CLAYEY SILT: GRAY TO BLUE-GRAY CLAYEY SILT WITH FINE SAND AND RARE GRAVEL, VERY STIFF

DENSE SILTY GRAVEL: GRAY-BROWN TO GRAY-OLIVE SILTY GRAVEL AND SAND WITH OCCASIONAL OXIDIZED CLASTS, EXTREMELY DENSE

FLUVIAL SAND:
DENSE TO VERY DENSE, GRAY-BROWN TO BROWN, WELL GRADED TO POORLY GRADED SAND WITH VARIABLE GRAVEL AND COBBLES.

MOBILE NAPL (SEE DEFINITION IN TEXT)

PW8 - 14'SE — BORING ID NUMBER AND DISTANCE OF OFFSET FROM ALIGNMENT

WELL SCREEN

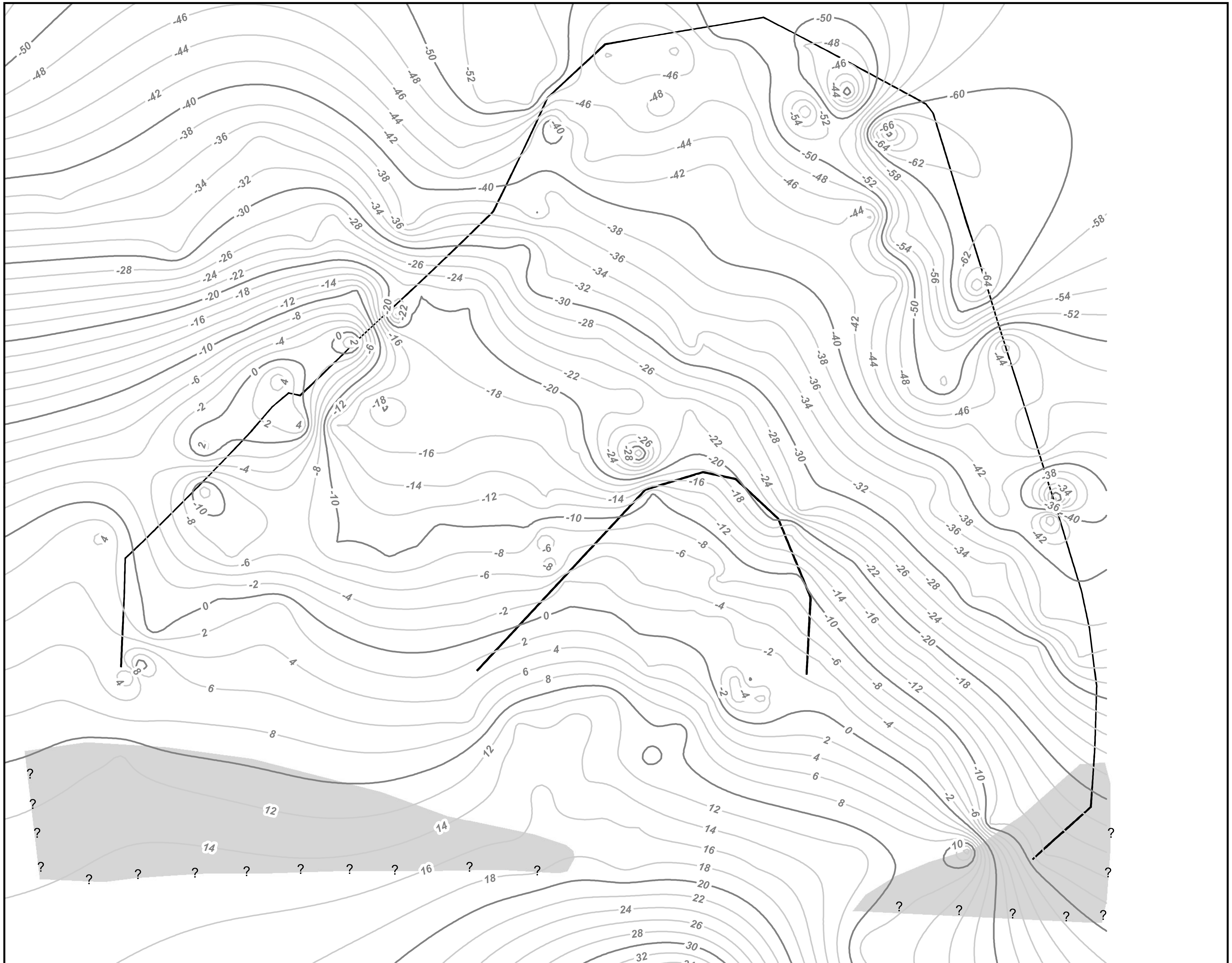
CH2MHILL

U.S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

Figure 4-15
D-D' Inset - Aquitard
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D				13
DSGN. BROOKSHIER		CHK. EASTERLY	FIGURE	

DATE AND TIME PLOTTED: $$$DATE$$$$ $TIME
DESIGN FILE: $$$DGN$$$



LEGEND

Top Elevation of Glacial Till (2 ft CI, ft MLLW)

Aquitard Thin (<4 ft) to Absent

Sheet Pile Wall

Notes:
CI = contour interval
ft MLLW = feet mean low low water

N

0 50 100 200 Feet

Figure 4-16
Top Elevation of the Glacial Till Portion of the Aquitard
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

C:\USERS\GGEE\DOCUMENTS\GIS\WYCKOFF\MAPFILES\2013\CSM\REPORT FIGURES\FIGURE4-16_GLACIALTILLSURFACE.MXD GGEE 1/30/2014 3:08:53 PM

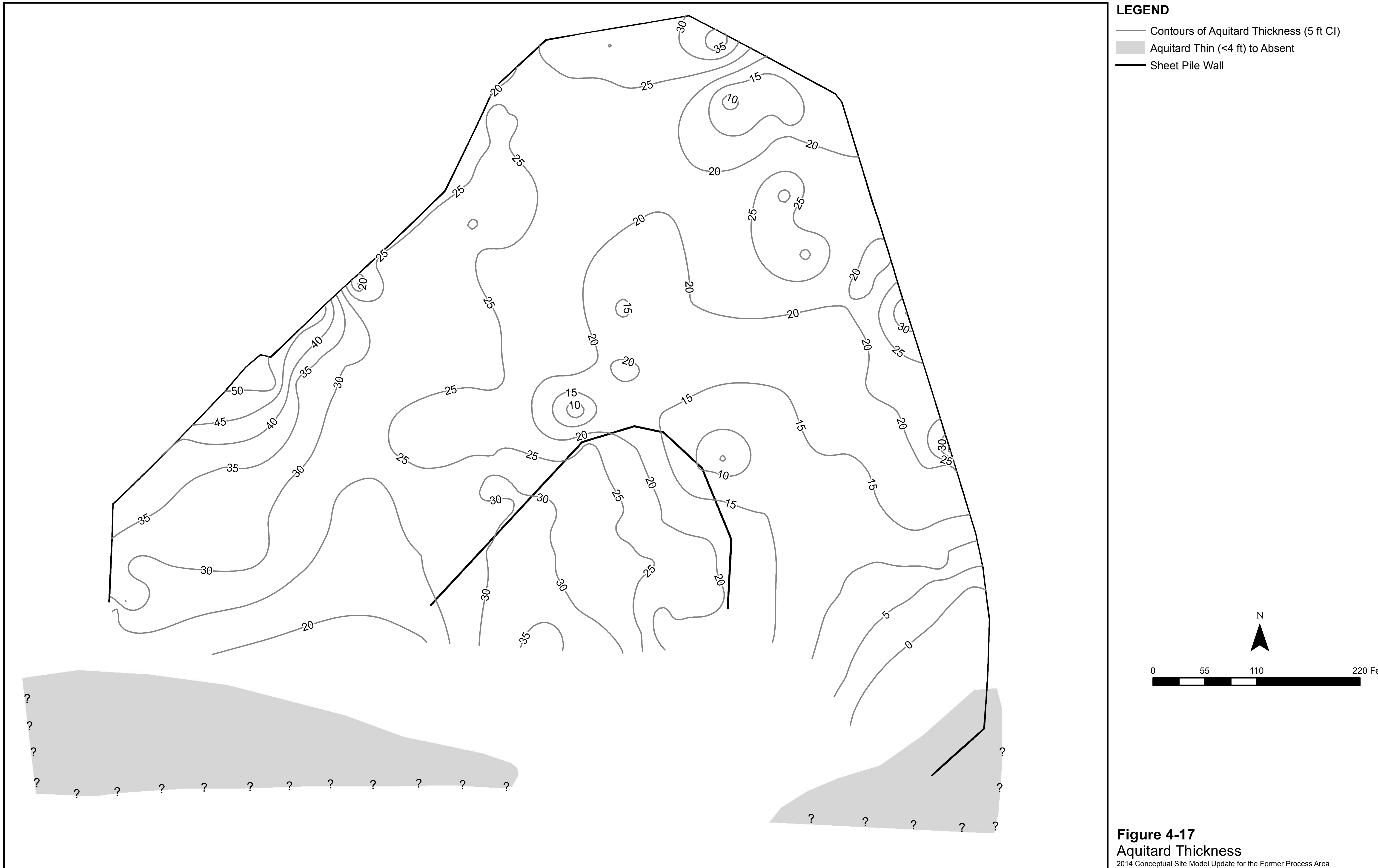
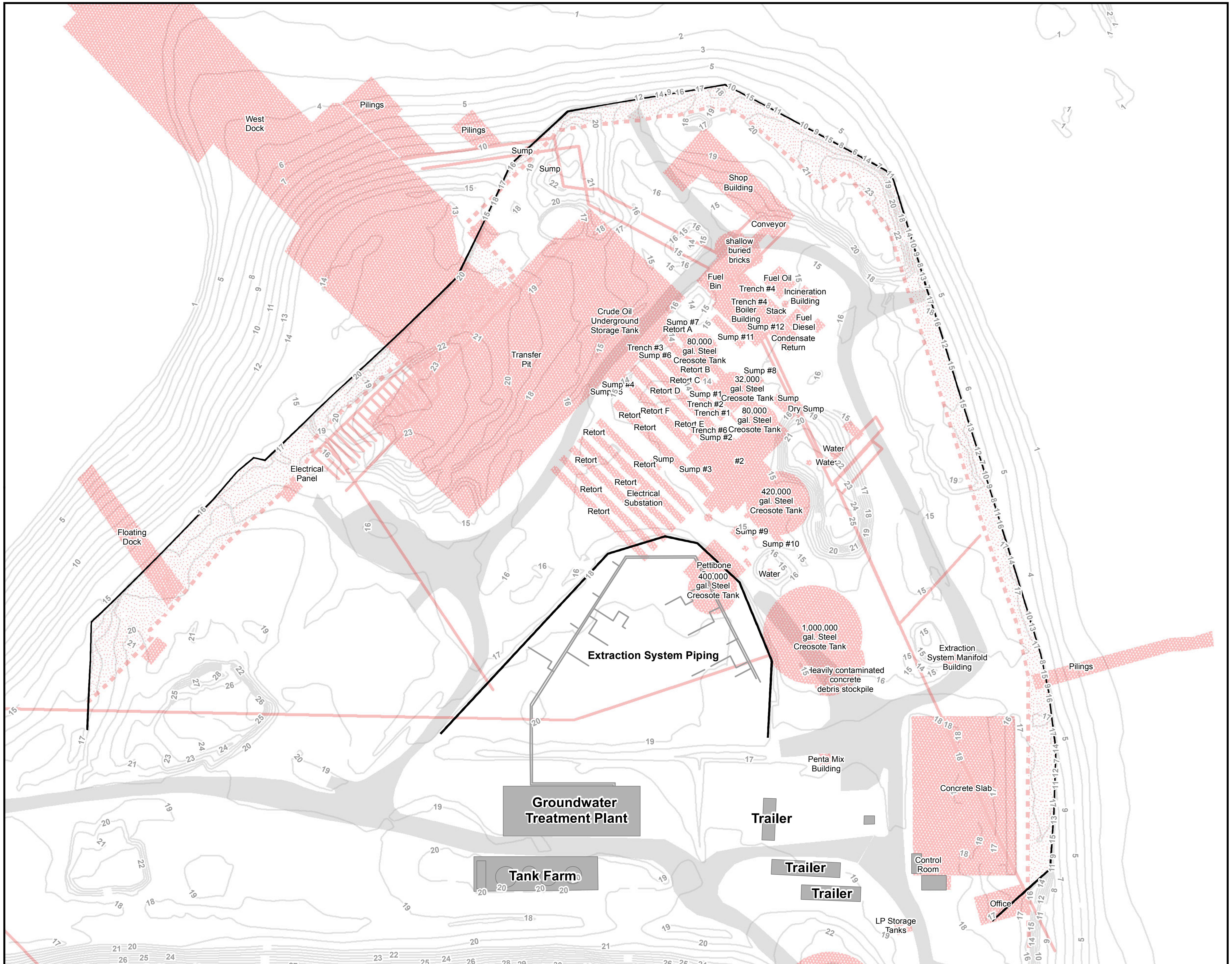


Figure 4-17
Aquitard Thickness
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

C:\USERS\GGEE\DOCUMENTS\GIS\WYCKOFF\MAPFILES\2013\CSM\REPORT FIGURES\FIGURE4-17_AQUITARDTHICKNESS.MXD GGEE 1/30/2014 3:07:36 PM



LEGEND

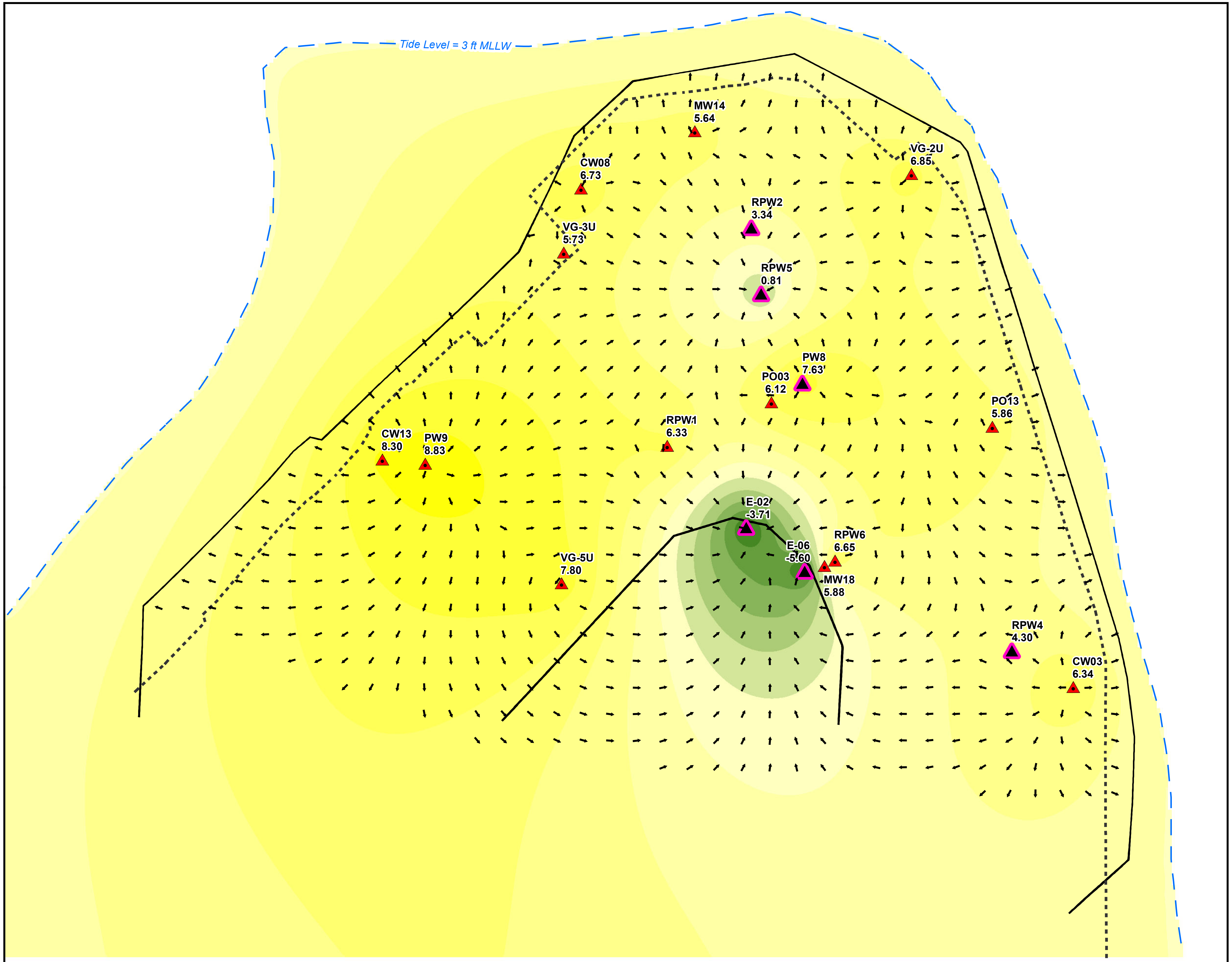
- Current Structures
- Sheet Pile Wall
- Old Bulk Head
- Debris Fill Between Old Bulk Head and Sheet Pile Wall
- Potential Buried Features
- Potential Remaining Foundations
- Current Roads
- Ground Surface Contours (ft MLLW)

N

0 50 100 200 Feet

Figure 4-18
Potential Foundation Locations
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

C:\USERS\GGEE\DOCUMENTS\GIS\WYCKOFF\MAPFILES\2013\CSM\REPORT FIGURES\FIGURE4-18_POTENTIALFOUNDATIONLOCATIONS.MXD GGEE 1/30/2014 2:28:29 PM



LEGEND

- Upper Aquifer Well (Well ID, Groundwater Elevation ft MLLW)
- Wells Pumping at the Time of Measurement
- Groundwater Flow Direction
- Bulk Head Prior to Current Sheet Pile Wall
- Tide Level (3 ft MLLW)
- Current Sheet Pile Wall

Groundwater Elevation (ft MLLW)

- -3.5 - -3
- -2.9 - -2
- -1.9 - -1
- -0.9 - 0
- 0.1 - 1
- 1.1 - 2
- 2.1 - 3
- 3.1 - 4
- 4.1 - 5
- 5.1 - 6
- 6.1 - 7
- 7.1 - 8
- 8.1 - 9

Displayed Data:
Tidal Data - Incoming Tide; July 25, 2012 at 1248
Surface water level = 2.96 MLLW
Well Transducer Data - July 25, 2012 at 1255

Pumping Data:
RPW1 (off)
RPW2 = 10.20 gpm
RPW4 = 7.46 gpm
RPW5 = 9.22 gpm
RPW6 (off)
PW8 = 6.87 gpm
PW9 (off)
E-02 = 4.80 gpm
E-06 = 5.60 gpm

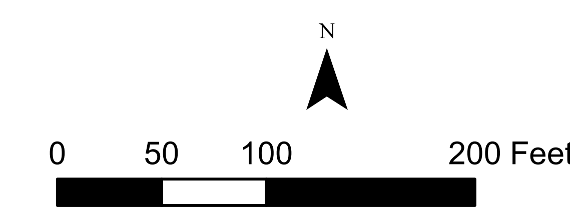
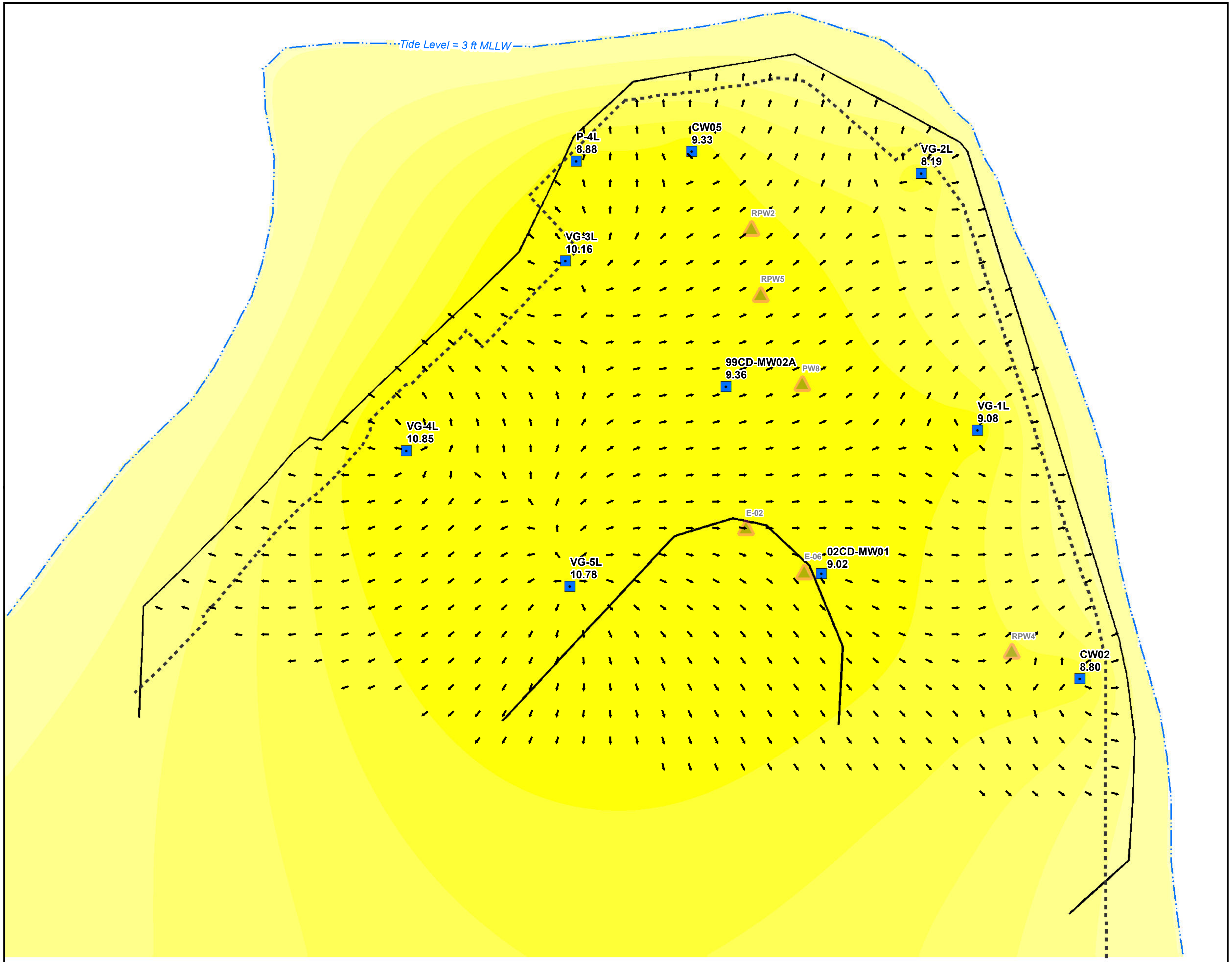


Figure 4-19a
Water Elevation Measurements (ft MLLW)
July 25, 2012, Pumping Wells Active
Upper Aquifer Wells

2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

C:\USERS\GGEE\DOCUMENTS\GIS\WYCKOFF\MAPFILES\2013\CSM\REPORT FIGURES\FIGURE4-20A_UPPER_JULY.MXD GGEE 9/20/2013 8:18:34 AM



LEGEND

- Lower Aquifer Well (Well ID, Groundwater Elevation ft MLLW)
- Wells Pumping at the Time of Measurement
- Groundwater Flow Direction
- Tide Level (3 ft MLLW)
- Bulk Head Prior to Current Sheet Pile Wall
- Current Sheet Pile Wall

Groundwater Elevation (ft MLLW)

- -3.5 - -3
- -2.9 - -2
- -1.9 - -1
- -0.9 - 0
- 0.1 - 1
- 1.1 - 2
- 2.1 - 3
- 3.1 - 4
- 4.1 - 5
- 5.1 - 6
- 6.1 - 7
- 7.1 - 8
- 8.1 - 9

Displayed Data:
Tidal Data - Incoming Tide; July 25, 2012 at 1248
Surface water level = 2.96 MLLW
Well Transducer Data - July 25, 2012 at 1255

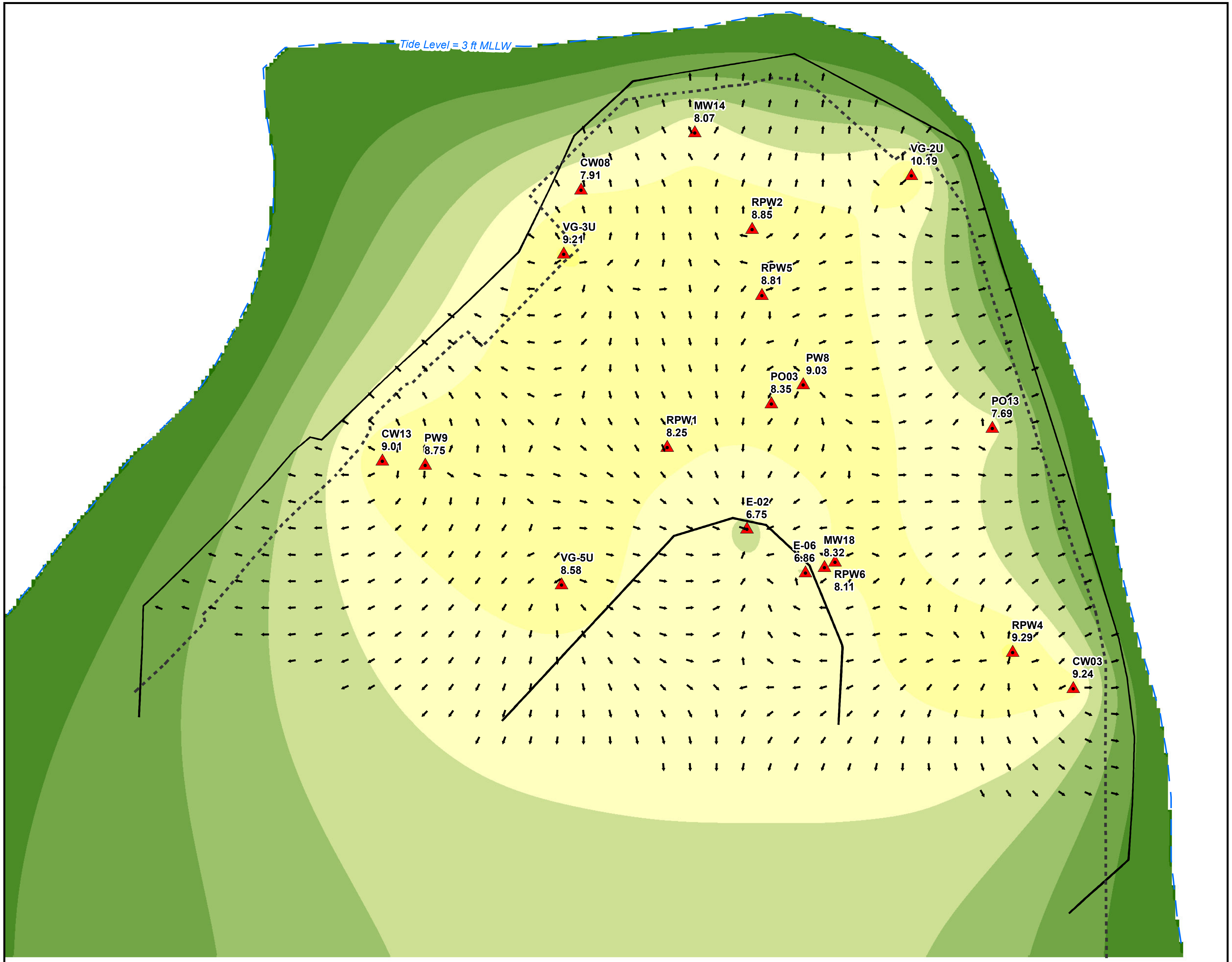
Pumping Data (Upper Aquifer):
RPW1 (off)
RPW2 = 10.20 gpm
RPW4 = 7.46 gpm
RPW5 = 9.22 gpm
RPW6 (off)
PW8 = 6.87 gpm
PW9 (off)
E-02 = 4.80 gpm
E-06 = 5.60 gpm

N

0 50 100 200 Feet

Figure 4-19b
Water Elevation Measurements (ft MLLW)
July 25, 2012, Pumping Wells Active
Lower Aquifer Wells
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

C:\USERS\GGEE\DOCUMENTS\GIS\WYCKOFF\MAPFILES\2013\CSM\REPORT FIGURES\FIGURE4-20B_LOWER_JULY.MXD GGEE 9/20/2013 8:18:07 AM



LEGEND

- Upper Aquifer Well (Well ID, Groundwater Elevation ft MLLW)
- Groundwater Flow Direction
- Tide Level (3 ft MLLW)
- Bulk Head Prior to Current Sheet Pile Wall
- Current Sheet Pile Wall

Groundwater Elevation (ft MLLW)

- 2.95 - 3.00
- 3.01 - 4.00
- 4.01 - 5.00
- 5.01 - 6.00
- 6.01 - 7.00
- 7.01 - 8.00
- 8.01 - 9.00
- 9.01 - 10.00
- 10.01 - 11.00
- 11.01 - 12.00
- 12.01 - 13.00

Displayed Data:
Tidal Data - Incoming Tide; September 3, 2012 at 2106
Surface water level = 2.99 MLLW
Well Transducer Data - September 3, 2012 at 2101
No wells pumping

Figure 4-20a
Water Elevation Measurements (ft MLLW)
September 3, 2012, Pumping Wells Inactive
Upper Aquifer Wells
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

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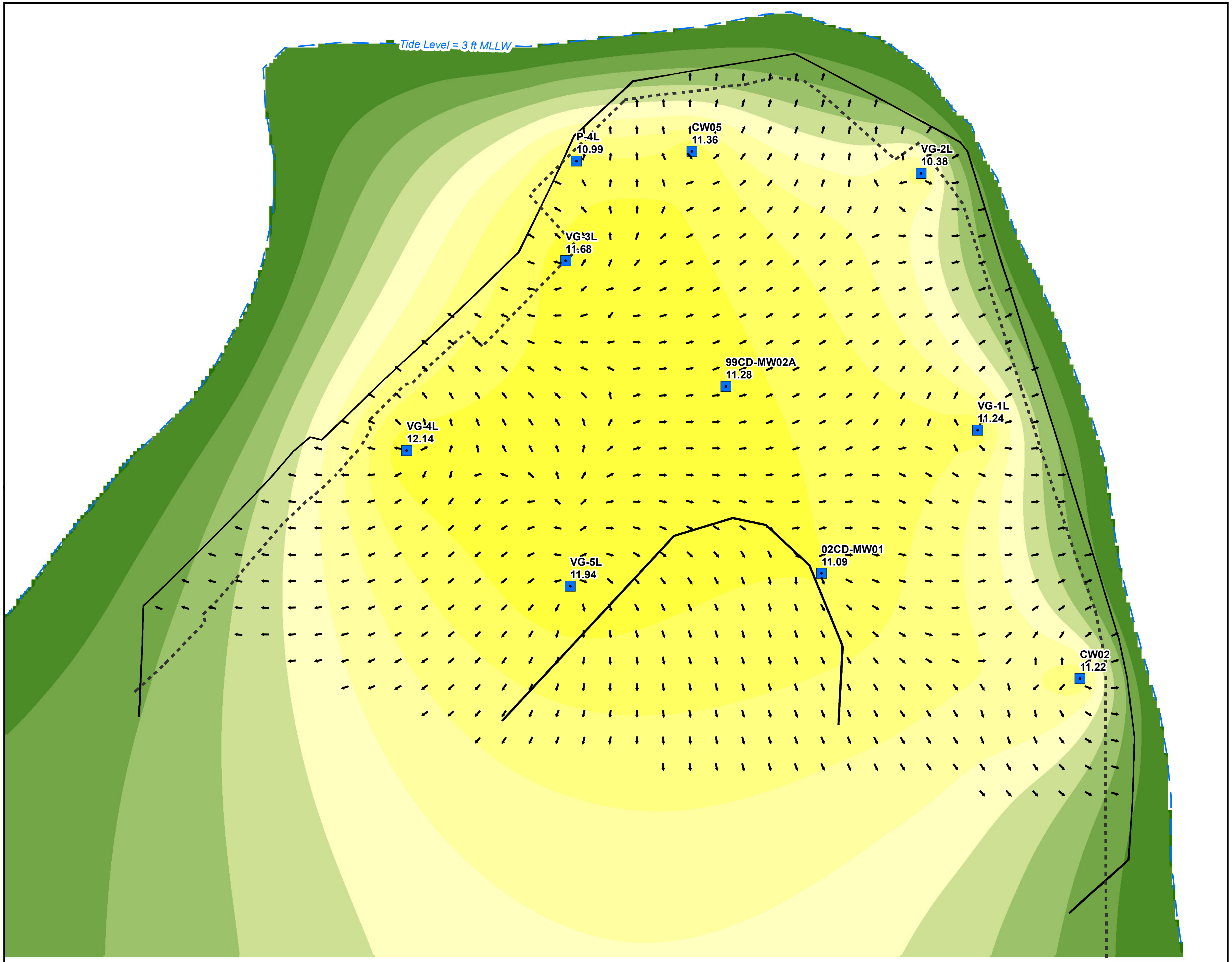

LEGEND

- Lower Aquifer Well (Well ID, Groundwater Elevation ft MLLW)
- Groundwater Flow Direction
- Tide Level (3 ft MLLW)
- Bulk Head Prior to Current Sheet Pile Wall
- Current Sheet Pile Wall

Groundwater Elevation (ft MLLW)

- 2.95 - 3.00
- 3.01 - 4.00
- 4.01 - 5.00
- 5.01 - 6.00
- 6.01 - 7.00
- 7.01 - 8.00
- 8.01 - 9.00
- 9.01 - 10.00
- 10.01 - 11.00
- 11.01 - 12.00
- 12.01 - 13.00

Displayed Data:
Tidal Data - Incoming Tide; September 3, 2012 at 2106
Surface water level = 2.99 MLLW
Well Transducer Data - September 3, 2012 at 2101
No wells pumping

N

0 50 100 200 Feet

Figure 4-20b
Water Elevation Measurements (ft MLLW)
September 3, 2012, Pumping Wells Inactive
Lower Aquifer Wells

2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

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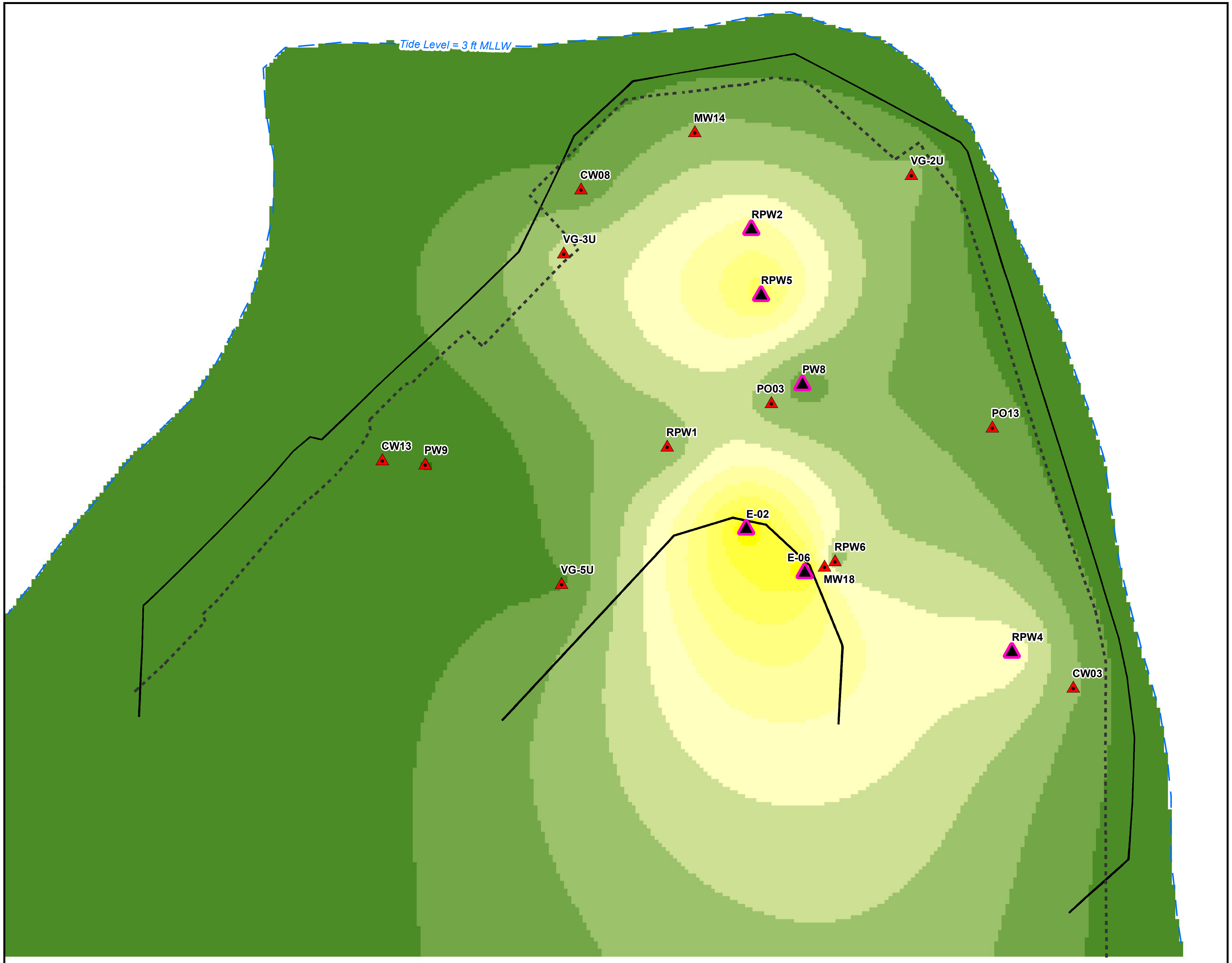

LEGEND

- Upper Aquifer Well (Well ID)
- Wells Pumping (July 25, 2012)
- Bulk Head Prior to Current Sheet Pile Wall
- Tide Level (3 ft MLLW)
- Current Sheet Pile Wall

Difference in Groundwater Elevation (ft MLLW)

- -0.3 - 0
- 0.1 - 1
- 1.1 - 2
- 2.1 - 3
- 3.1 - 4
- 4.1 - 5
- 5.1 - 6
- 6.1 - 7
- 7.1 - 8
- 8.1 - 9
- 9.1 - 10

July 25, 2012 Data:
Tidal Data - Incoming Tide; July 25, 2012 at 1248
Surface water level = 2.96 MLLW
Well Transducer Data - July 25, 2012 at 1255

Pumping Data (July 25):
RPW1 (off)
RPW2 = 10.20 gpm
RPW4 = 7.46 gpm
RPW5 = 9.22 gpm
RPW6 (off)
PW8 = 6.87 gpm
PW9 (off)
E-02 = 4.80 gpm
E-06 = 5.60 gpm

September 3, 2012 Data:
Tidal Data - Incoming Tide; September 3, 2012 at 2106
Surface water level = 2.99 MLLW
Well Transducer Data - September 3, 2012 at 2101
No wells pumping

N

0 50 100 200 Feet

Figure 4-21
Difference in Water Elevation Measurements (ft MLLW) Between Pumping and Non-Pumping Scenarios
Upper Aquifer Wells

2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

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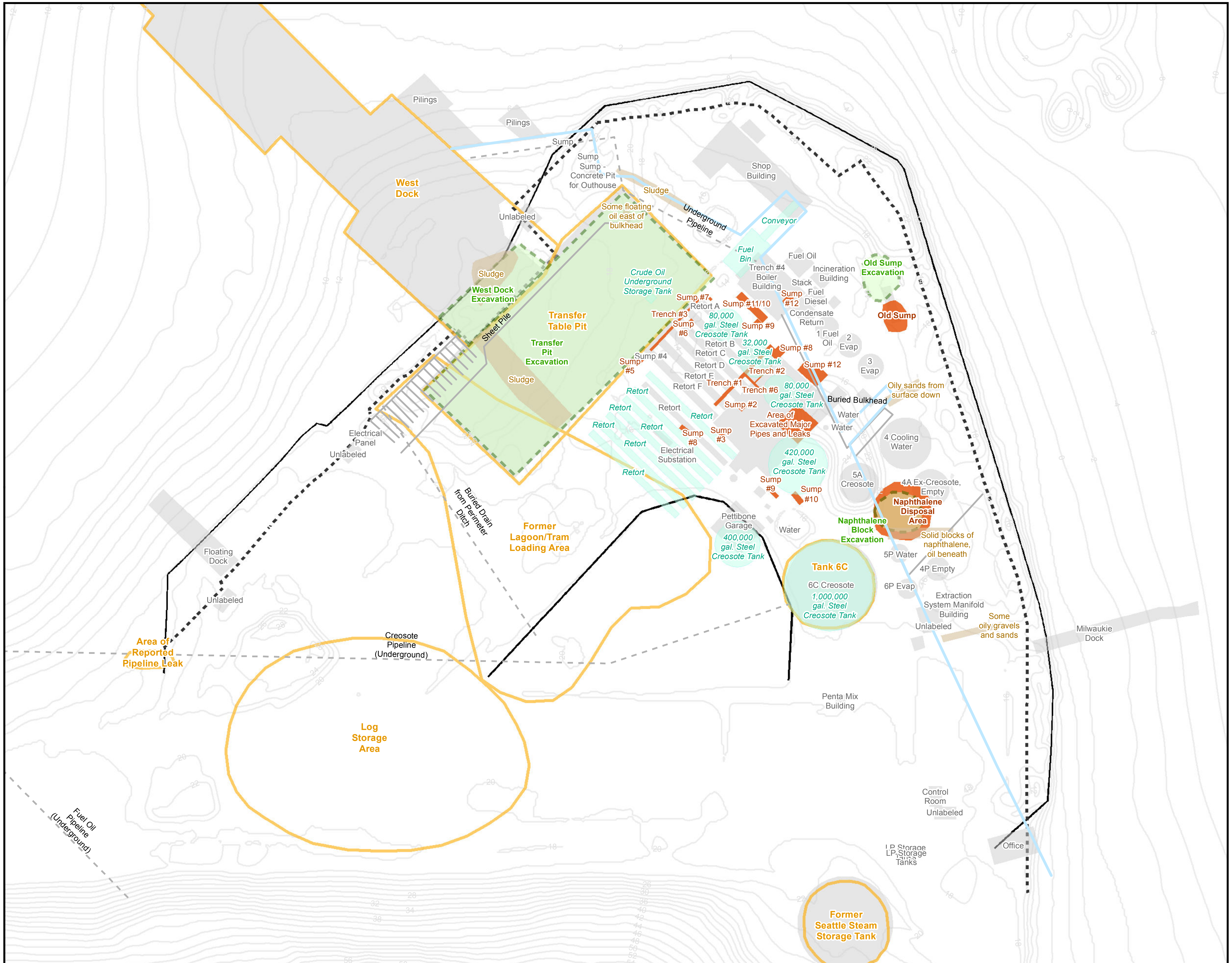

LEGEND

- Historic Features
- Historic Features Identified from 1917 Sandborn Map
- Site Remediation Excavation Performed in 1992 through 1994
- Potential Primary NAPL Sources (Sumps, Trenches, and other features with observed contamination)
- Potential Secondary NAPL Source Areas
- Trenching and other features of interest identified in April 1989 Map
- Facility Shoreline as of 1917
- Bulk Head Prior to Current Sheet Pile Wall
- Current Sheet Pile Wall
- Ground Surface Contours (2 ft CI, ft MLLW)

Sources:
Bulk Head Prior to Current Sheet Pile Wall digitized from current sheet pile wall design drawings (USACE, 2000)
Some sumps and trenches were digitized from "Figure 1 Site Location" (Environment and Ecology, 1995)
Sumps and Trenches were digitized from "Figure B Area 1 Trenches and Sumps"; "Figure C Area 2 Drums, Sumps, 7 Tanks"; "Figure D Area 3 Containers, Drums, Sumps, Tanks & Trenches" (Environment and Ecology, 1995)
Secondary NAPL Source Locations digitized from "Figure 2-1 Wycoff Site Vicinity Map" (CH2M HILL, 1993)
Trenching observations digitized from 1989 hand markup.
Prioritizing of source areas conducted 2012.

N

0 50 100 200 Feet

Figure 5-1
Potential Source Areas and Site Features
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

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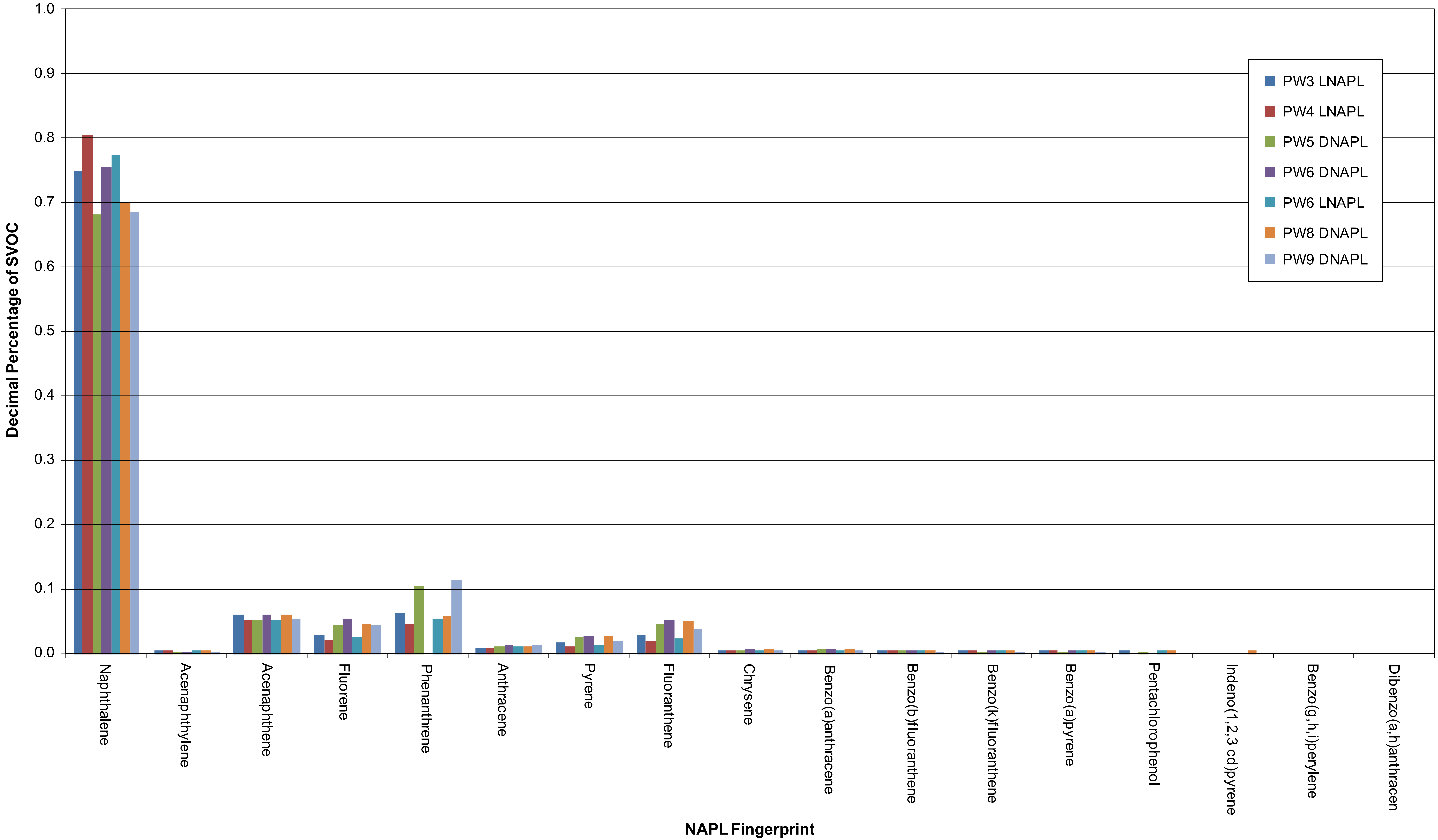
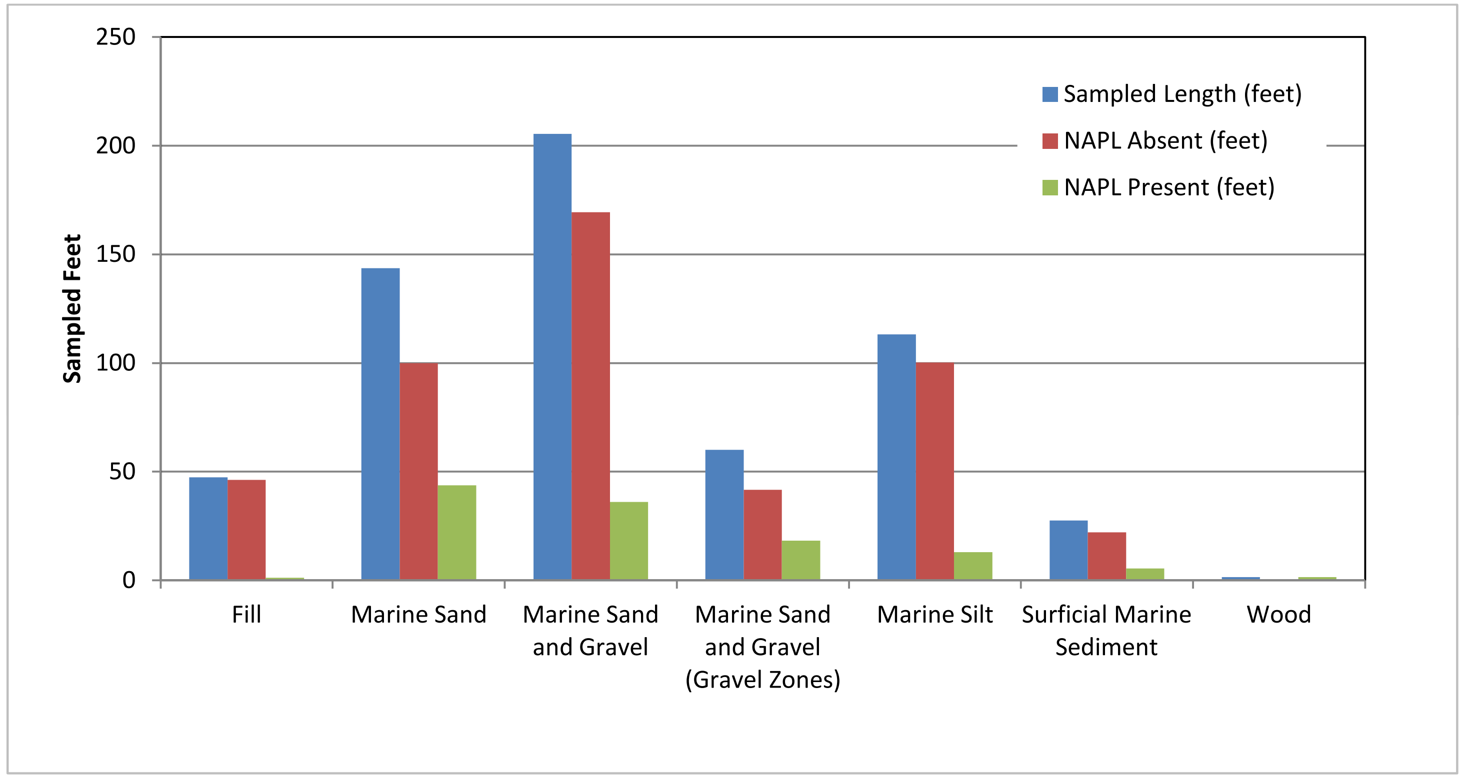
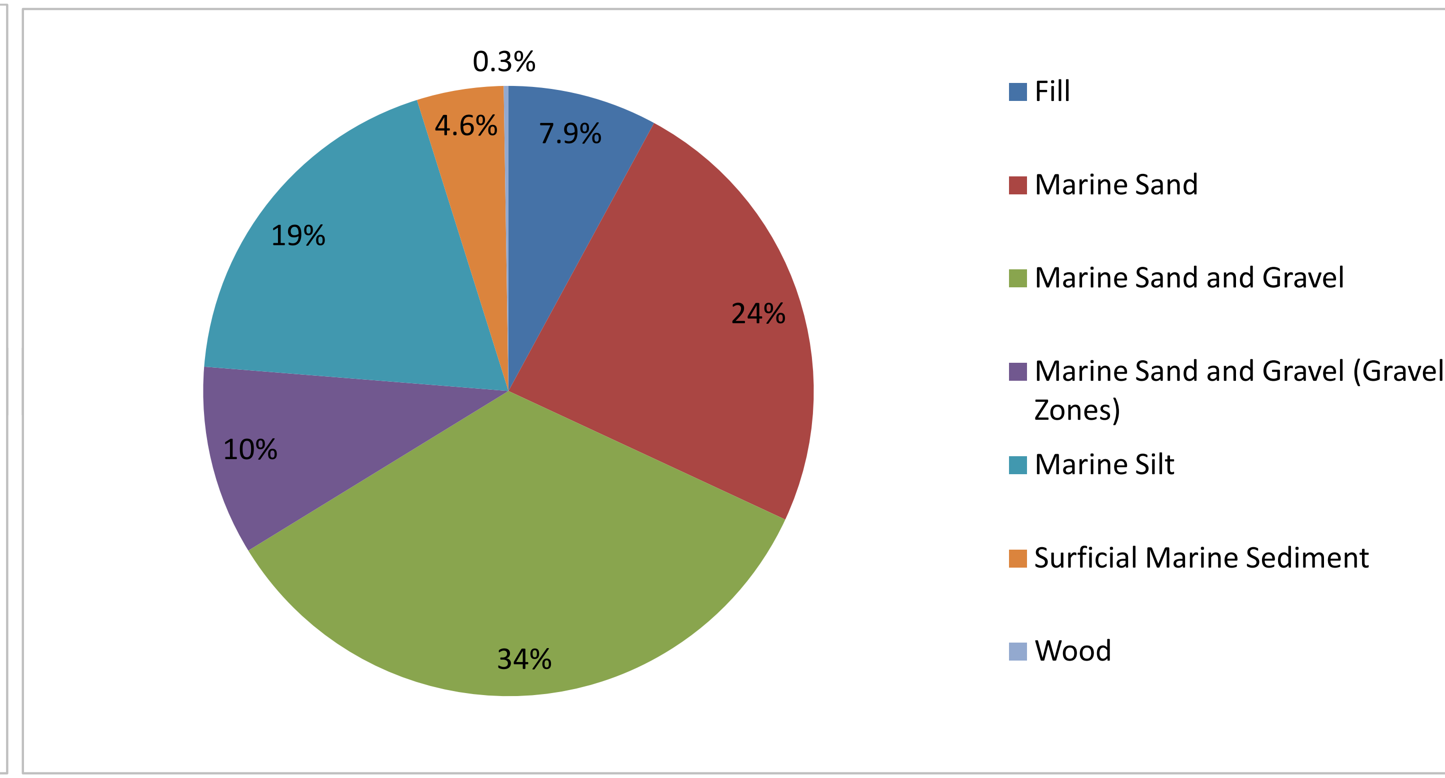


FIGURE 5-2
Graphical Fingerprint of PAH and PCP Constituents in NAPL Samples
2014 Conceptual Site Model Update

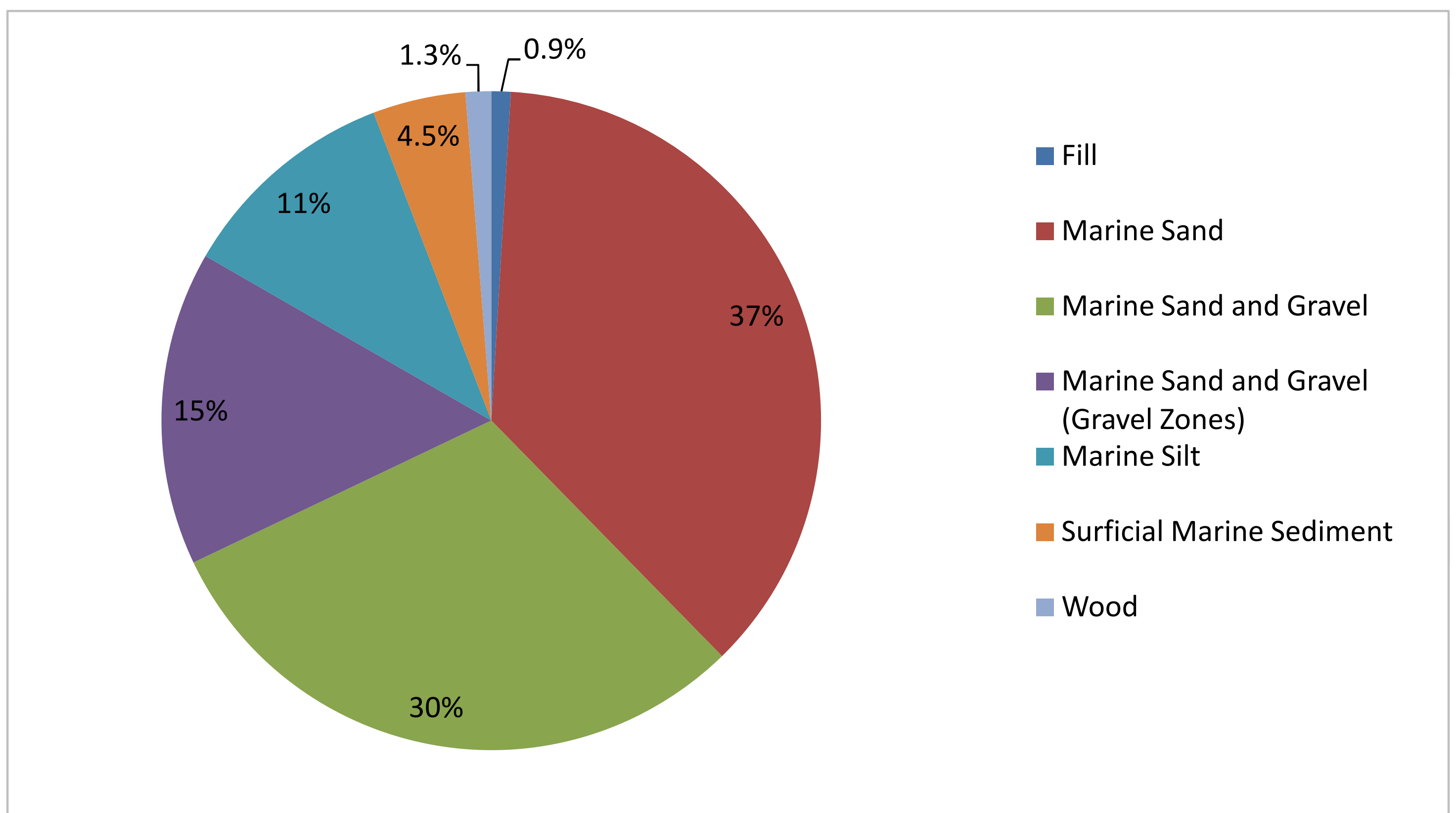
CH2MHILL.



Summary of Lithology and NAPL Absence/Presence by feet



Summary of Lithology by Percentage of Confirmation Boring Footage

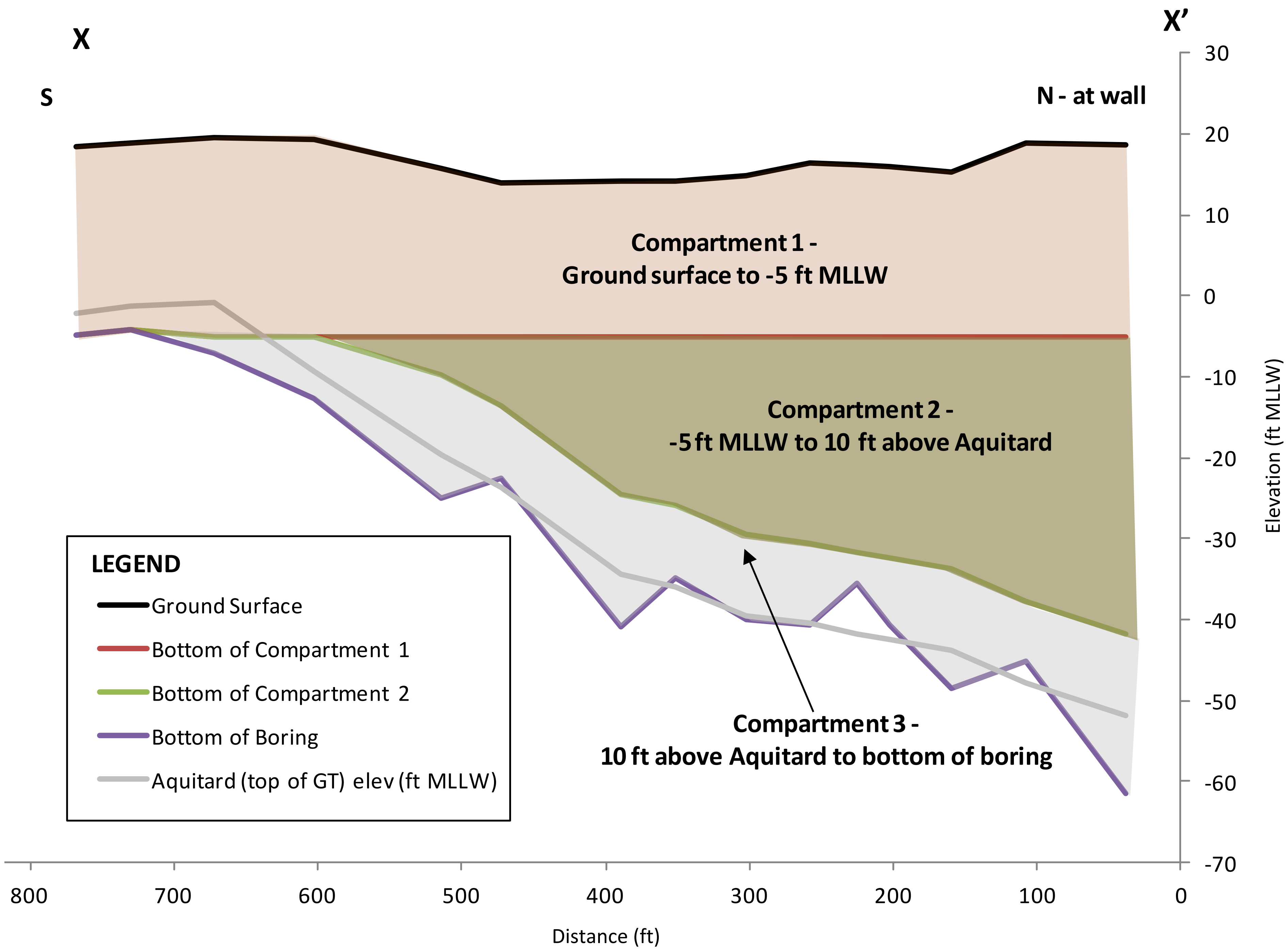


Summary of NAPL Presence in Lithology by Total Observed NAPL

Data Table

Lithology	Sampled Length (feet)	NAPL Absent (feet)	NAPL Present (feet)
Fill	47	46	1.1
Marine Sand	144	100	44
Marine Sand and Gravel	205	169	36
Marine Sand and Gravel (Gravel Zones)	60	42	18
Marine Silt	113	100	13
Surficial Marine Sediment	27	22	5.4
Wood	1.5	0	1.5
Grand Total	**598**	**479**	**119**

Figure 5-3
Confirmation Boring Lithology and NAPL Observations by Historical Geologic Unit Descriptions
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site



LOCATION MAP

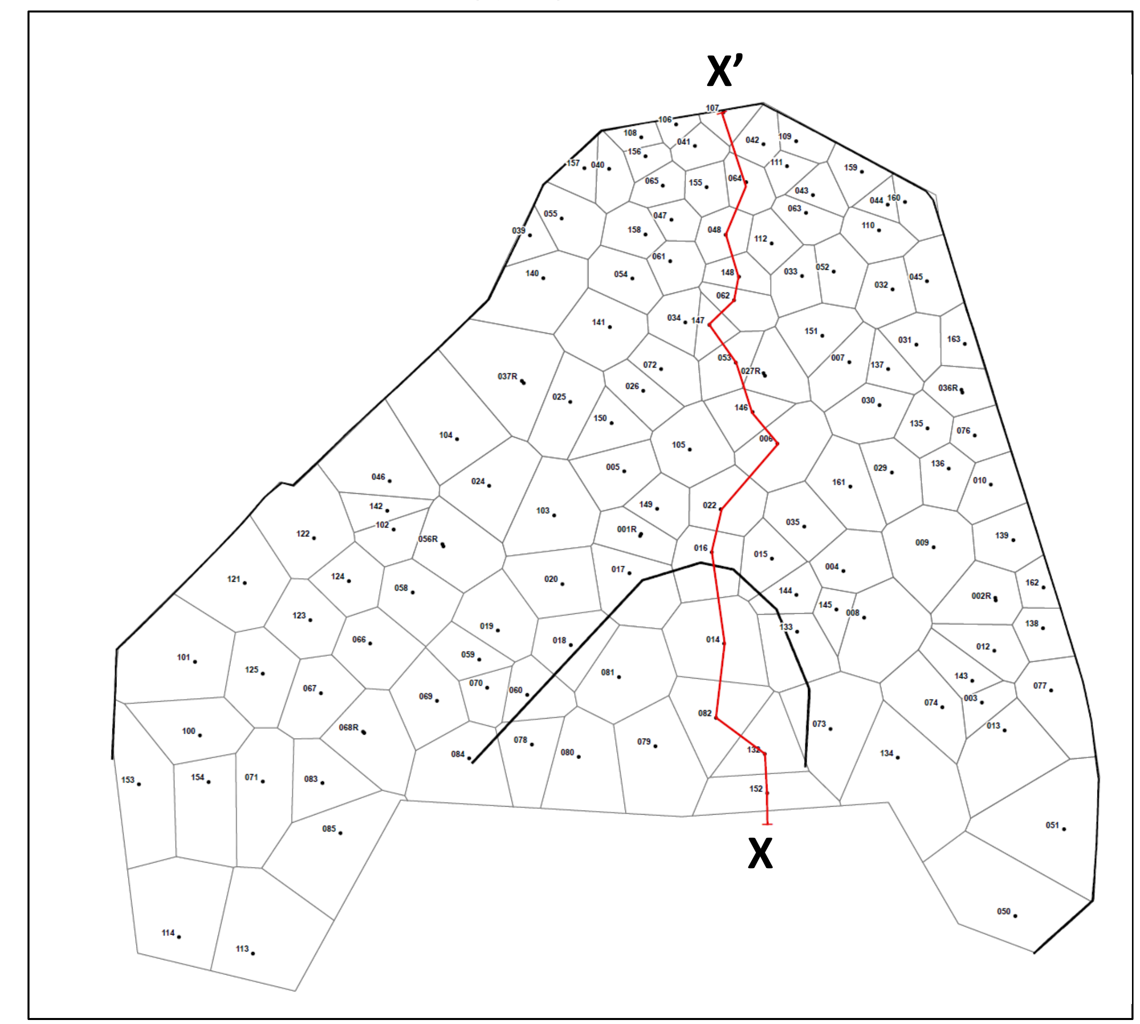


Figure 5-4
Fence Diagram Illustrating Compartment Thicknesses
Upland Dataset
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

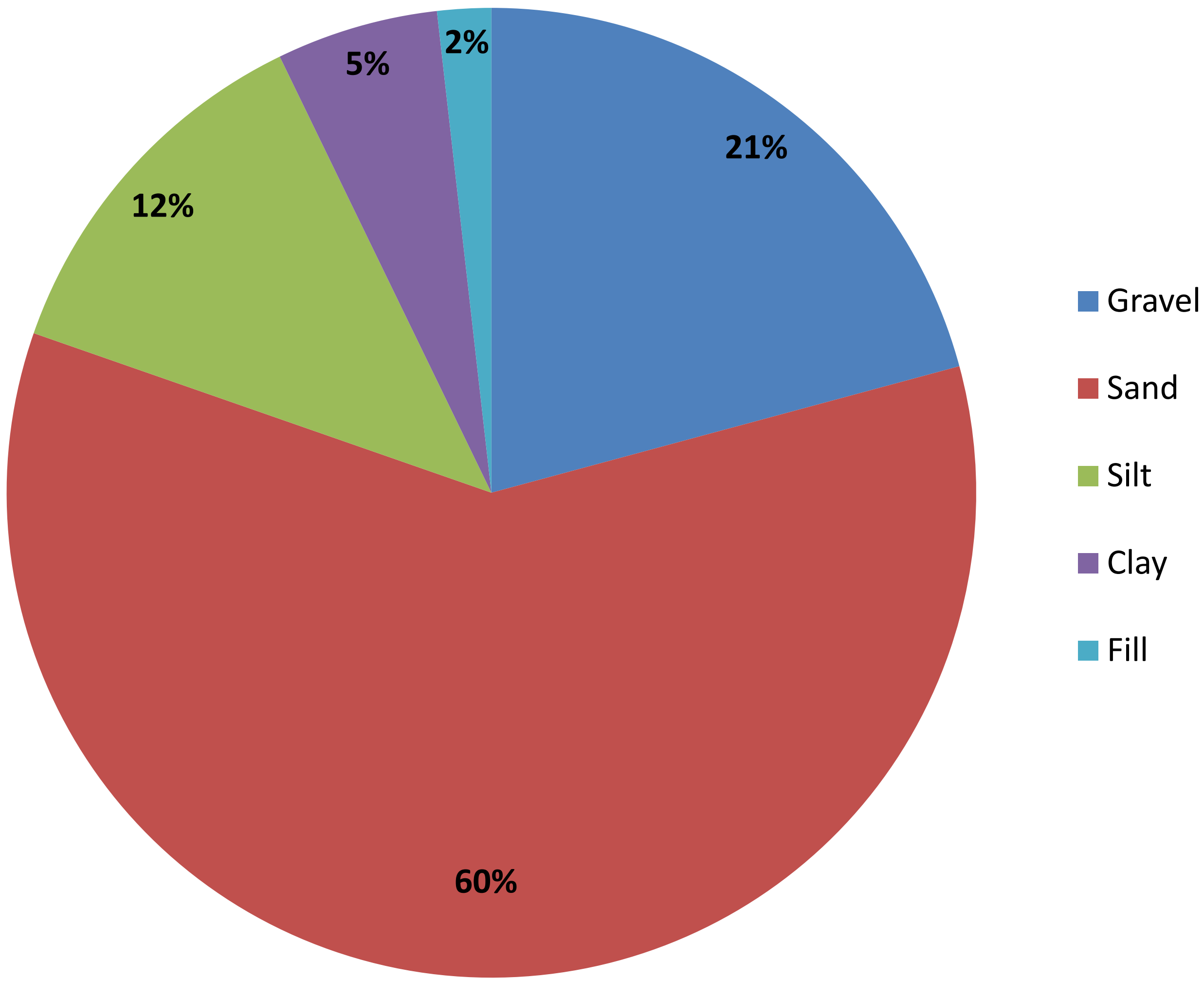


Figure 5-5
NAPL Distribution: Total of Subareas and Compartments
(see Table 5-2)
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

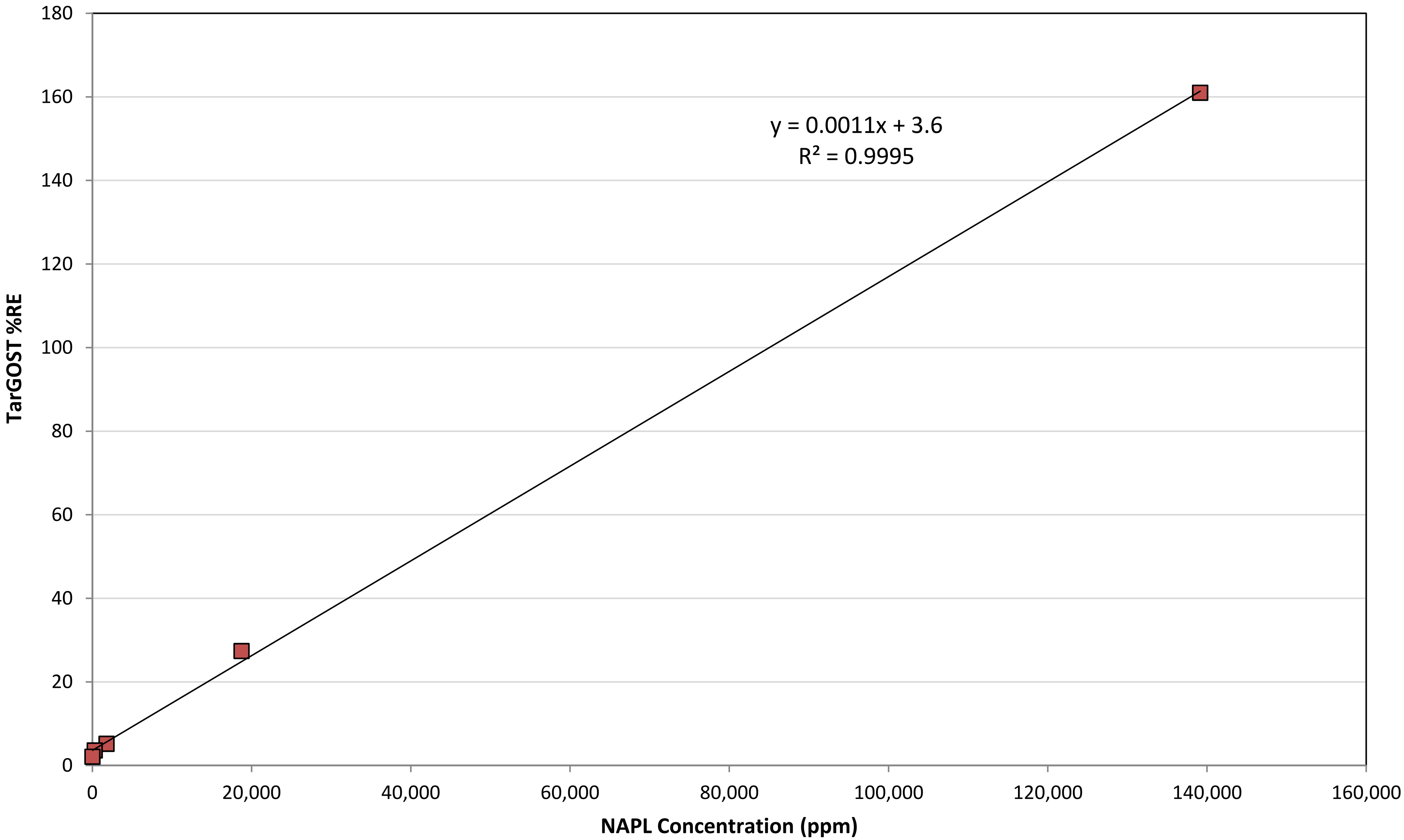
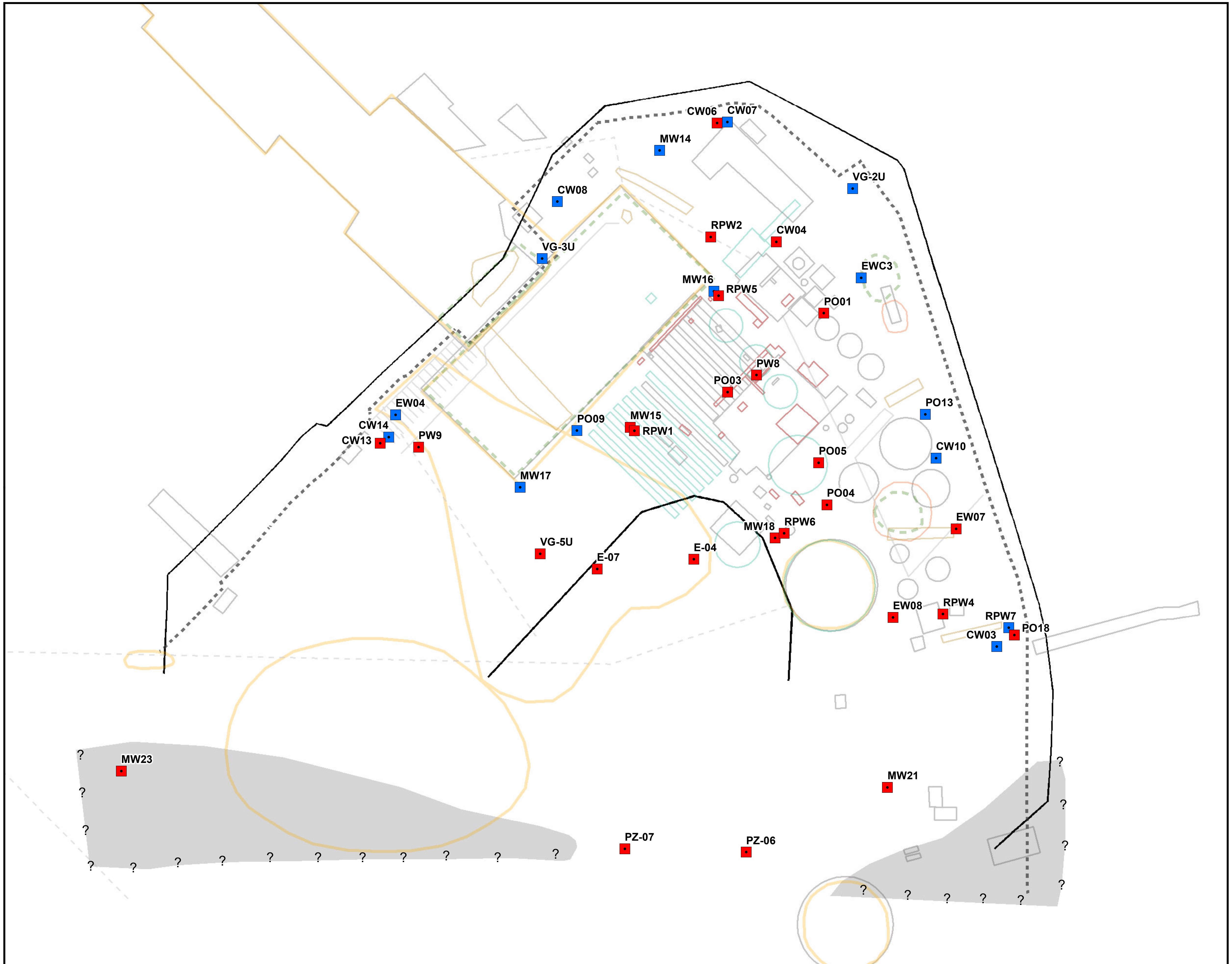


Figure 5-6
Calibration Curve Between TarGOST LIF Response and Weight Percentage of LNAPL
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site



LEGEND

- Upper Aquifer Well with Measured NAPL Presence
- Upper Aquifer Well with No NAPL Present
- Trenching and other features of interest identified in April 1989 Map
- Historic Features Identified from 1917 Sandborn Map
- Site Remediation Excavation Performed in 1992 through 1994
- Potential Primary NAPL Sources (Sumps, Trenches, and other features with observed contamination)
- Potential Secondary NAPL Source Areas
- Historic Features
- Bulk Head Prior to Current Sheet Pile Wall
- Current Sheet Pile Wall
- Aquitard Thin (<4 ft) to Absent

Sources:
Bulk Head Prior to Current Sheet Pile Wall digitized from current sheet pile wall design drawings (USACE, 2000)
Some sumps and trenches were digitized from "Figure 1 Site Location" (Environment and Ecology, 1995)
Sumps and Trenches were digitized from "Figure B Area 1 Trenches and Sumps"; "Figure C Area 2 Drums, Sumps, 7 Tanks"; "Figure D Area 3 Containers, Drums, Sumps, Tanks & Trenches" (Environment and Ecology, 1995)
Secondary NAPL Source Locations digitized from "Figure 2-1 Wycoff Site Vicinity Map" (CH2M HILL, 1993)
Trenching observations digitized from 1989 hand markup.
Prioritizing of source areas conducted 2012.
Prior remediation excavation areas from 1992 through 1994 digitized from Ecology and Environment, Inc., 1995.

N

0 60 120 240 Feet

Figure 5-7
NAPL Presence in Upper Aquifer Wells Measured September 2012
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

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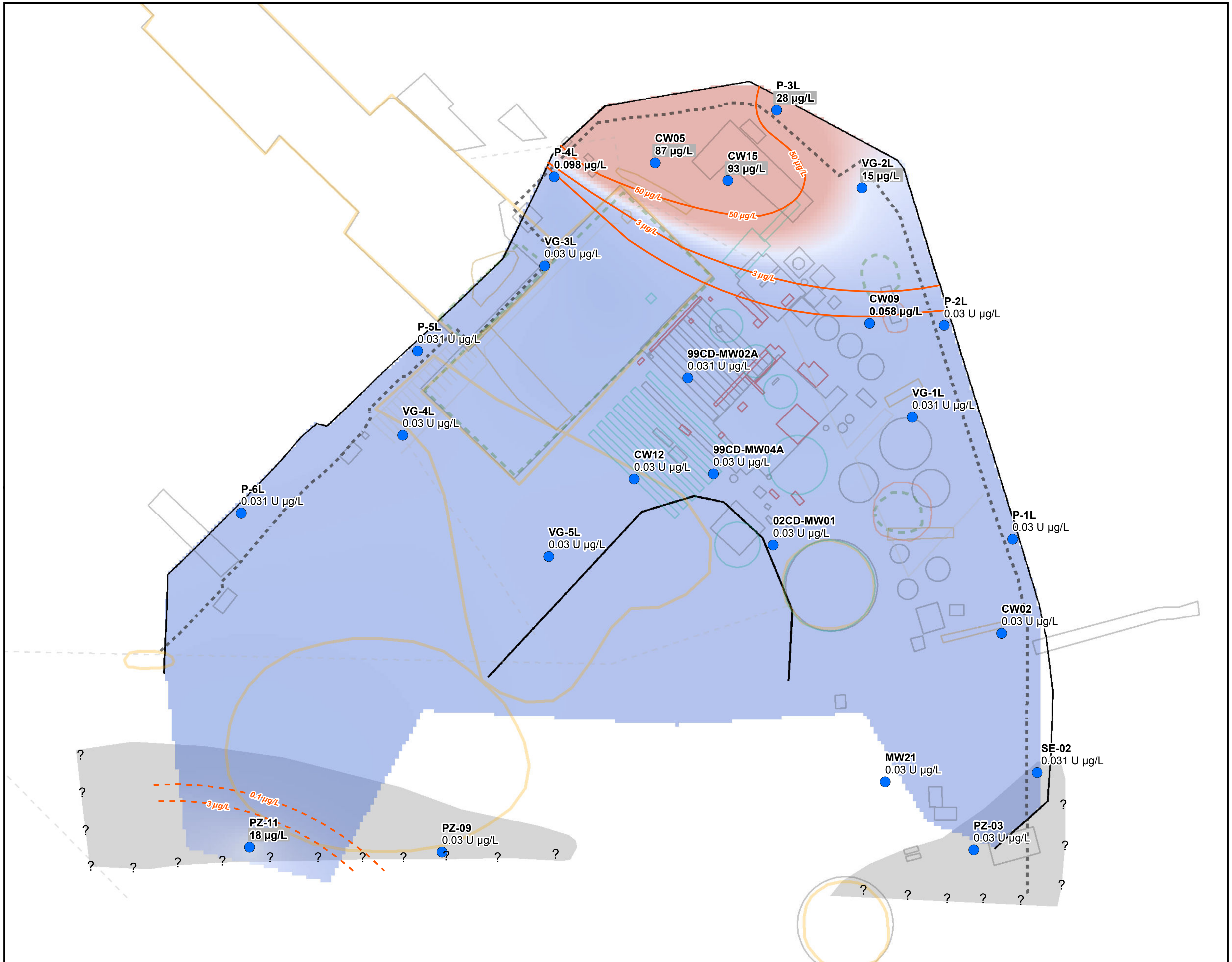

LEGEND

- Acenaphthene Measured May 2013 (µg/L)
- Acenaphthene Isopleth (0.1, 3, and 50 µg/L)
- Inferred Acenaphthene Isopleth

Interpolated Acenaphthene Concentration (µg/L)

High : 90

Low : 0

Historic Features and Potential Source Areas

- Trenching and other features of interest identified in April 1989 Map
- Historic Features Identified from 1917 Sandborn Map
- Site Remediation Excavation Performed in 1992 through 1994
- Potential Primary NAPL Sources (Sumps, Trenches, and other features with observed contamination)
- Potential Secondary NAPL Source Areas
- Historic Features
- Bulk Head Prior to Current Sheet Pile Wall
- Aquitard Thin (<4 ft) to Absent
- Current Sheet Pile Wall

Notes:
Bold values = Acenaphthene was detected in well.
Shaded/Bold values = Acenaphthene exceeds groundwater cleanup level of 3.0 µg/L established in the Wyckoff ROD 2/2000.
µg/L = micrograms per Liter

Sources:
Bulk Head Prior to Current Sheet Pile Wall digitized from current sheet pile wall design drawings (USACE, 2000)
Some sumps and trenches were digitized from "Figure 1 Site Location" (Environment and Ecology, 1995)
Sumps and Trenches were digitized from "Figure B Area 1 Trenches and Sumps"; "Figure C Area 2 Drums, Sumps, 7 Tanks"; "Figure D Area 3 Containers, Drums, Sumps, Tanks & Trenches" (Environment and Ecology, 1995)
Secondary NAPL Source Locations digitized from "Figure 2-1 Wycoff Site Vicinity Map" (CH2M HILL, 1993)
Trenching observations digitized from 1989 hand markup.
Prioritizing of source areas conducted 2012.
Prior remediation excavation areas from 1992 through 1994 digitized from Ecology and Environment, Inc., 1995.

N

0 60 120 240 Feet

Figure 5-8
Acenaphthene Concentration Isopleths Measured May 2013
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

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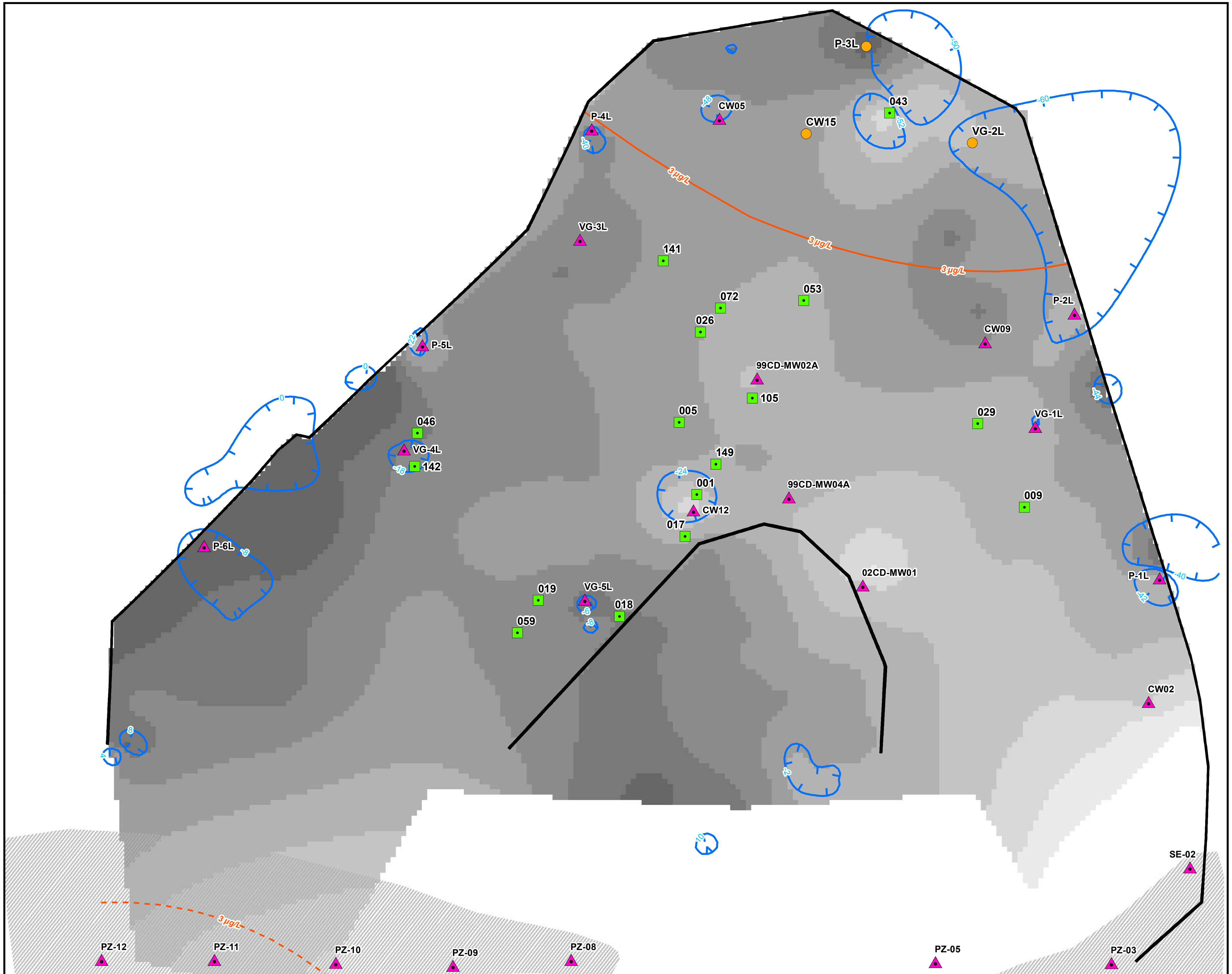

LEGEND

- TarGOST Location where NAPL pool height at aquitard > 9.4 feet
- Lower Aquifer Well with Observed NAPL Presence
- Lower Aquifer Well
- Acenaphthene Isopleth (3 µg/L)
- Inferred Acenaphthene Isopleth (3 µg/L)
- Aquitard Surface Depressions

Aquitard Thickness (ft MLLW)

- <0
- 0 - 5
- 5 - 10
- 10 - 15
- 15 - 20
- 20 - 25
- 25 - 30
- 30 - 35
- >35
- Aquitard Thin (<4 ft) to Absent

Notes:
Acenaphthene groundwater cleanup level of 3.0 µg/L established in the Wyckoff ROD 2/2000.
µg/L = micrograms per Liter
ft MLLW = feet mean low low water

N

0 45 90 180 Feet

Figure 5-9
Aquitard Observations for Assessing Potential for NAPL Migration to Lower Aquifer
2014 Conceptual Site Model Update for the Former Process Area
Wyckoff/Eagle Harbor Superfund Site

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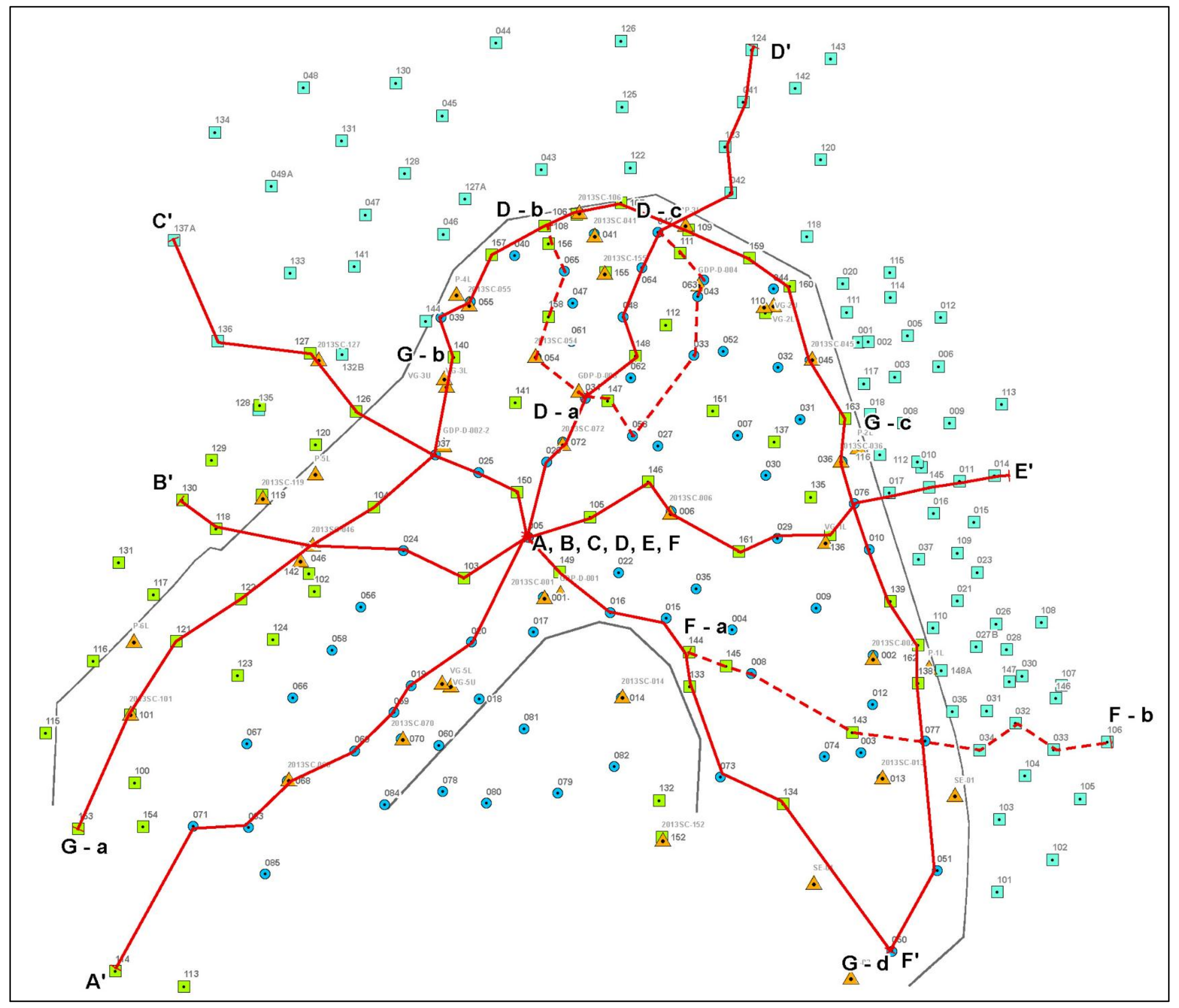
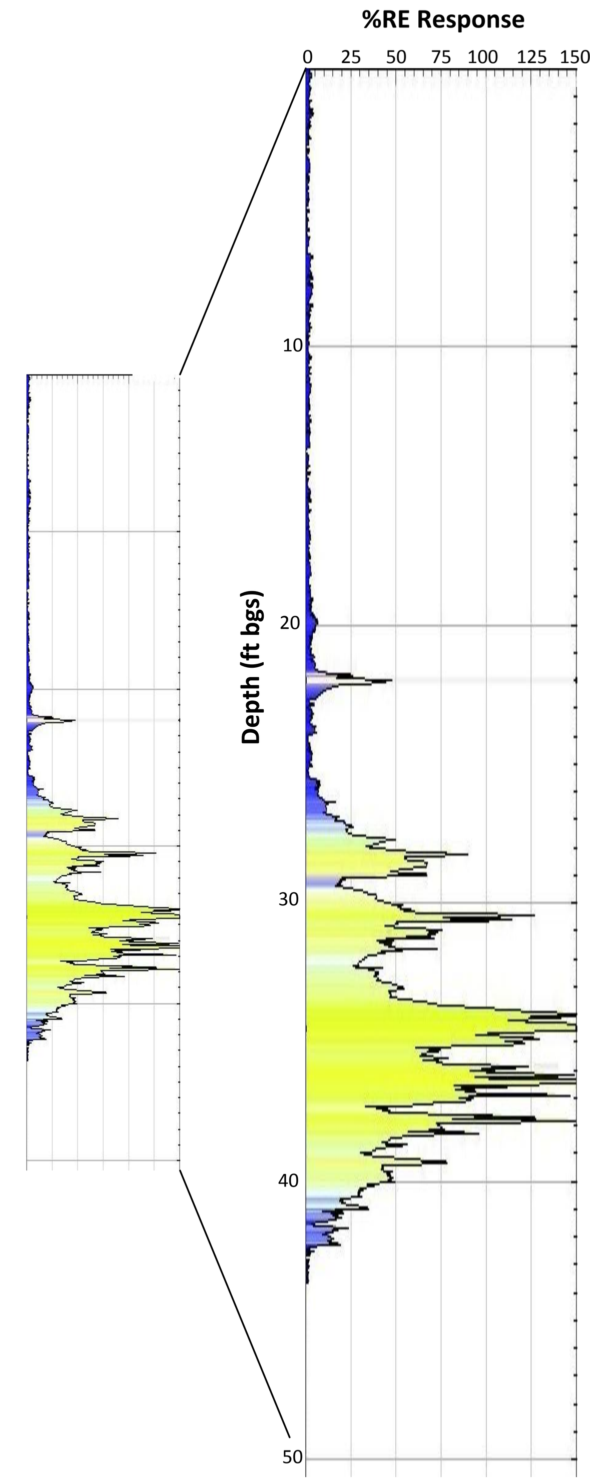
Plates

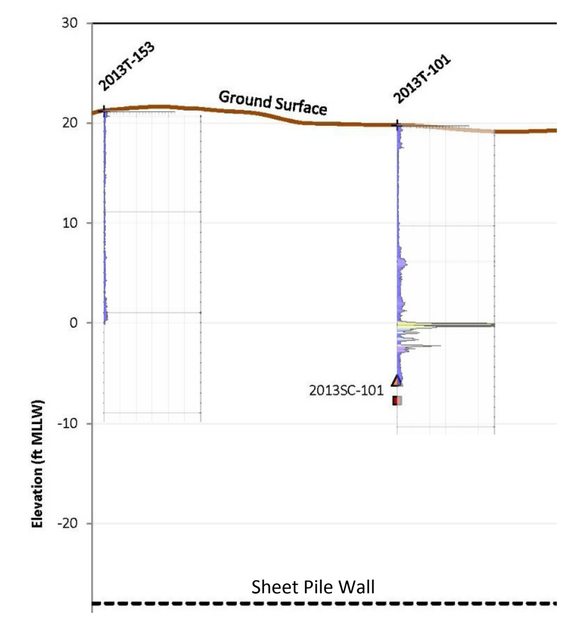
Fence diagrams A through F radiate out from a TarGOST location central to the site (2013T-005). Fence diagram G (a through c) parallels the sheet pile wall on the upland portion of the site.
Dashed sub-fence diagrams are intended to follow potential flow paths of NAPL to the sheet pile wall.

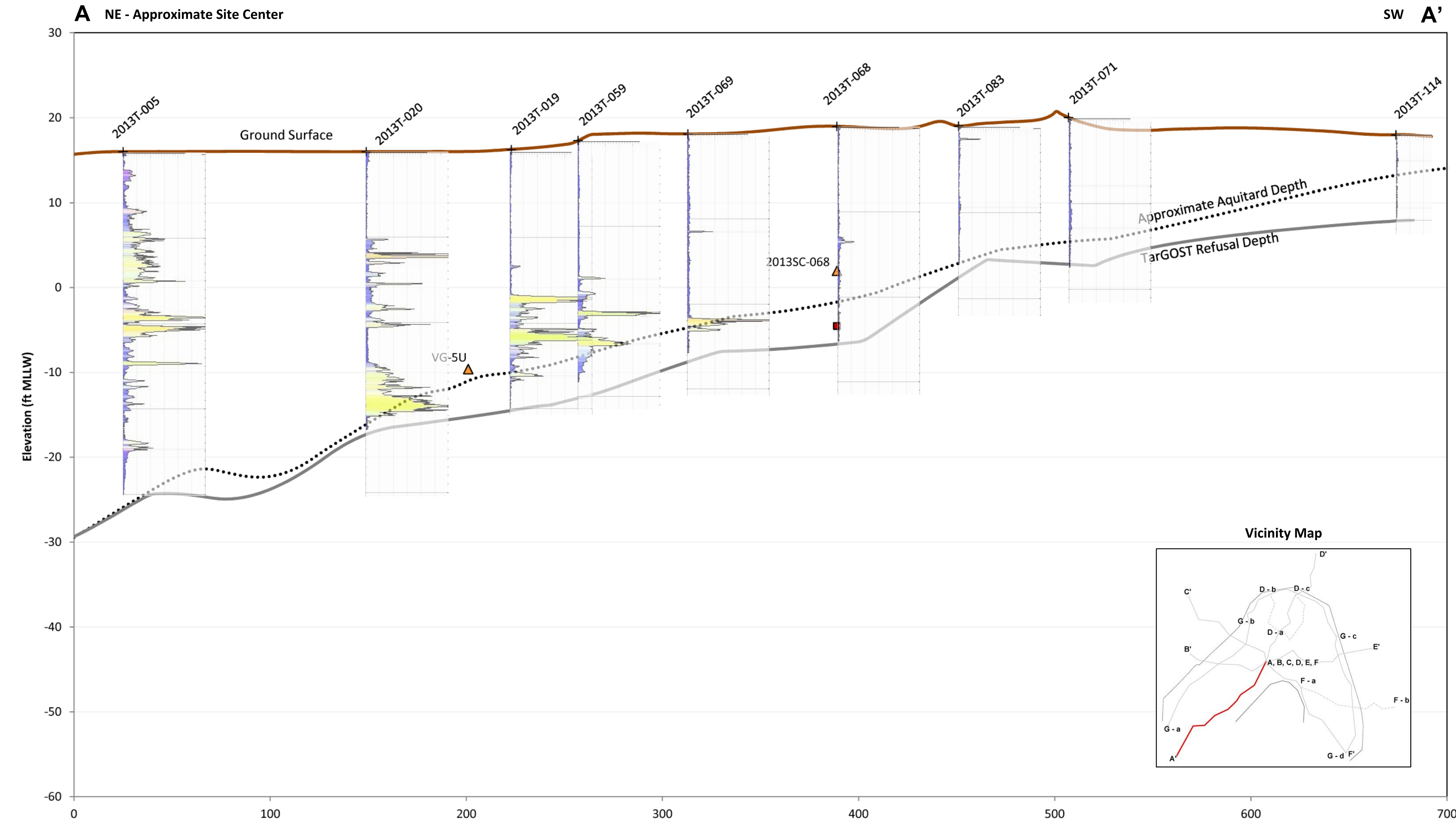


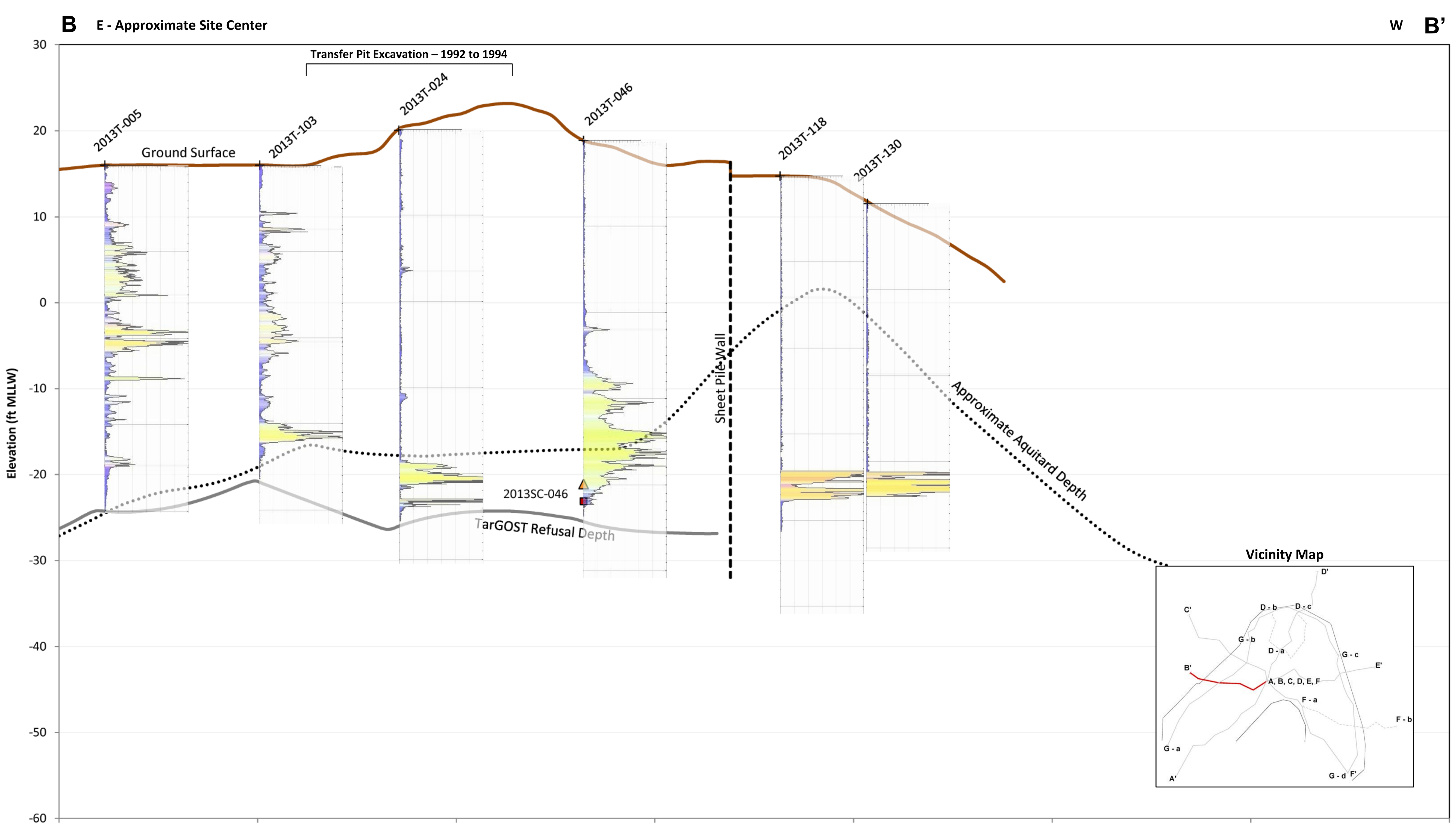


LEGEND FOR FENCE DIAGRAM ELEMENTS

- Ground surface extracted from GIS
- Sheet Pile Wall
- Glacial till depth indicated by recent boring <20 ft from fence
- Depth to refusal of recent boring <20 ft from fence







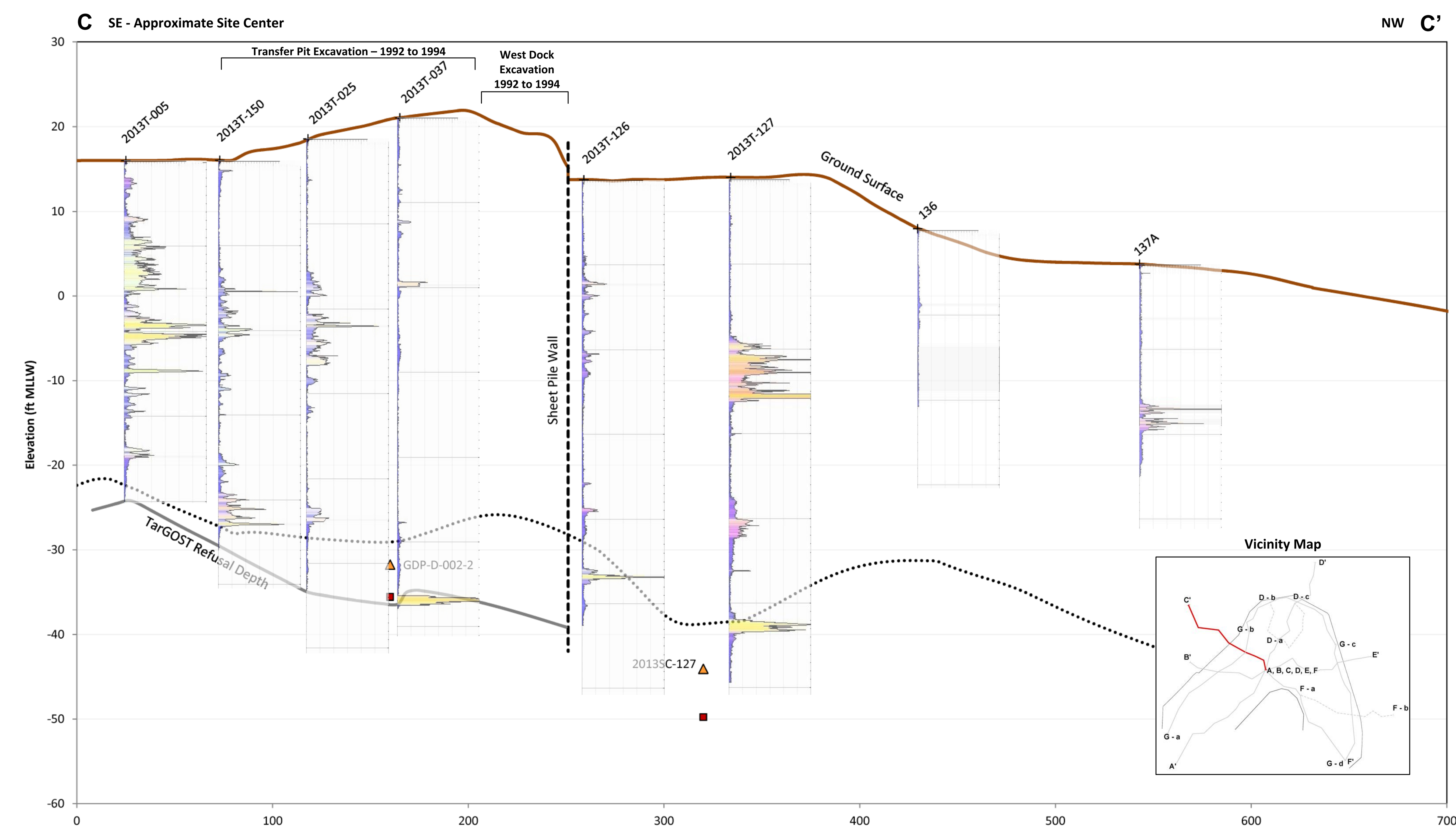


Plate 1
Fence Diagrams Overview, A-A', B-B', and C-C'
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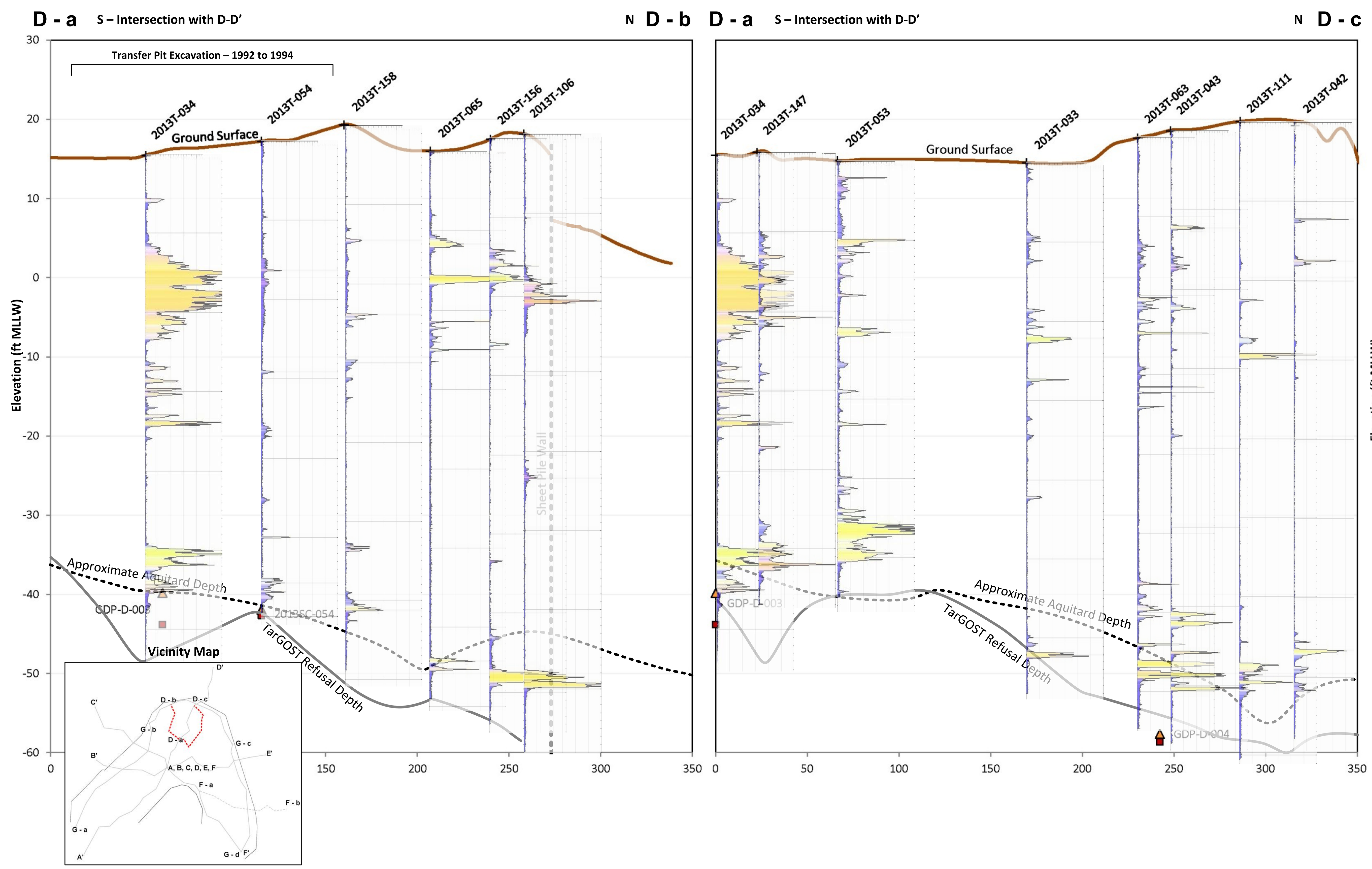

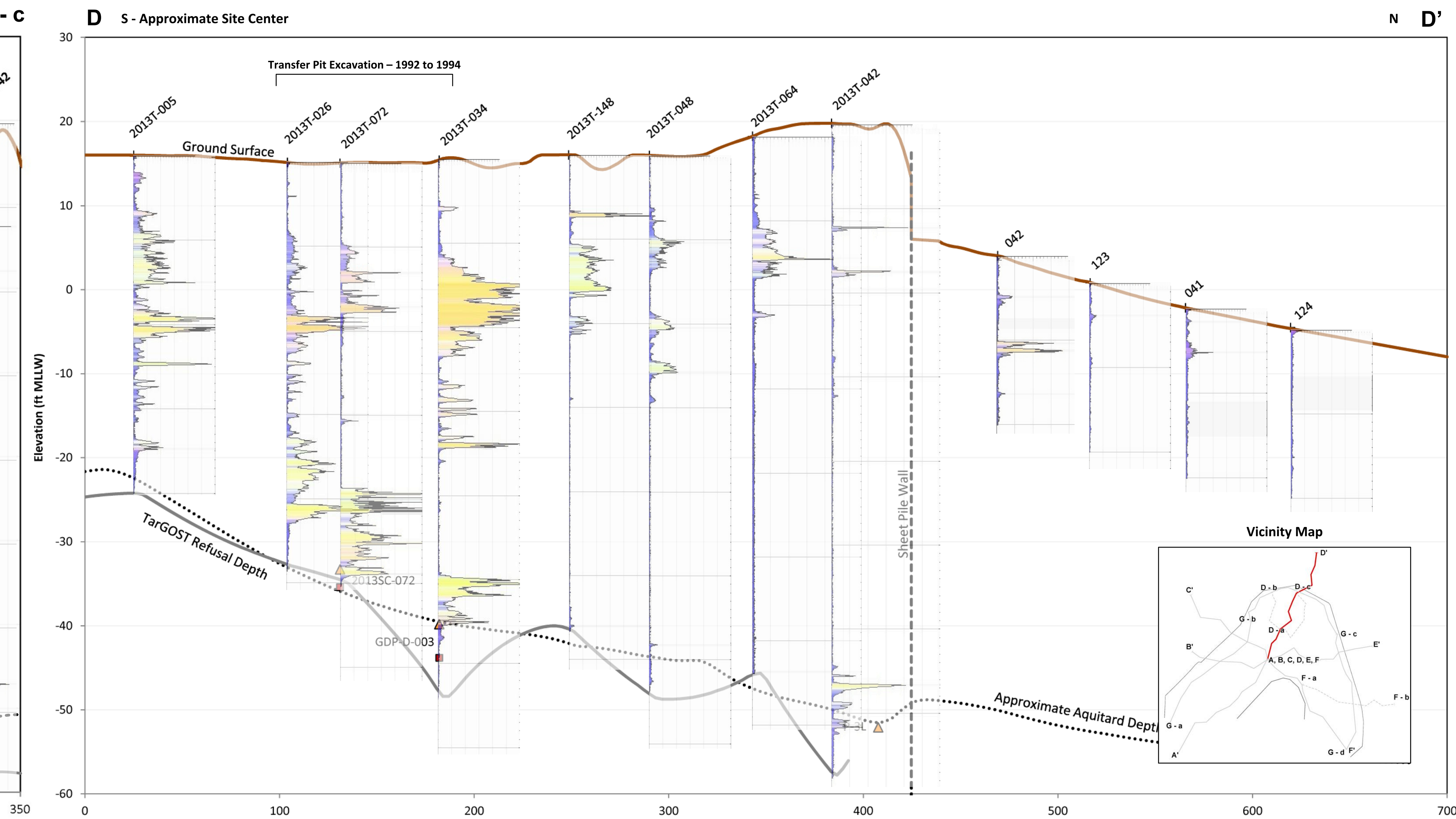

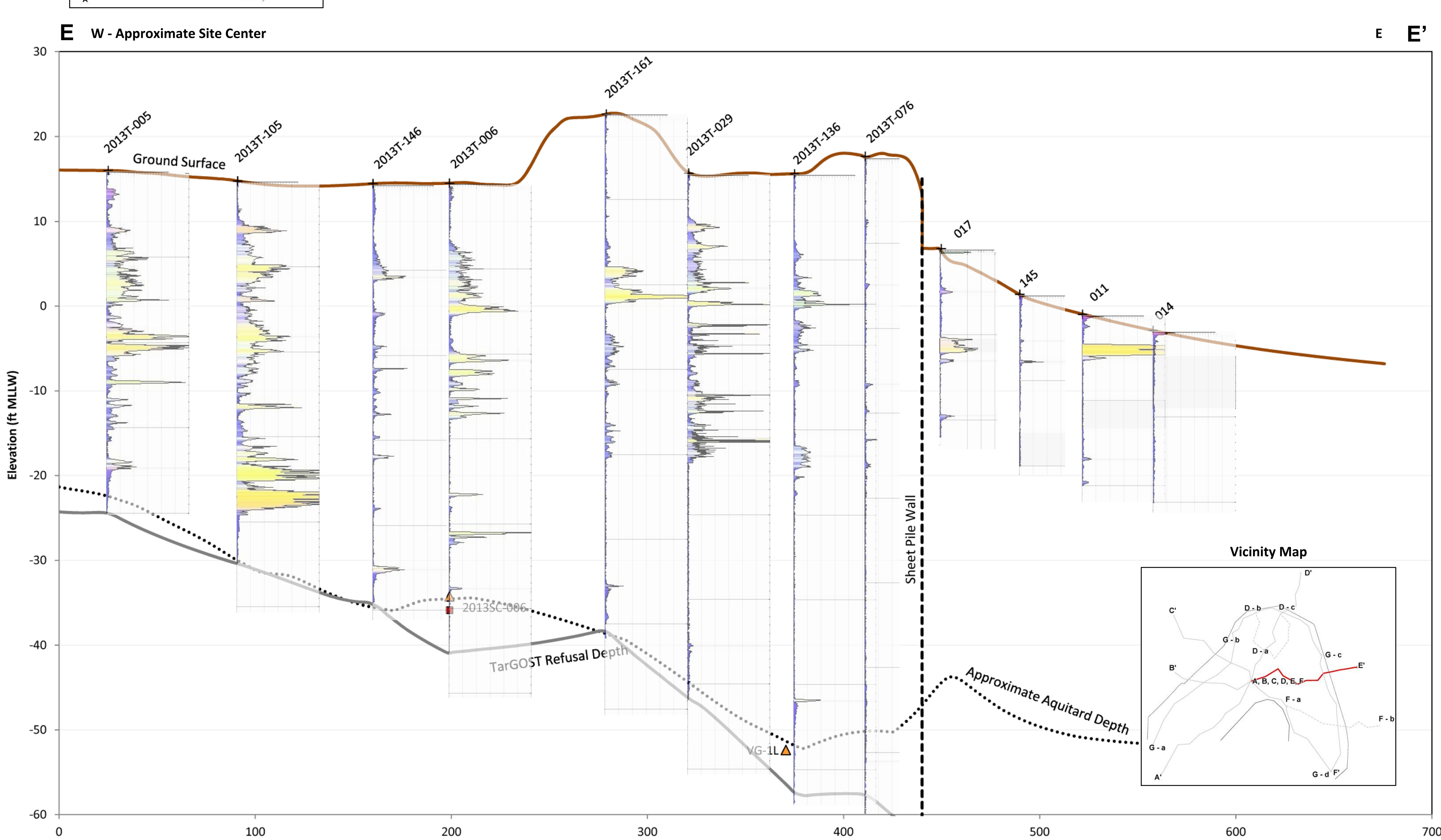

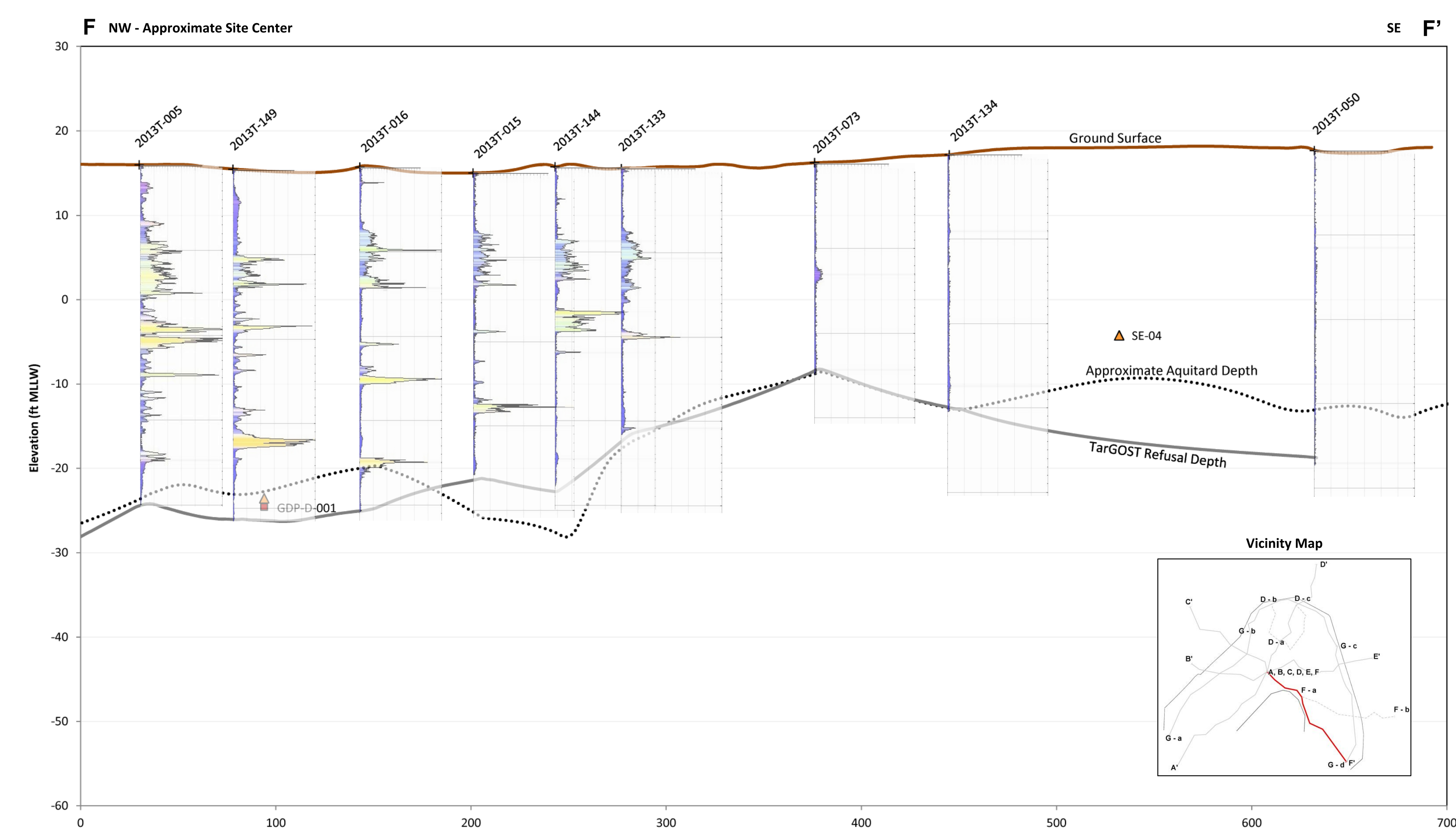

Plate 2

Fence Diagrams D-a – D-b, D-a – D-c, D-D', E-E', and F-F'

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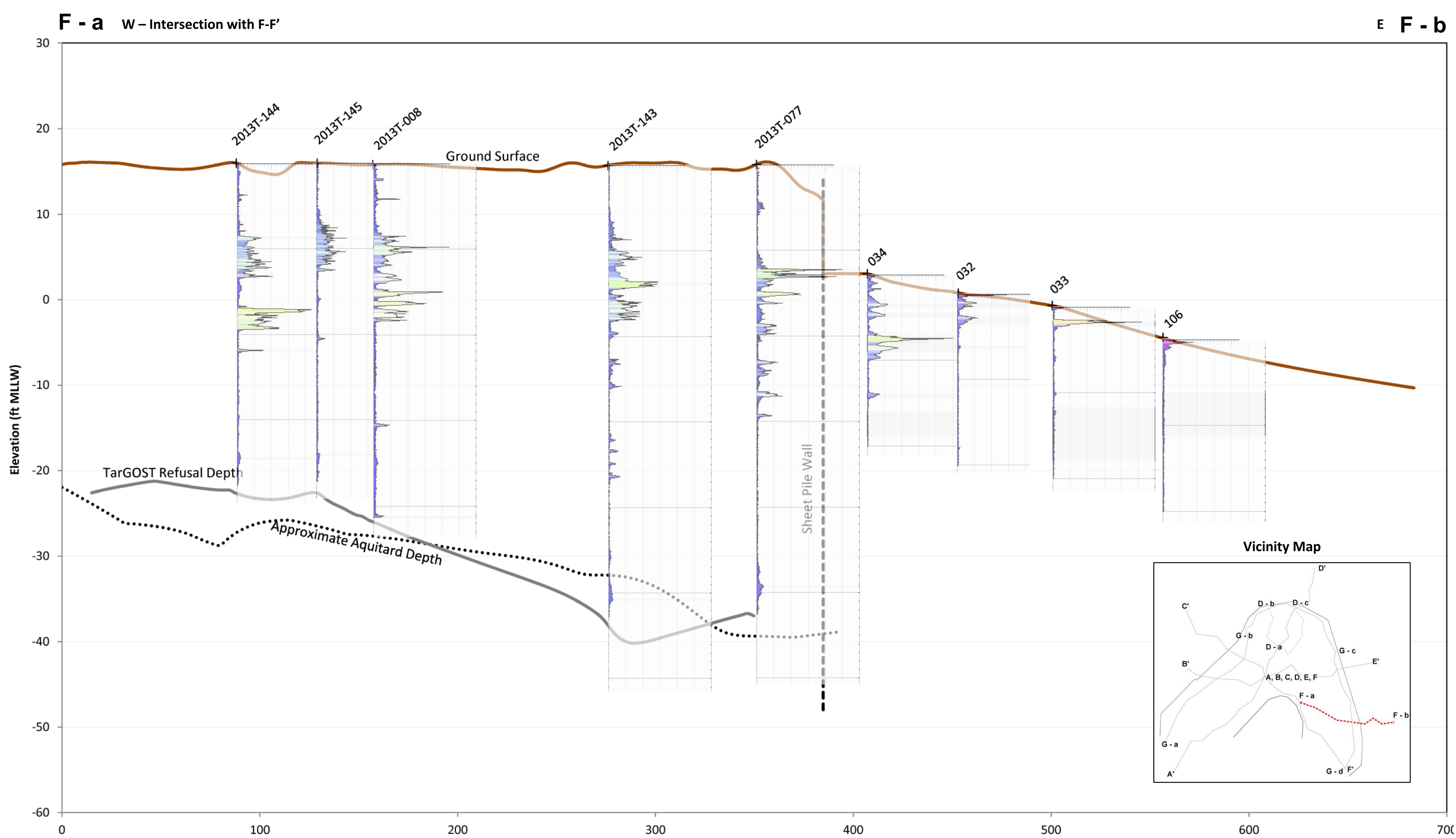

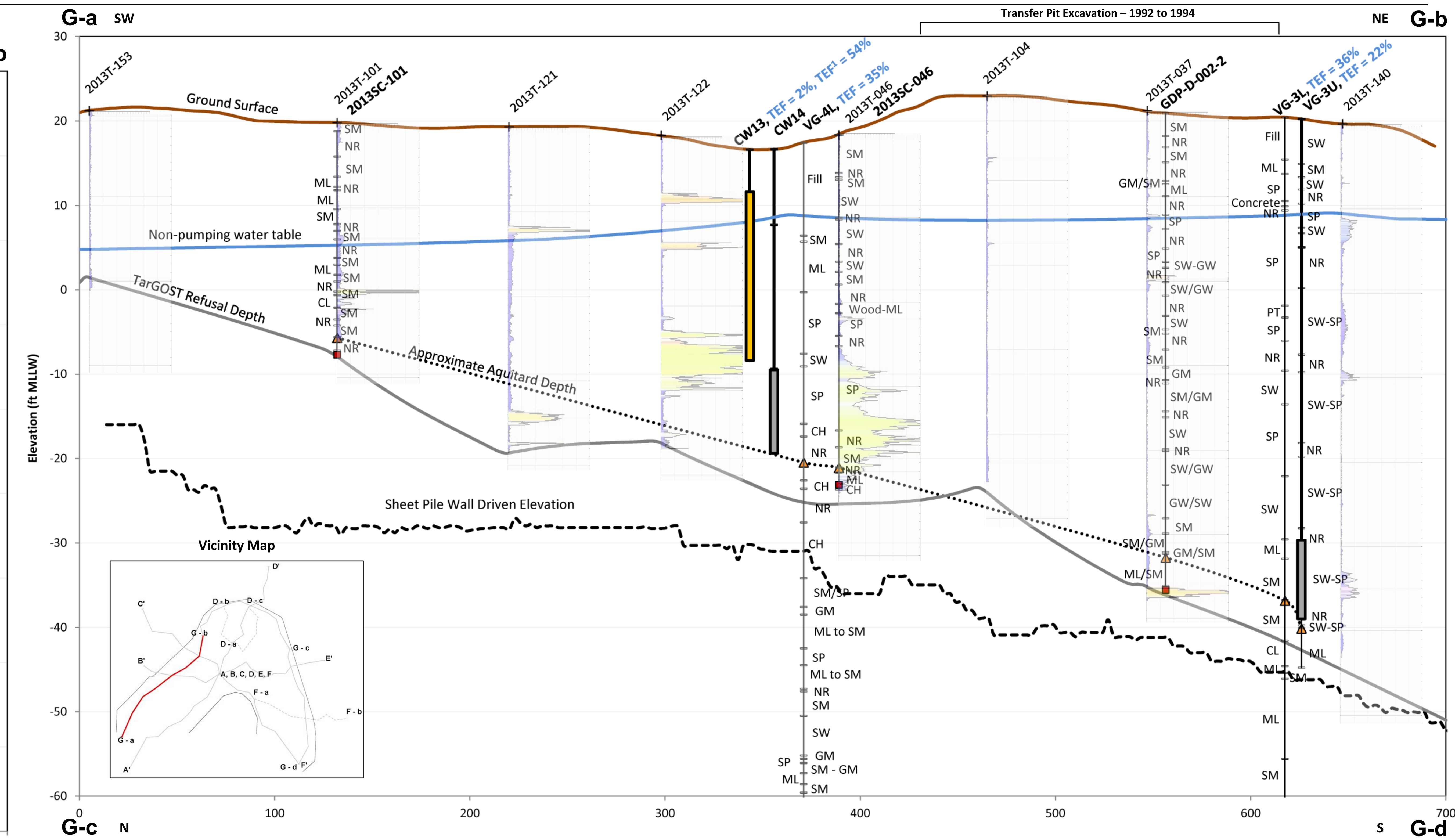

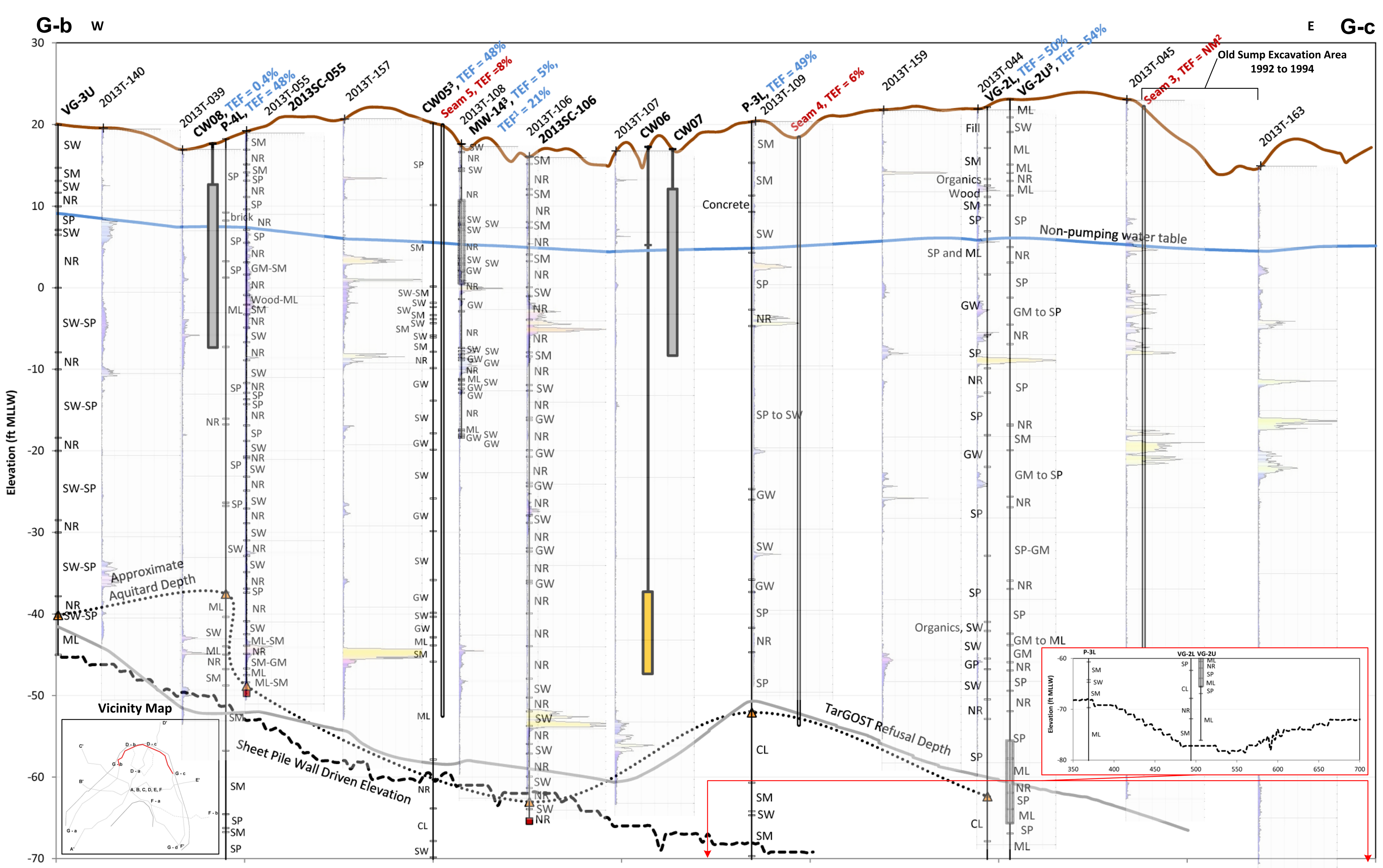

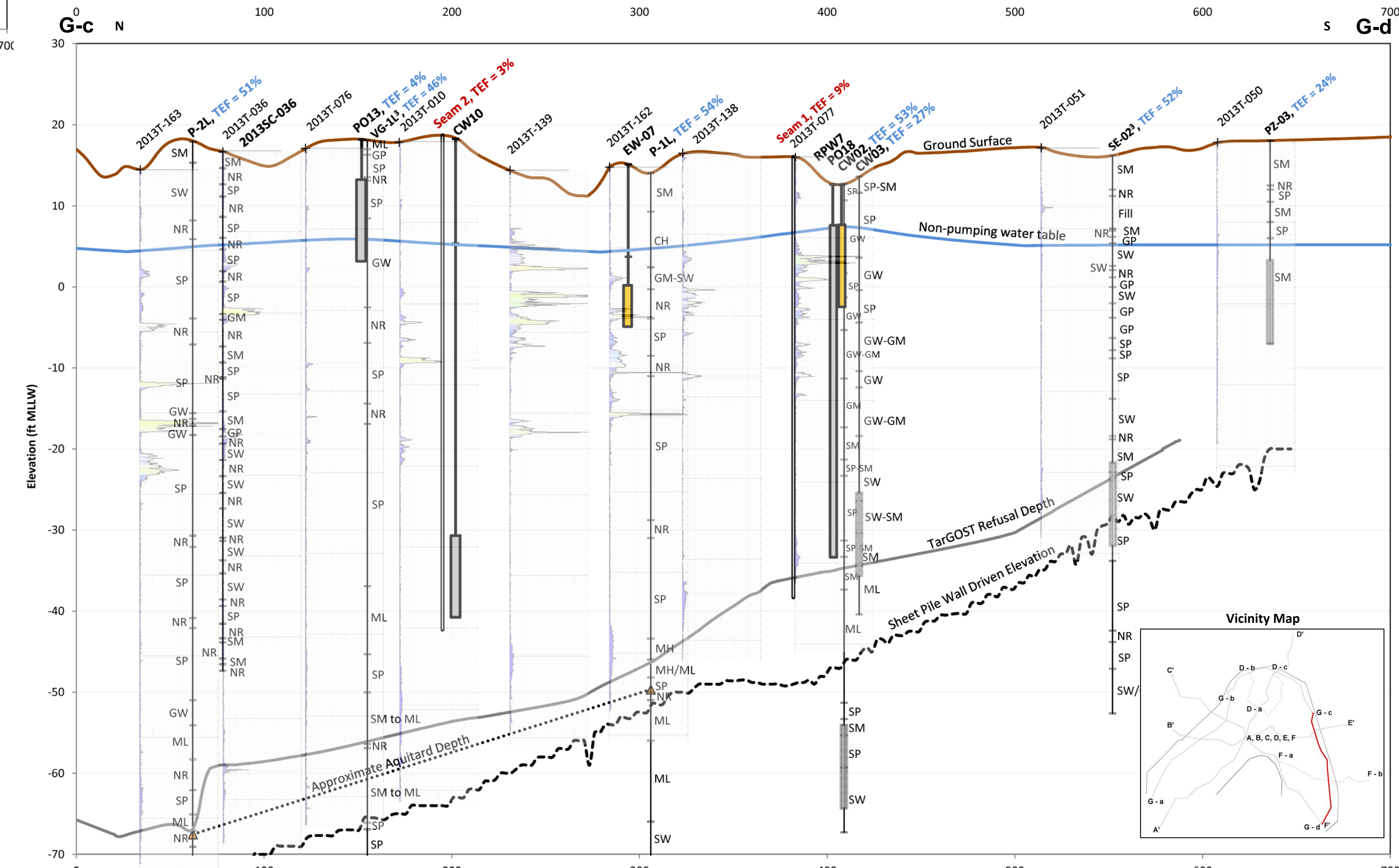

Groundwater Level Non-pumping Conditions (measured September 3, 2012)

Monitoring well screened interval
Orange color-code = NAPL was observed in well during water level monitoring (9/12); Gray color-code = NAPL was not observed in well during water level monitoring (9/12)

Notes:
TEF = Tidal Efficiency Factor
[1]Historical TEF measured prior to sheet pile wall installation.
[2]Tidal efficiency could not be measured from available data.

Plate 3

Fence Diagrams F-a – F-b, G-a – G-b, G-b – G-c, and G-c – G-d

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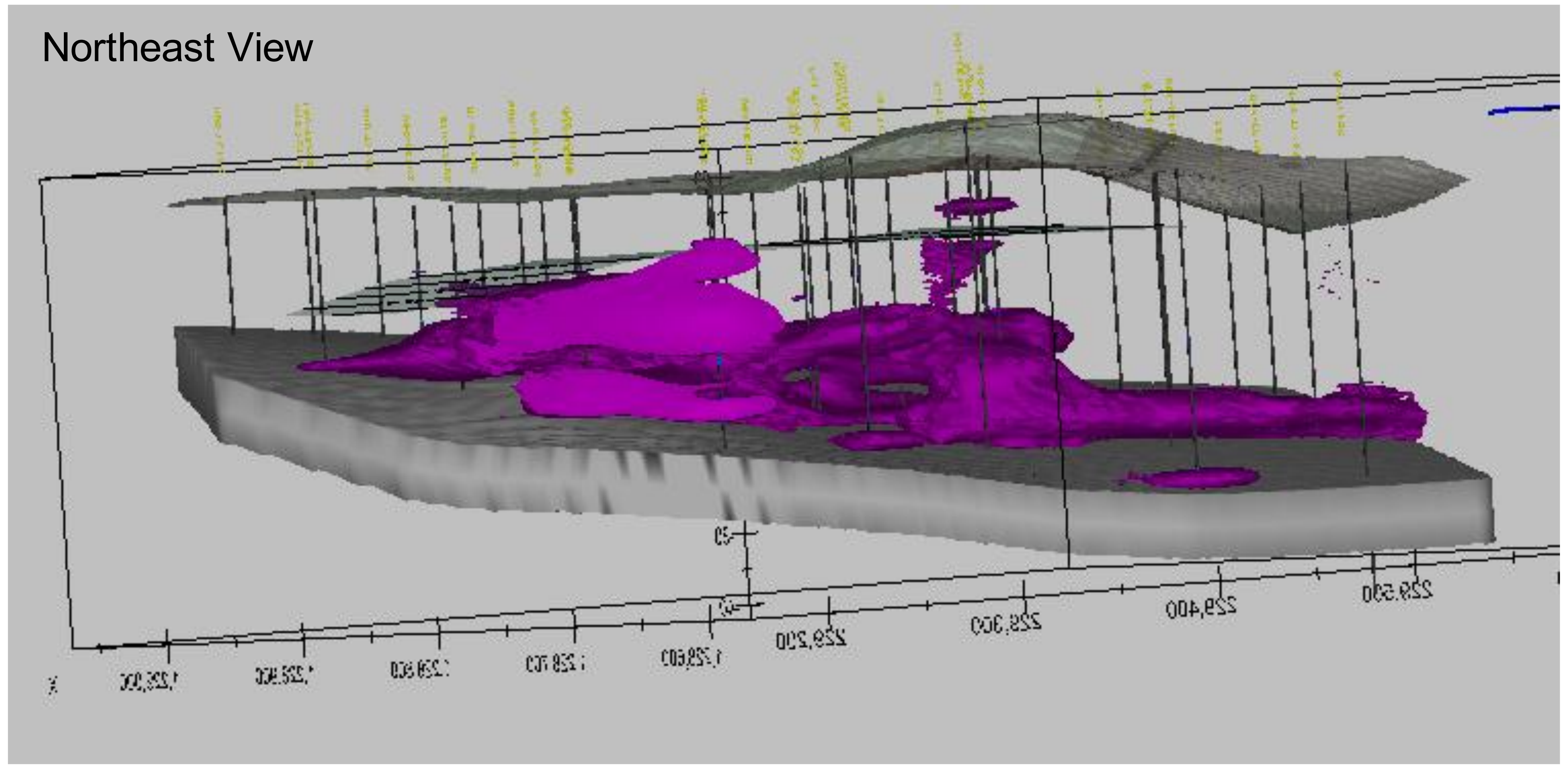
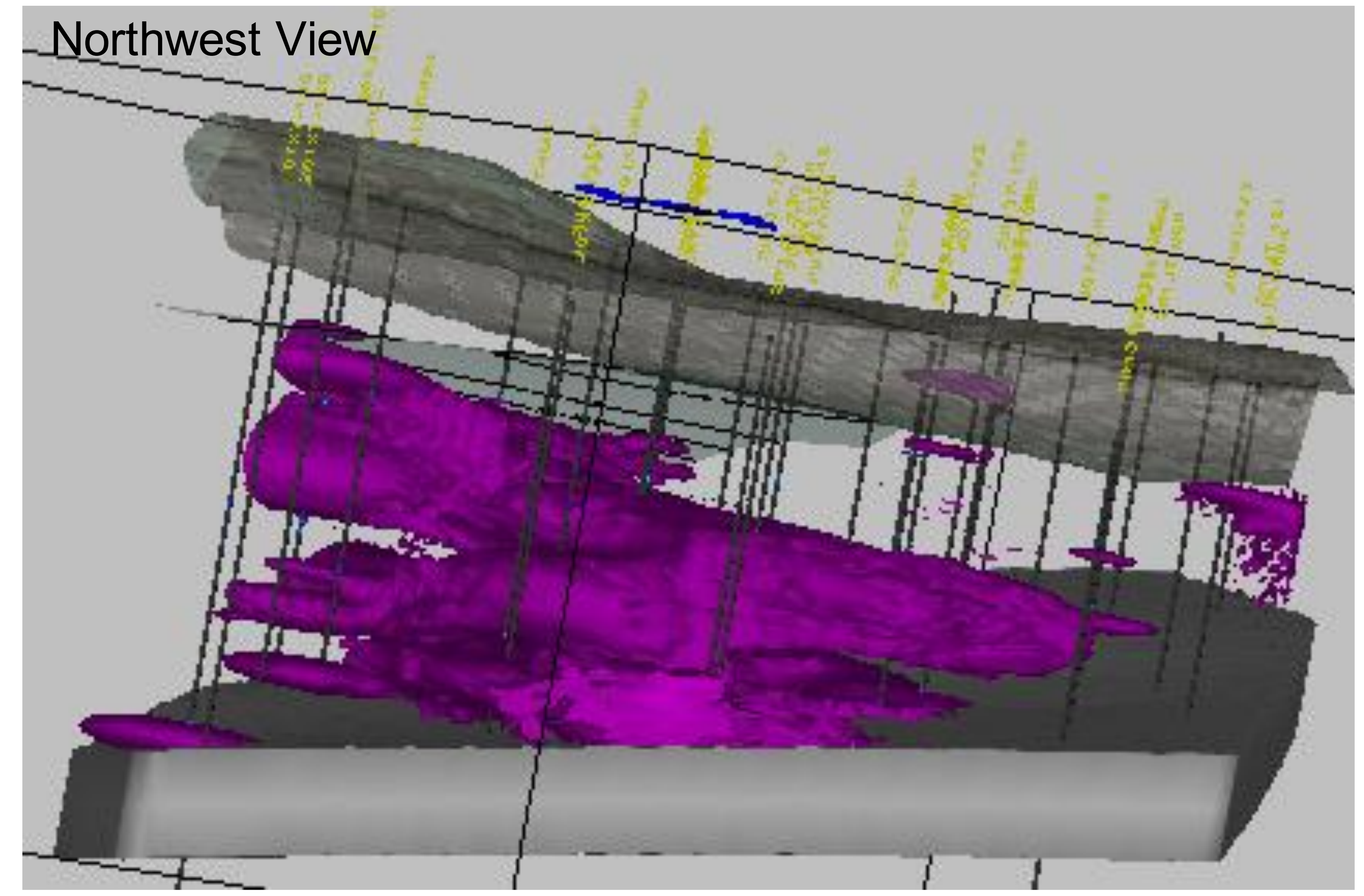
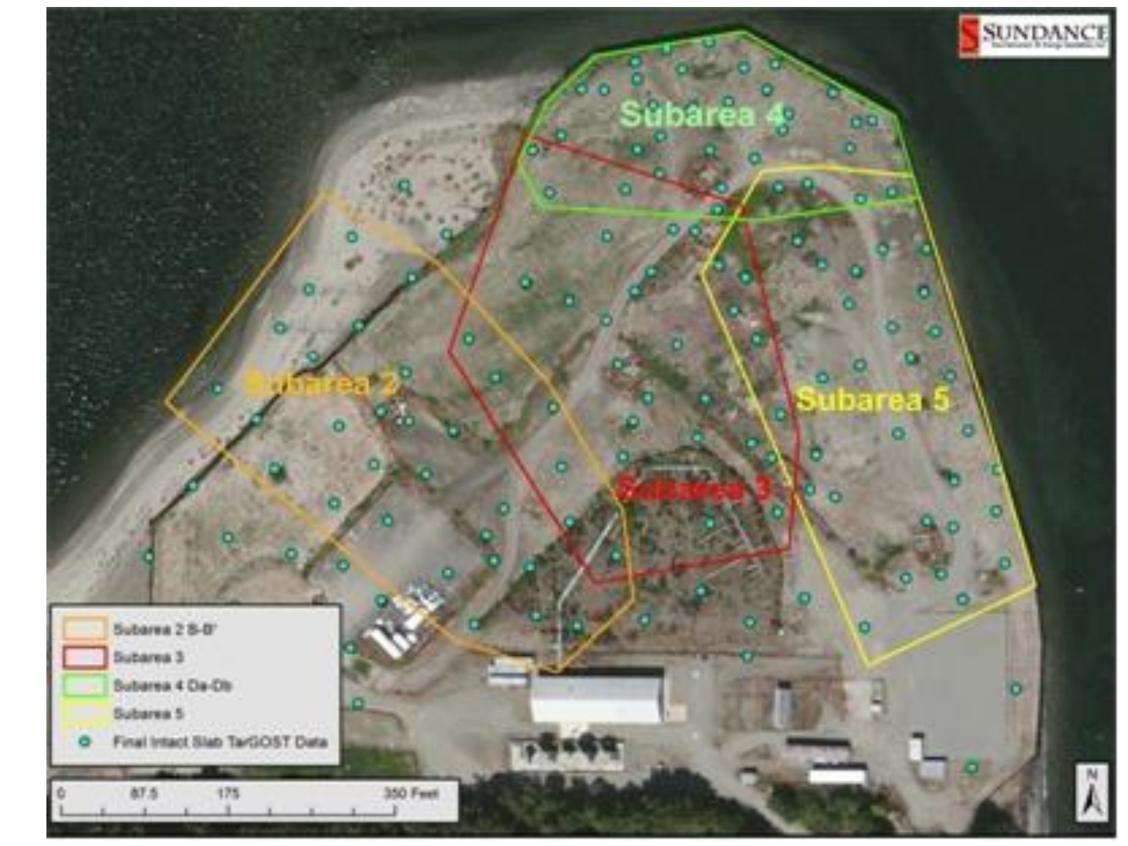
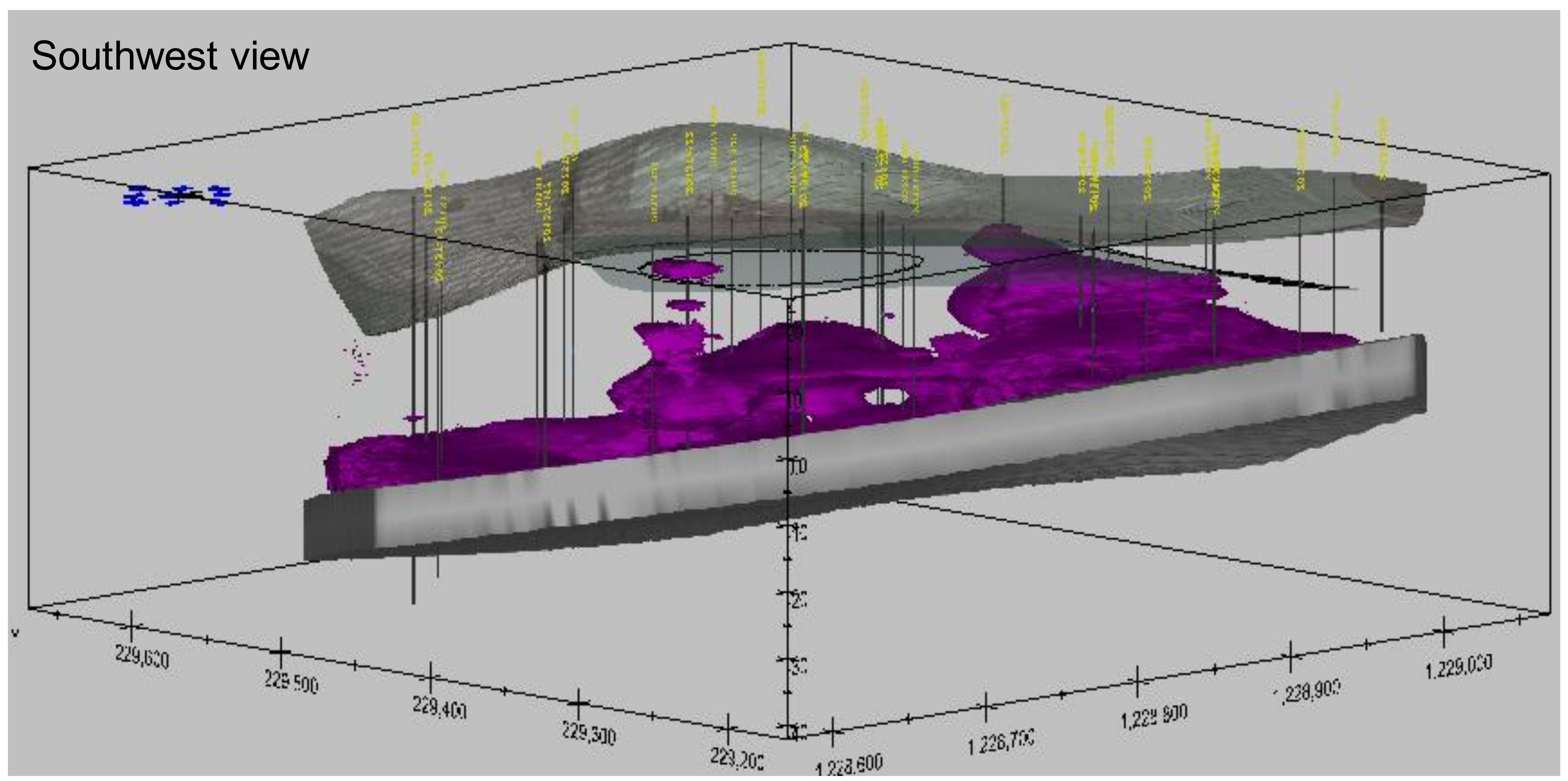
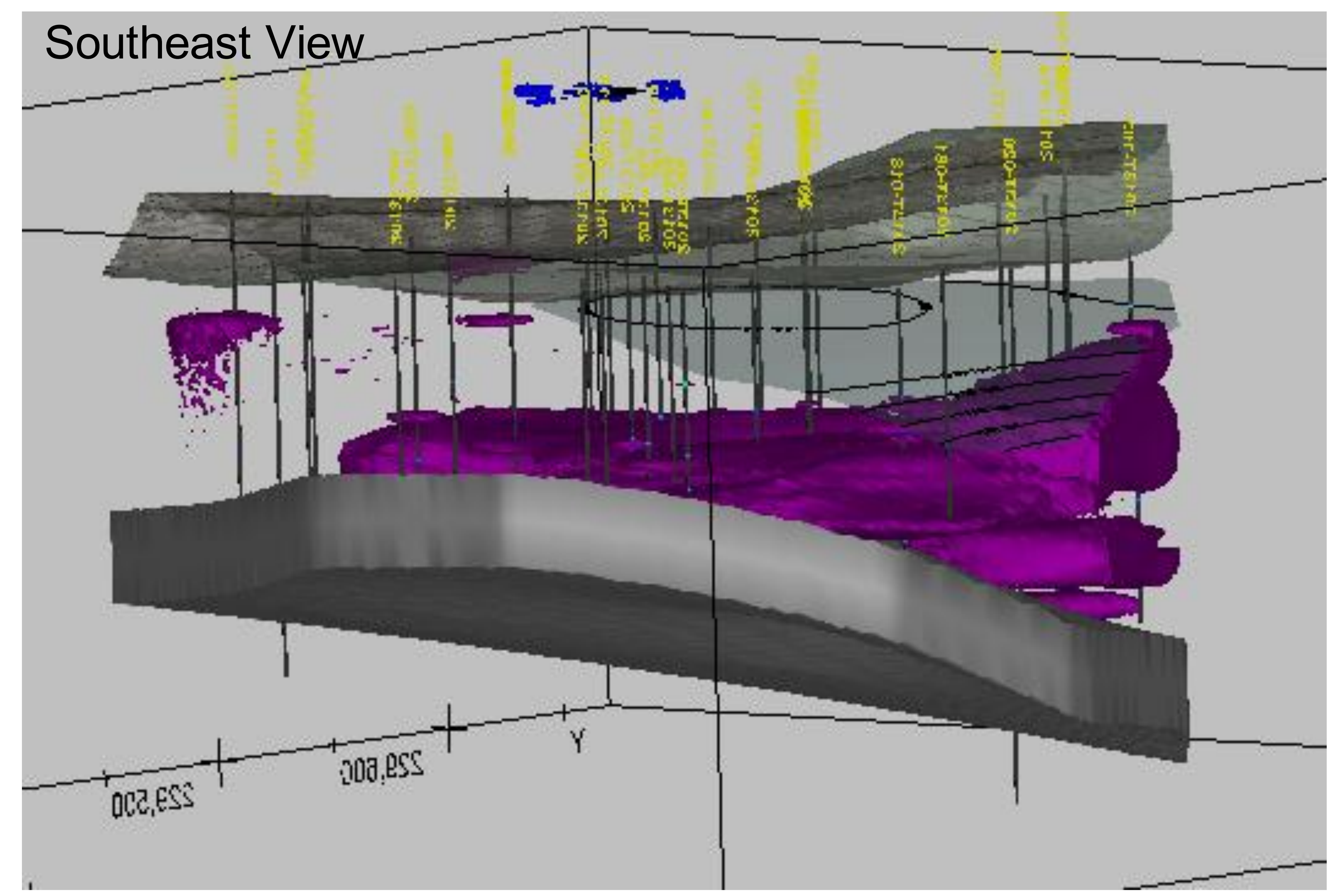


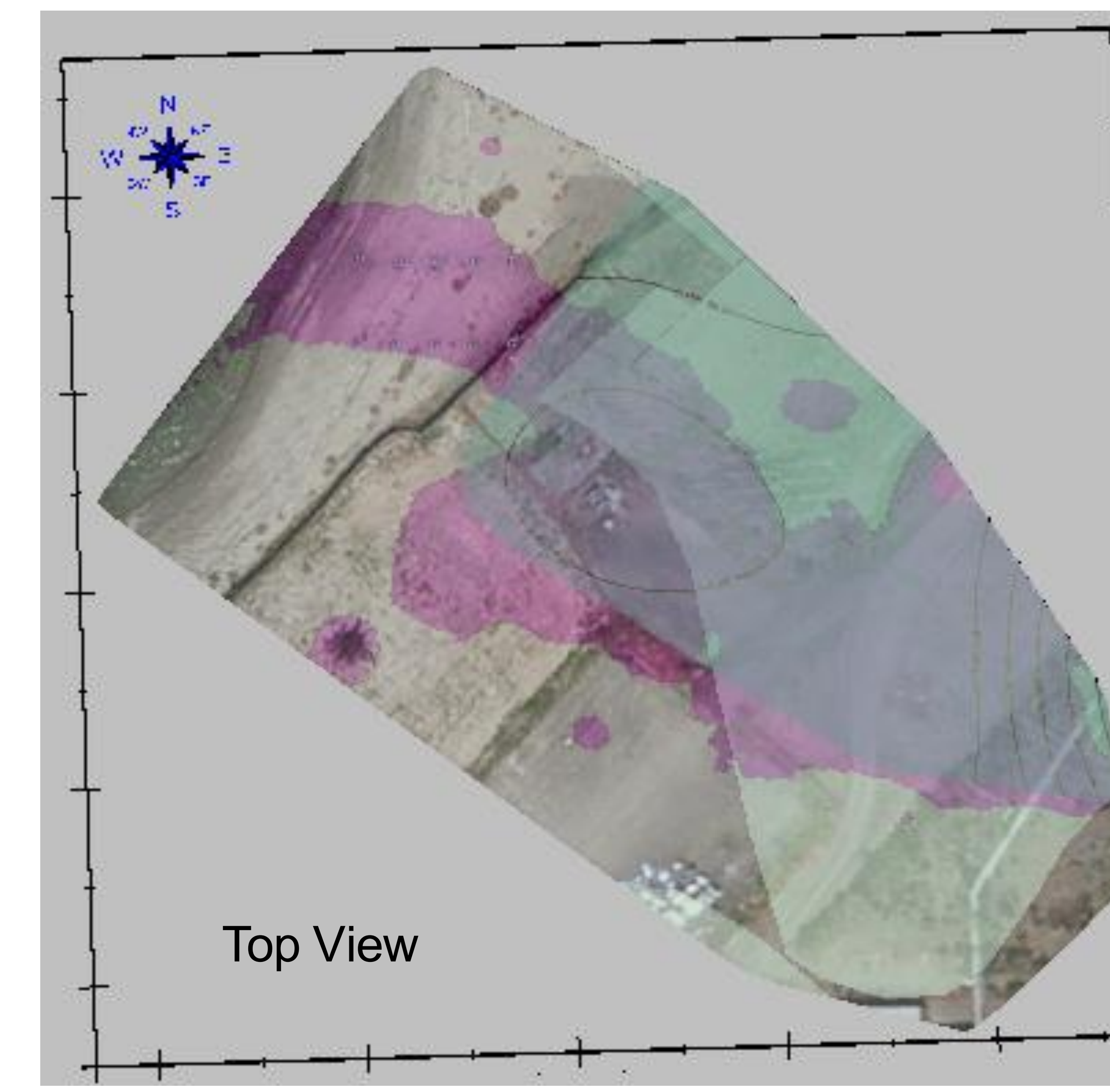


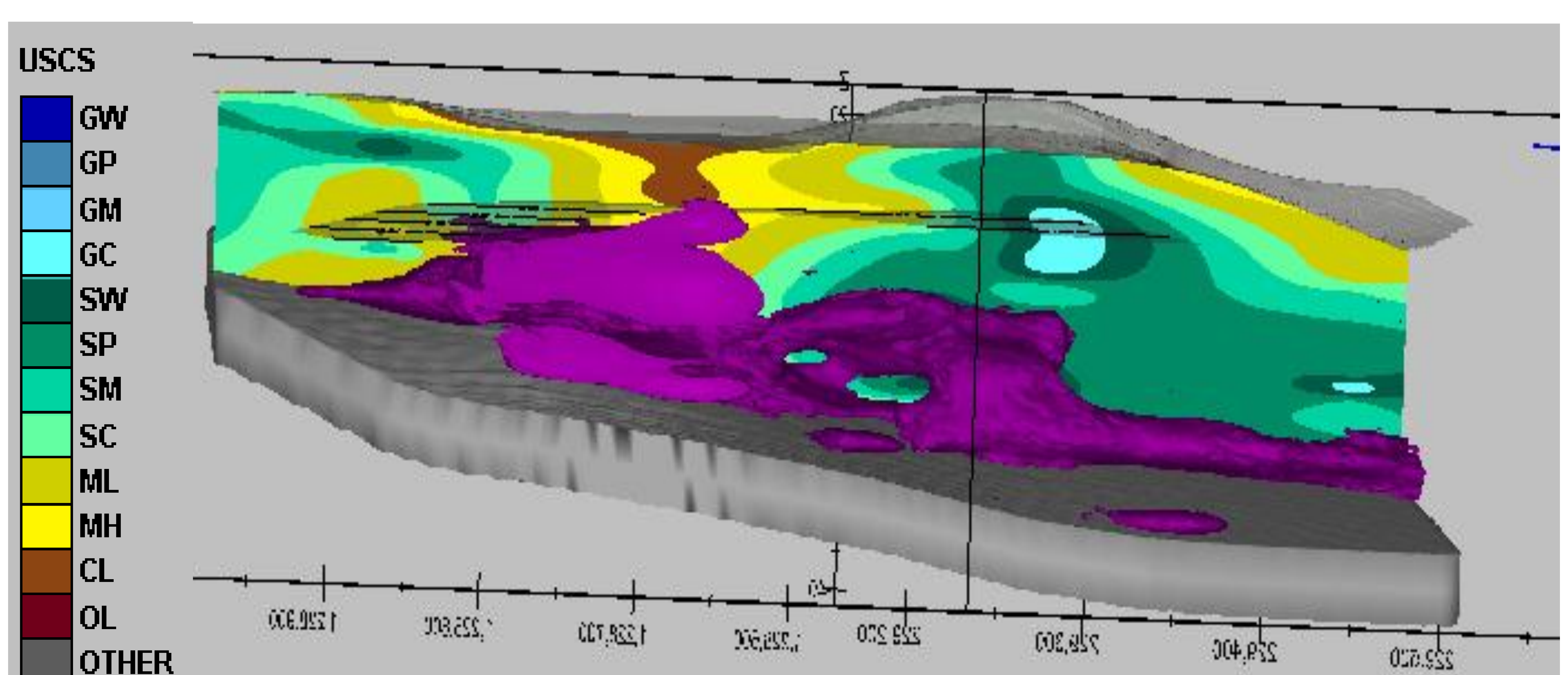


Site Map

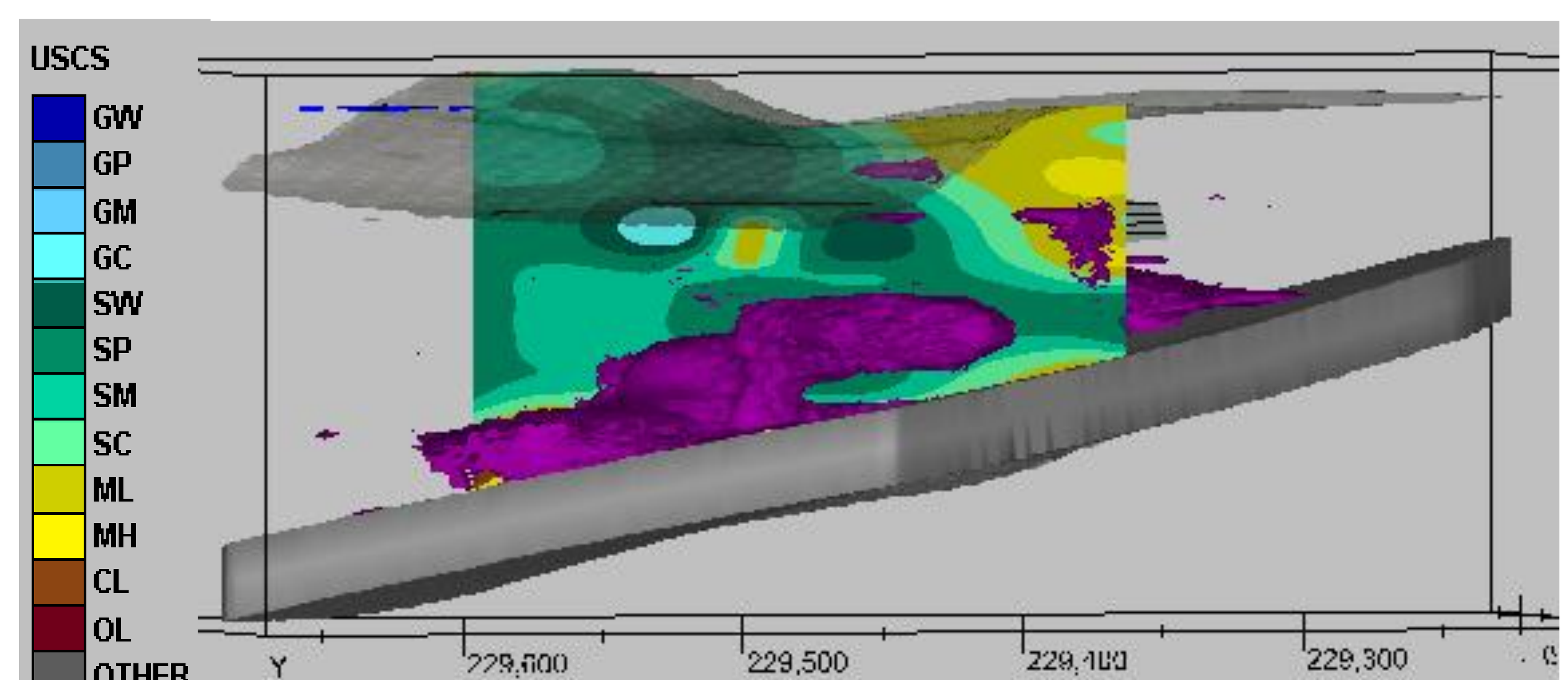








Northeast View - Lithology



West View - Lithology

Plate 4
Visualization of Subarea 2
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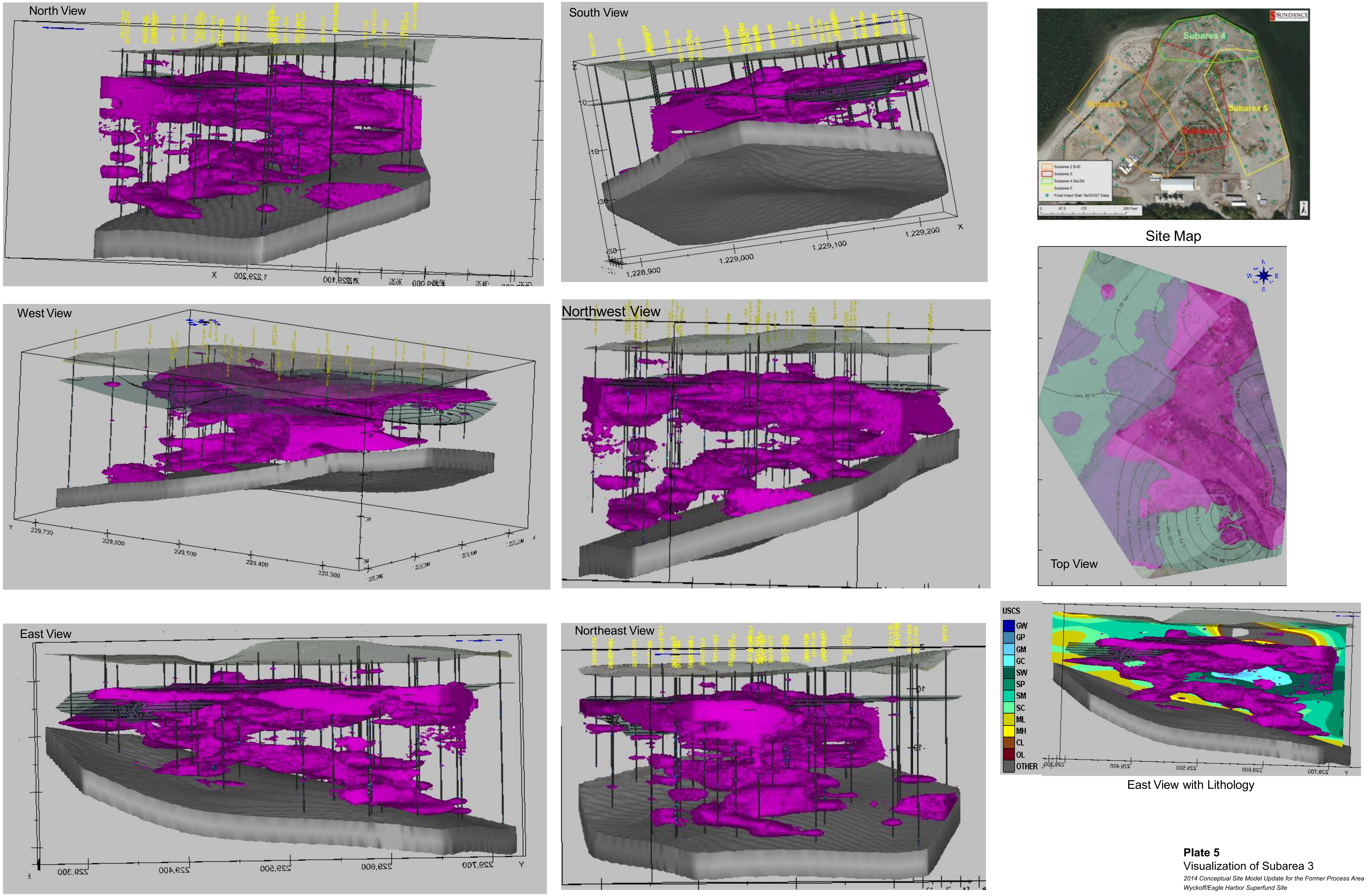

Plate 5
Visualization of Subarea 3
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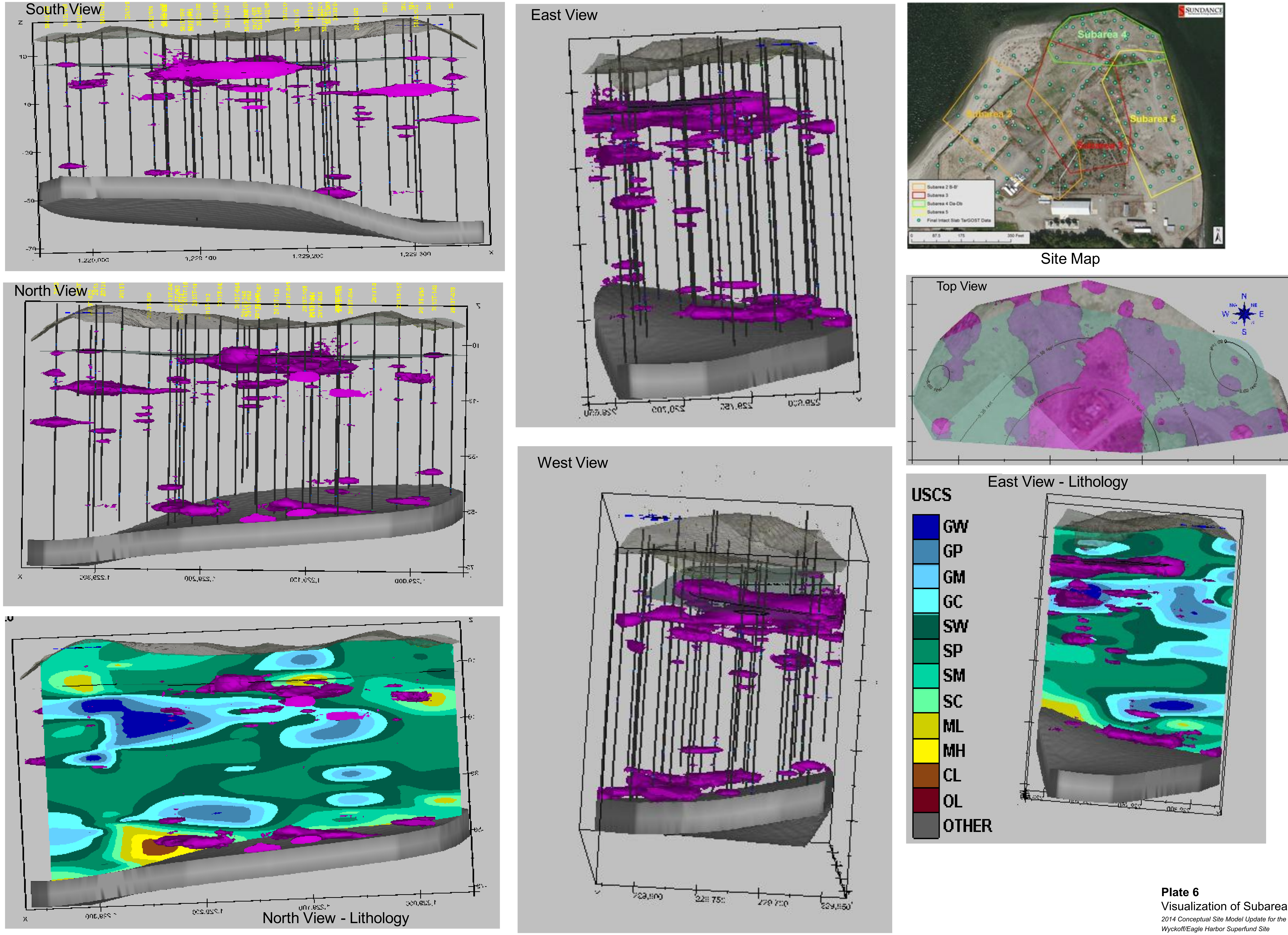

Plate 6
Visualization of Subarea 4
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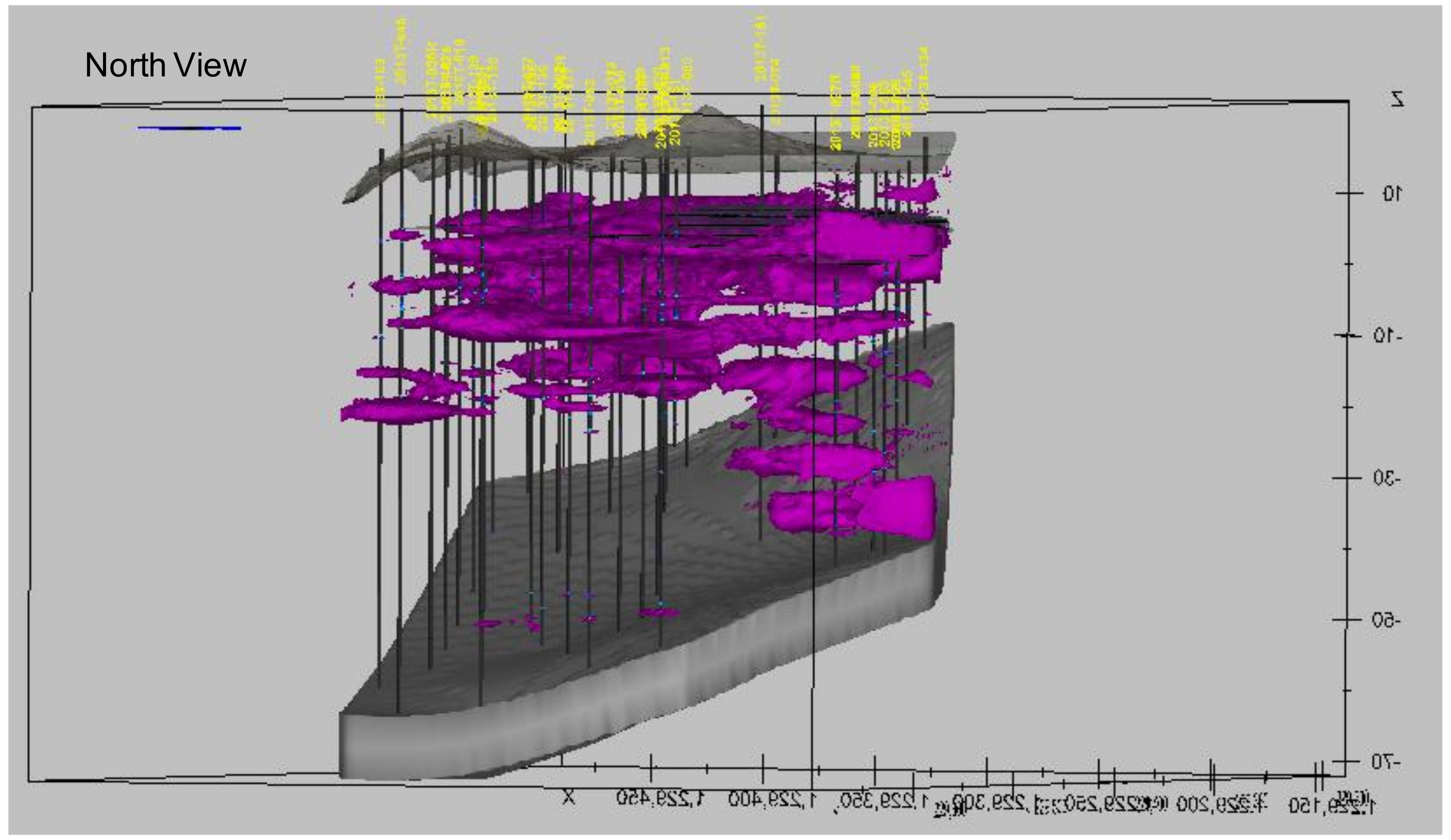
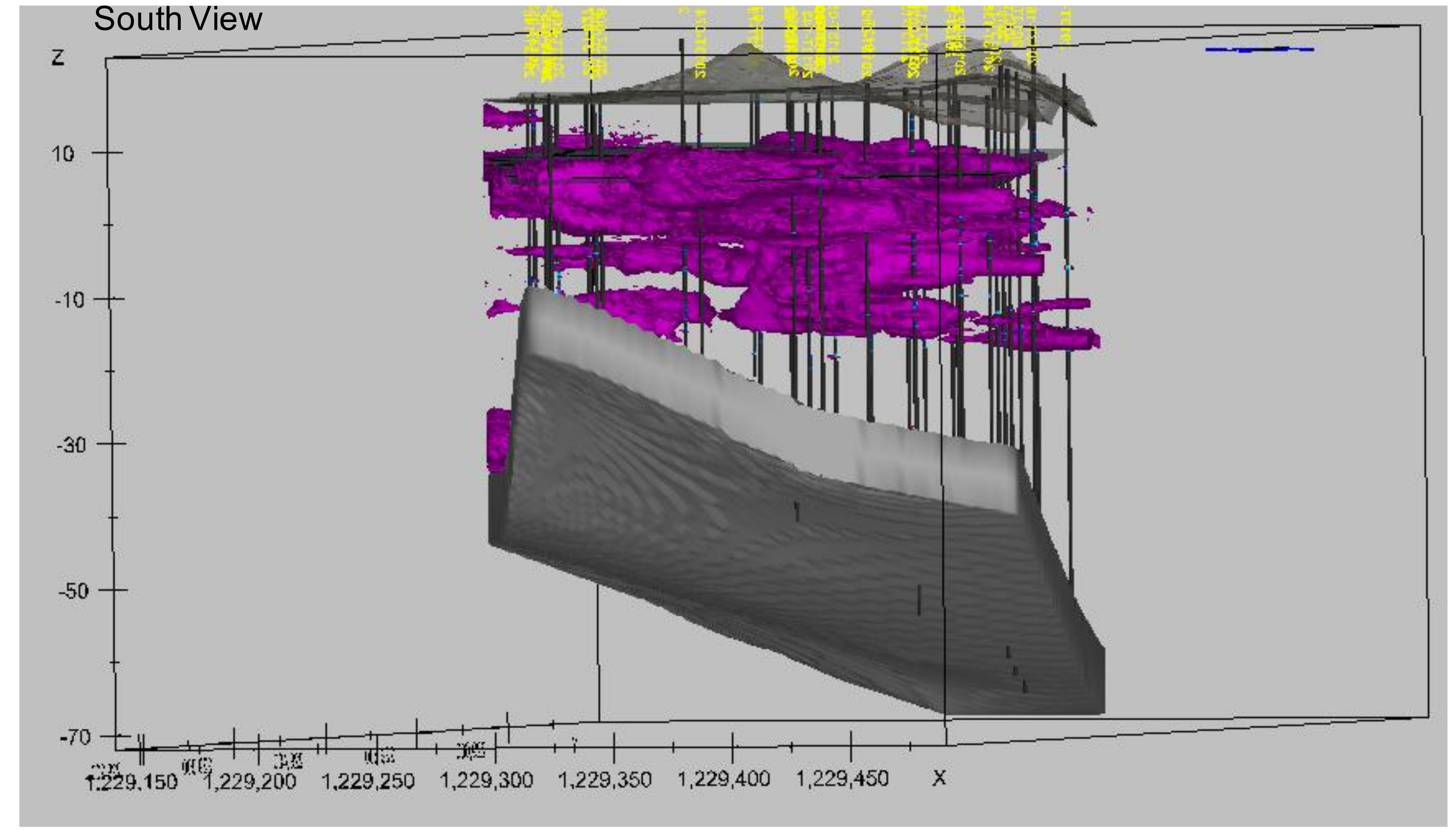
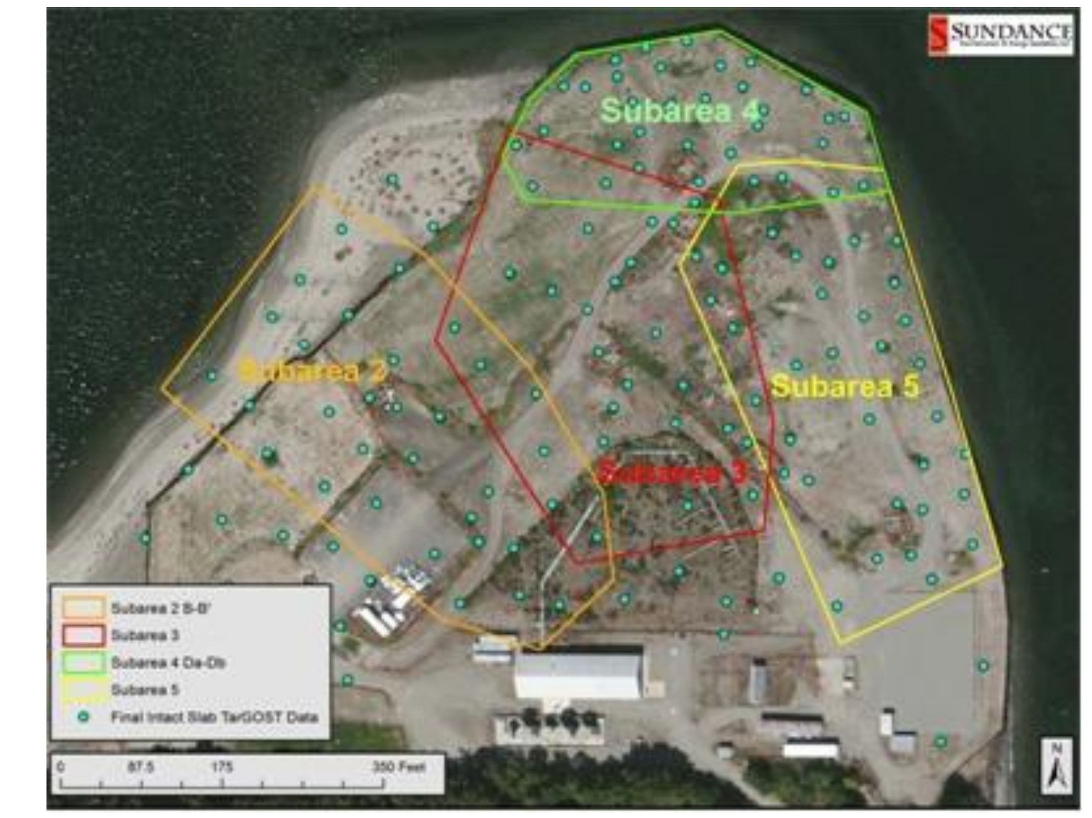
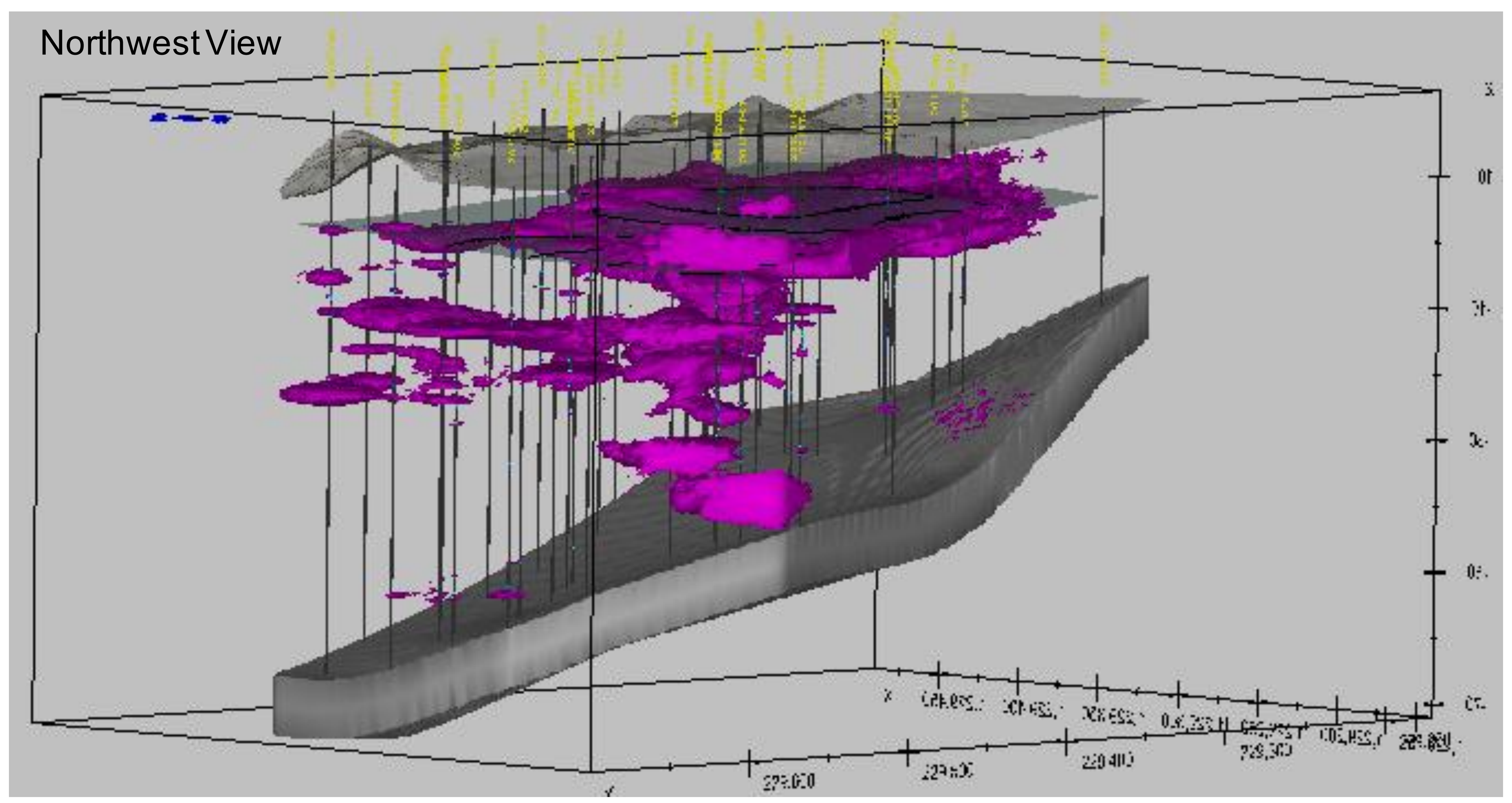
Wyckoff/Eagle Harbor Superfund Site

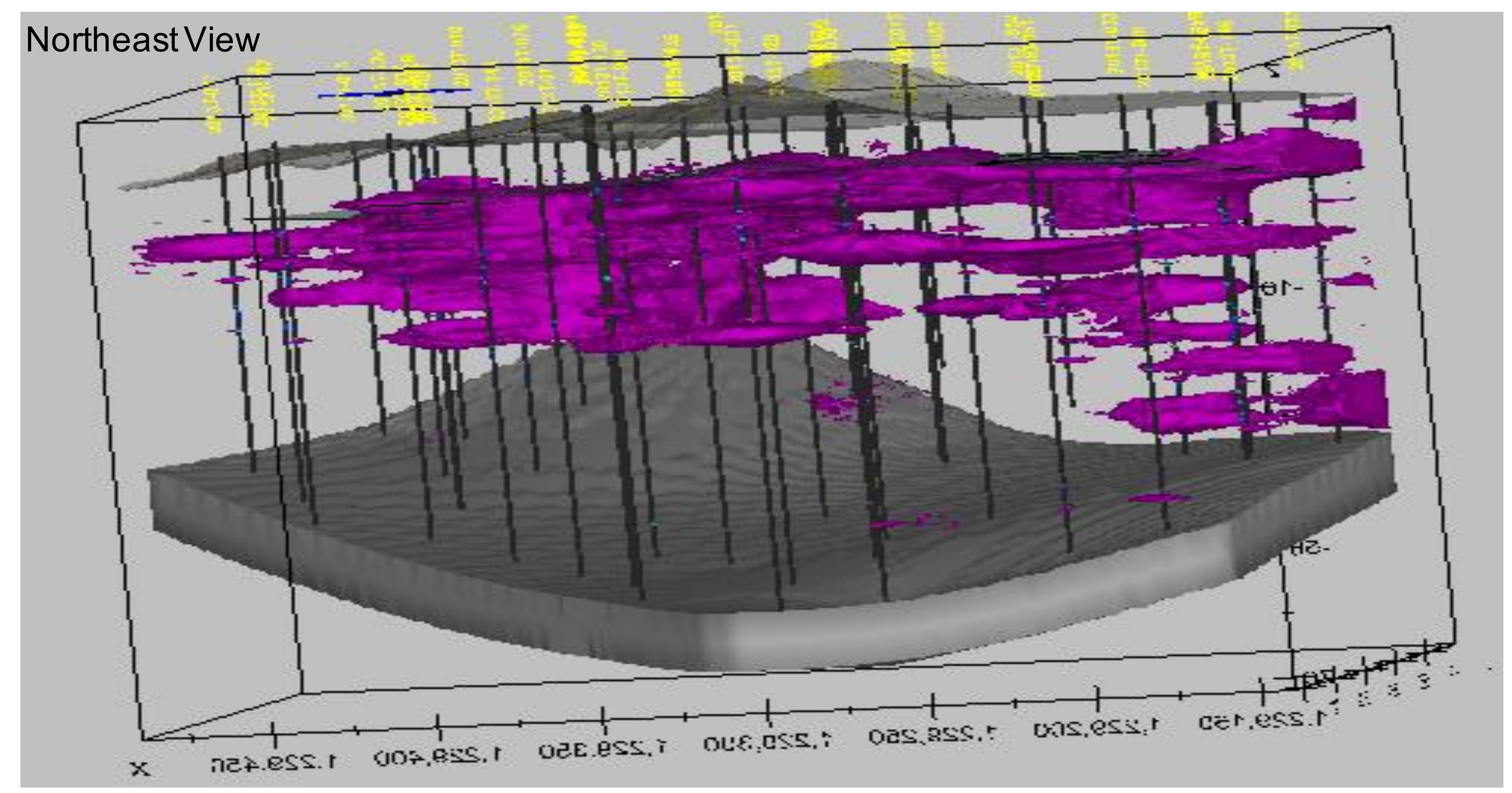


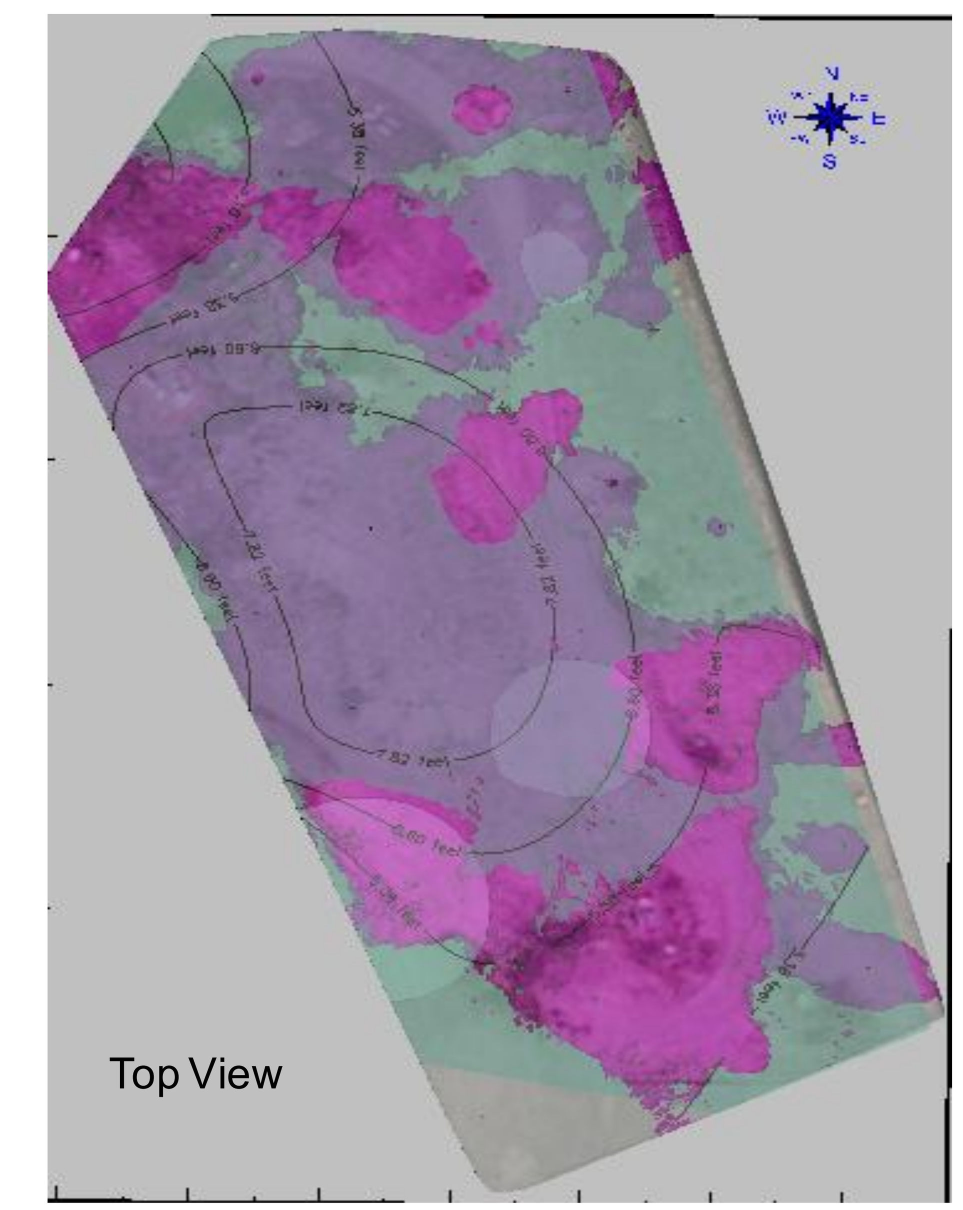


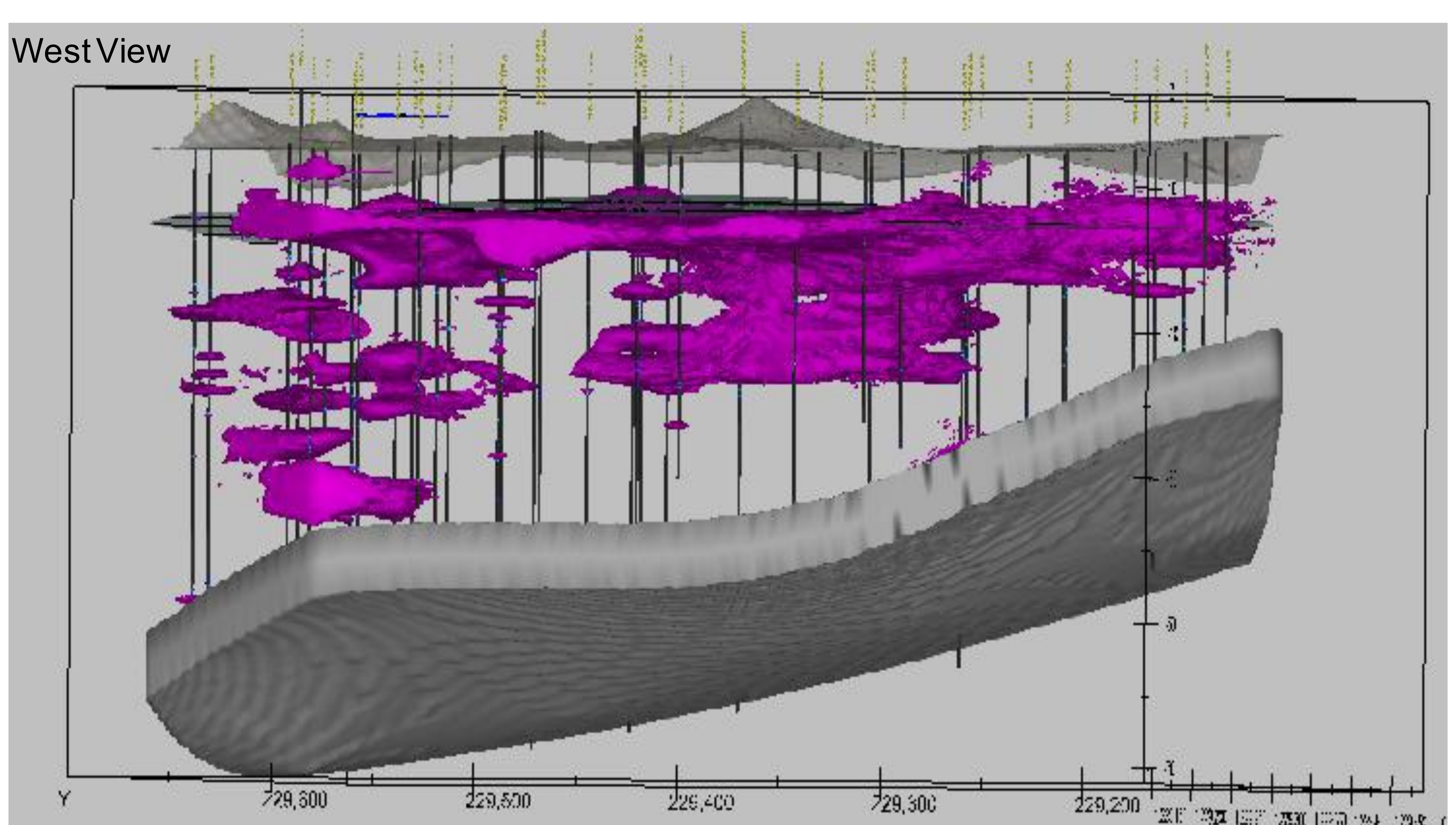


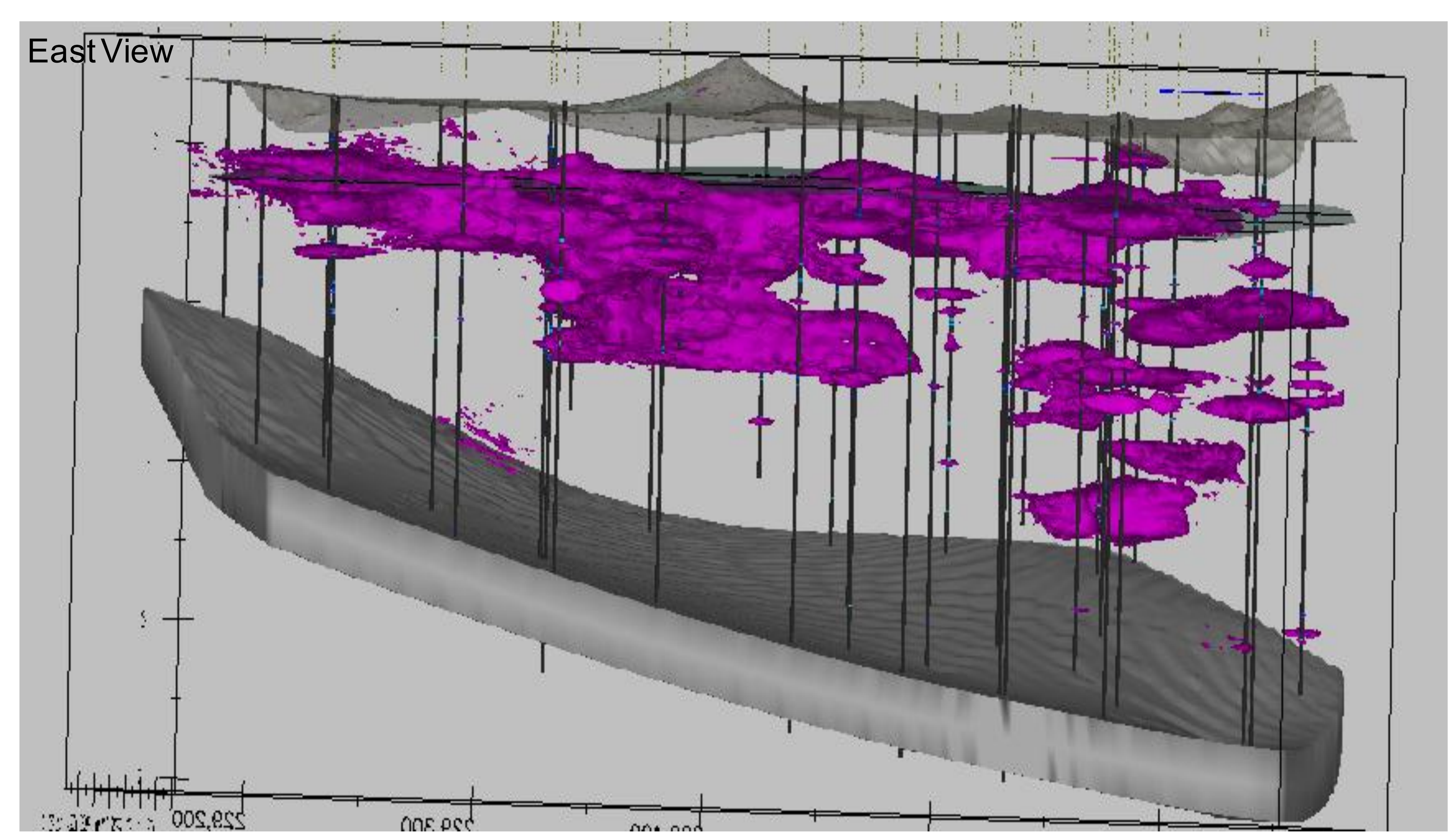
Site Map

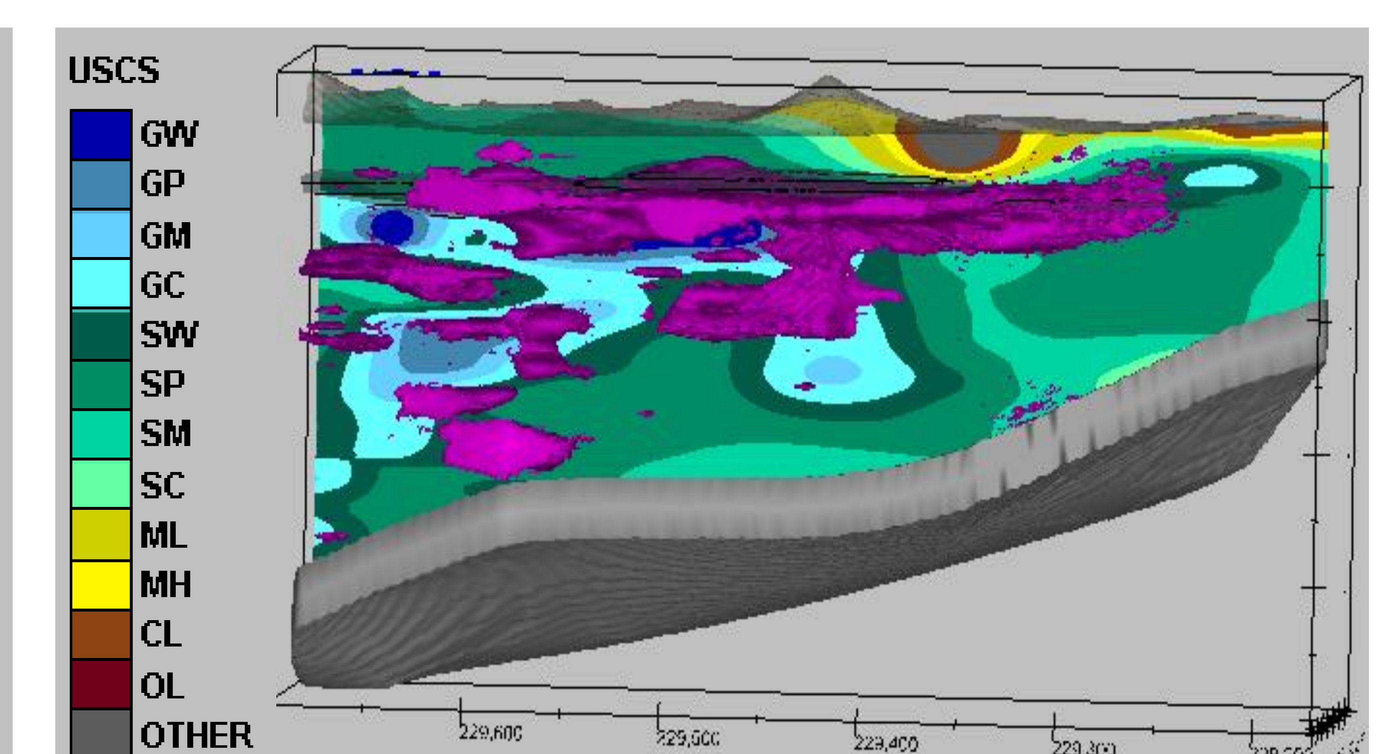












West View - Lithology

Plate 7

Visualization of Subarea 5

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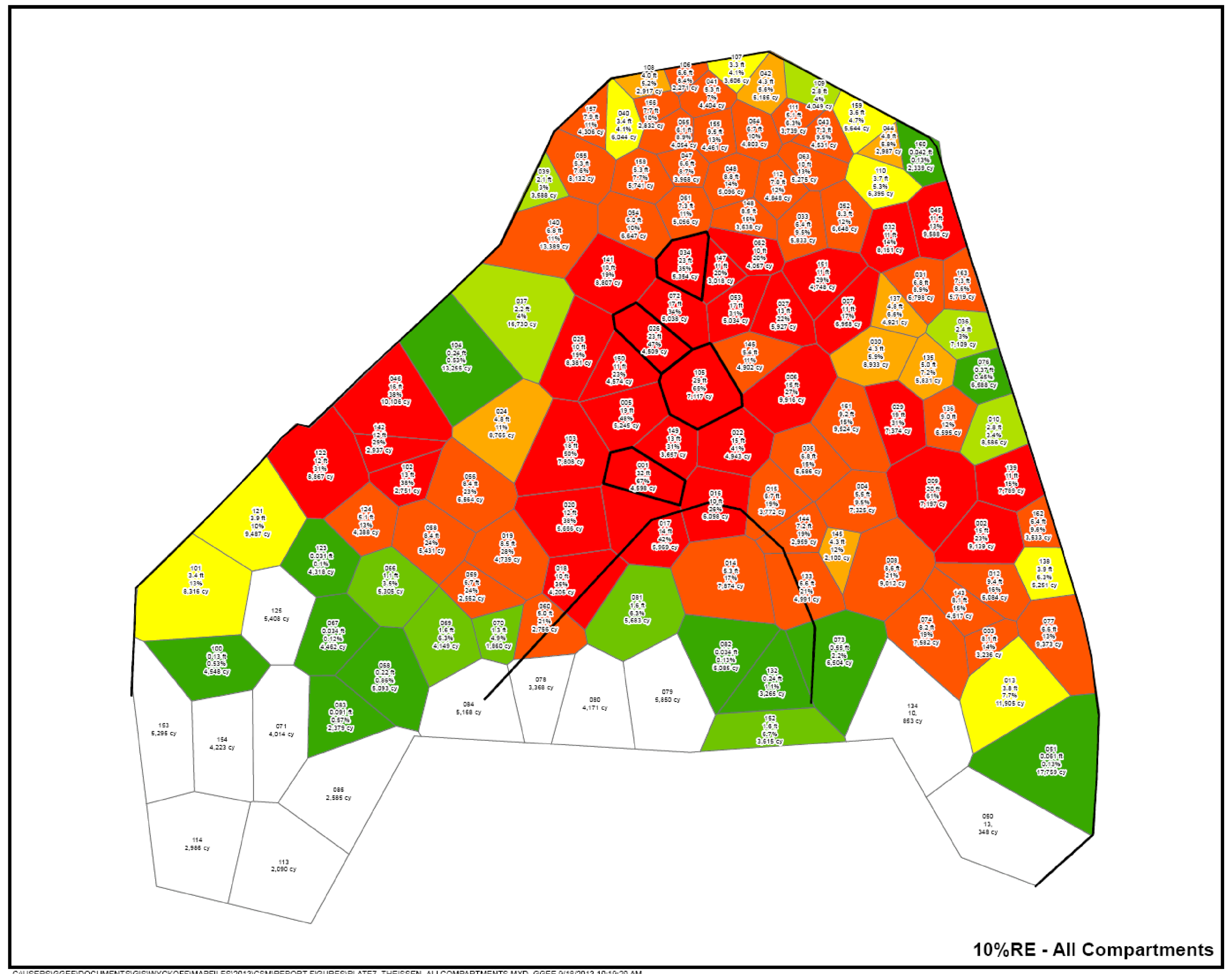
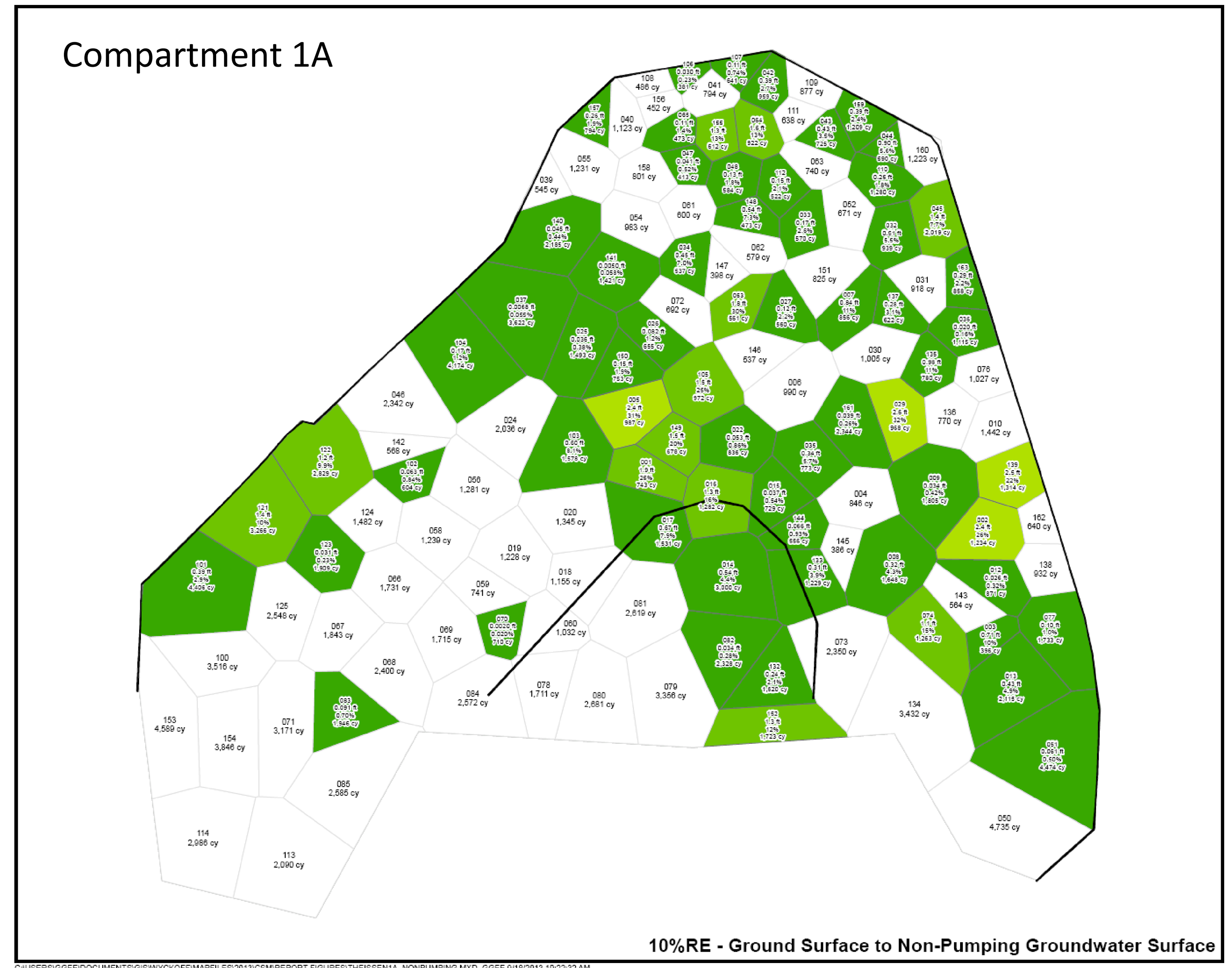
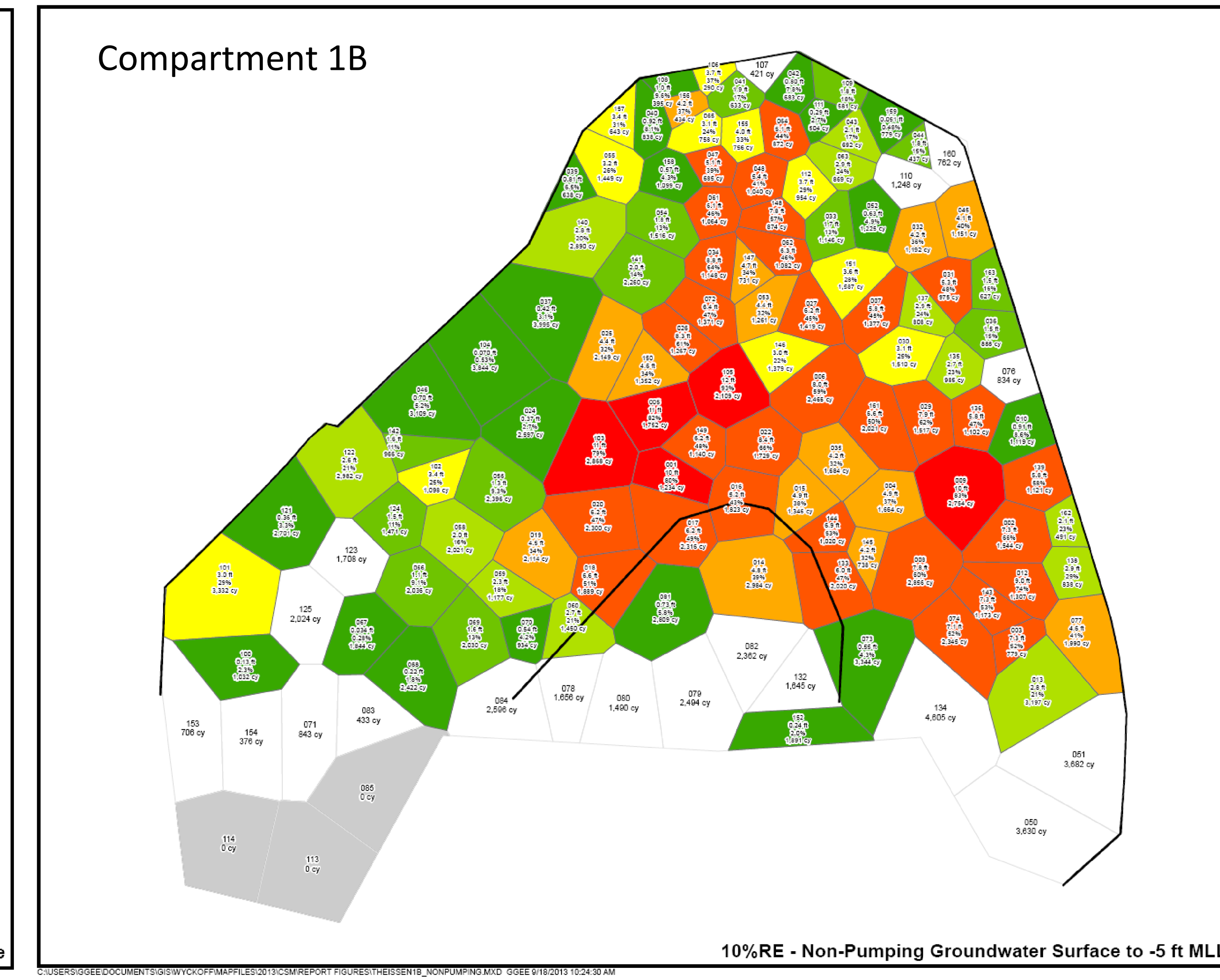
All Compartments

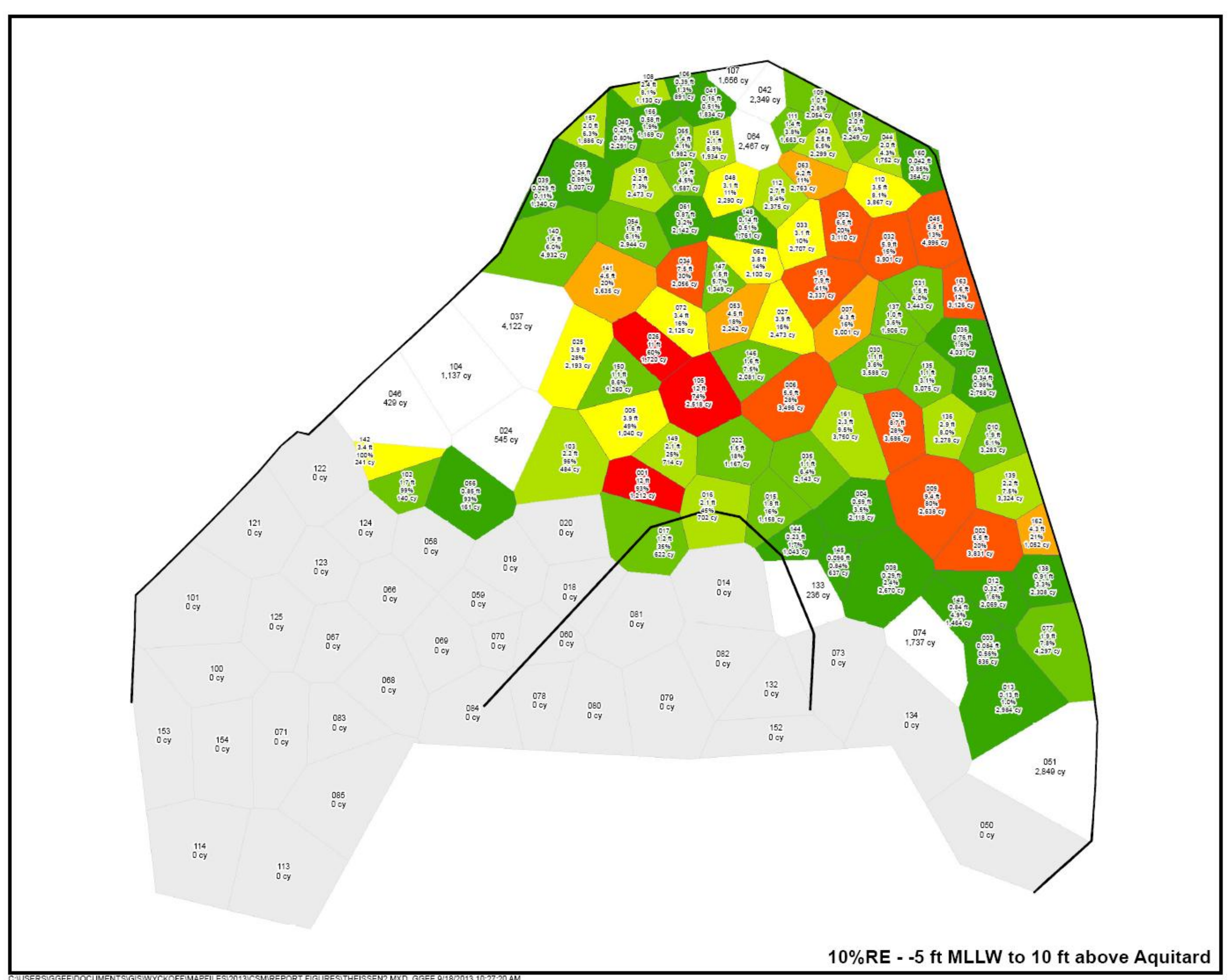


Compartment 1

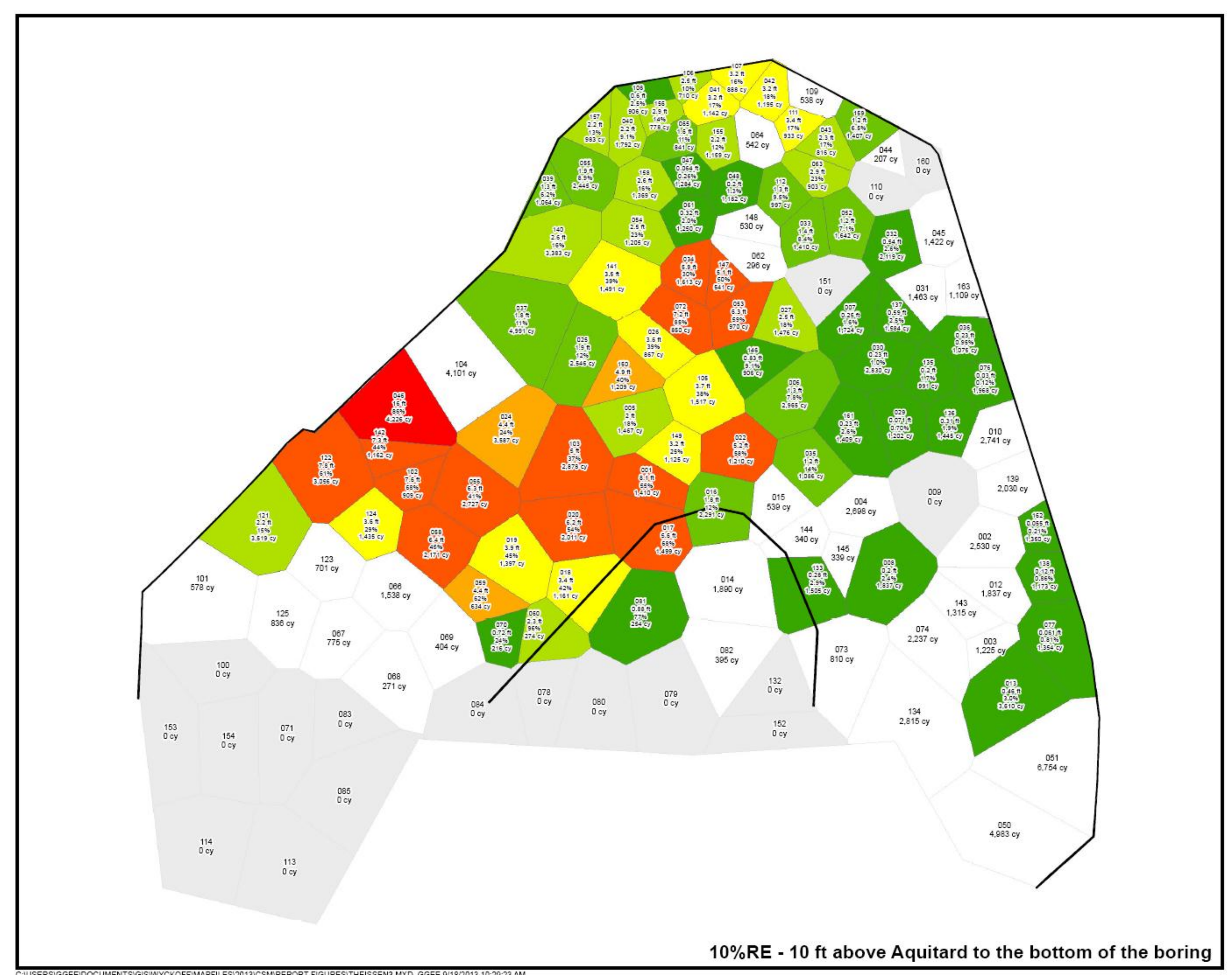




Compartment 2



Compartment 3



LEGEND

Thickness of Affected TarGOST Sample (ft)

>0 - 1.0 (1.4 acres)
1.0 - 2.0 (0.5 acres)
2.0 - 3.0 (0.4 acres)
3.0 - 4.0 (0.7 acres)
4.0 - 5.0 (0.4 acres)
5.0 - 10 (2.9 acres)
>10 (2.7 acres)
Thickness of Affected TarGOST Sample Greater than 20 ft
No impacts above 10%RE
Compartment Thickness is Null

Labels:
135 TarGOST ID
3.6 ft Length of TarGOST core above 10%RE (feet)
17% Percentage of NAPL impacted polygon
1,765 cy Total volume of polygon (cubic yards)

N

0 55 110 220 Feet

Plate 8
TarGOST Distribution by Thiessen Polygon
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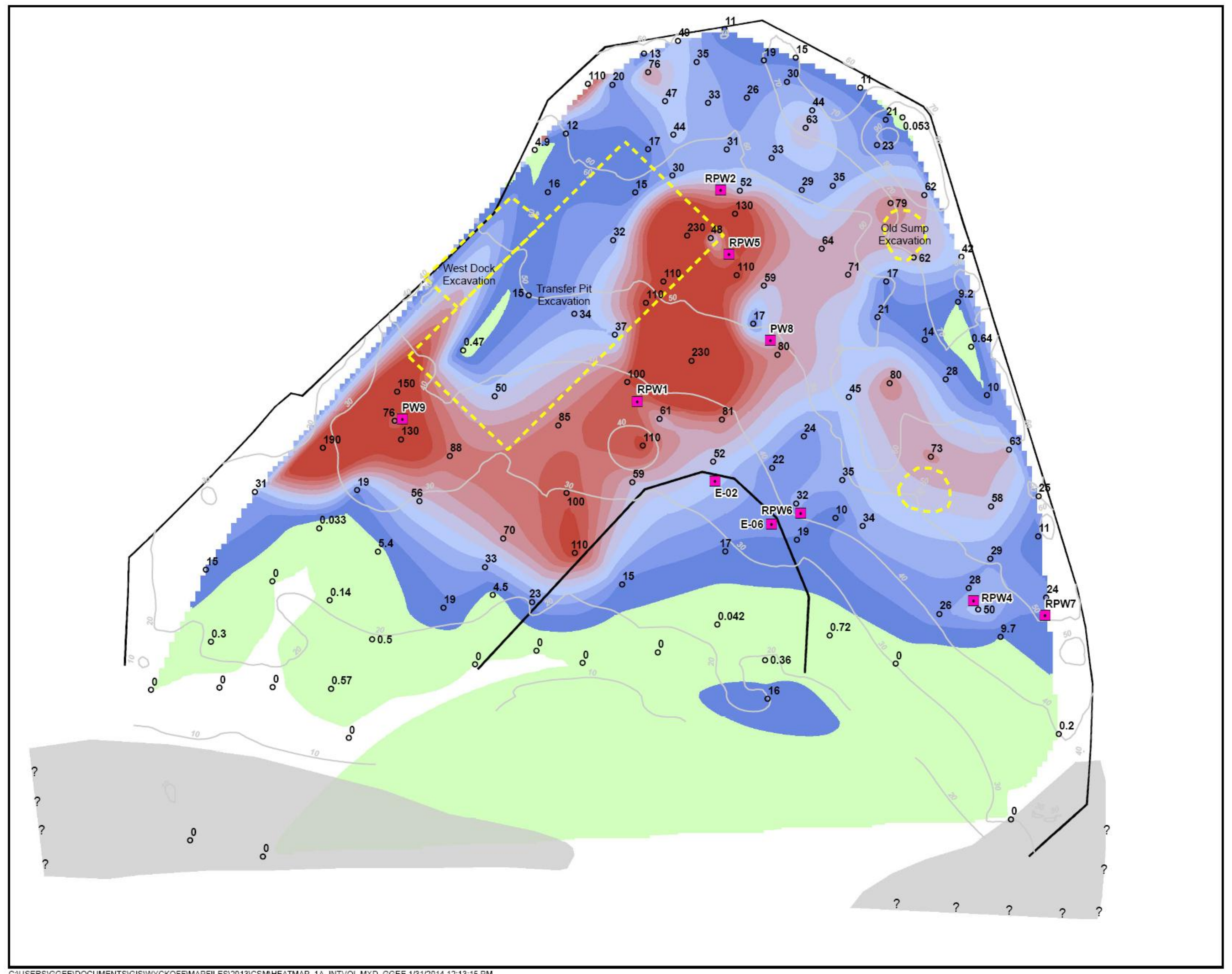
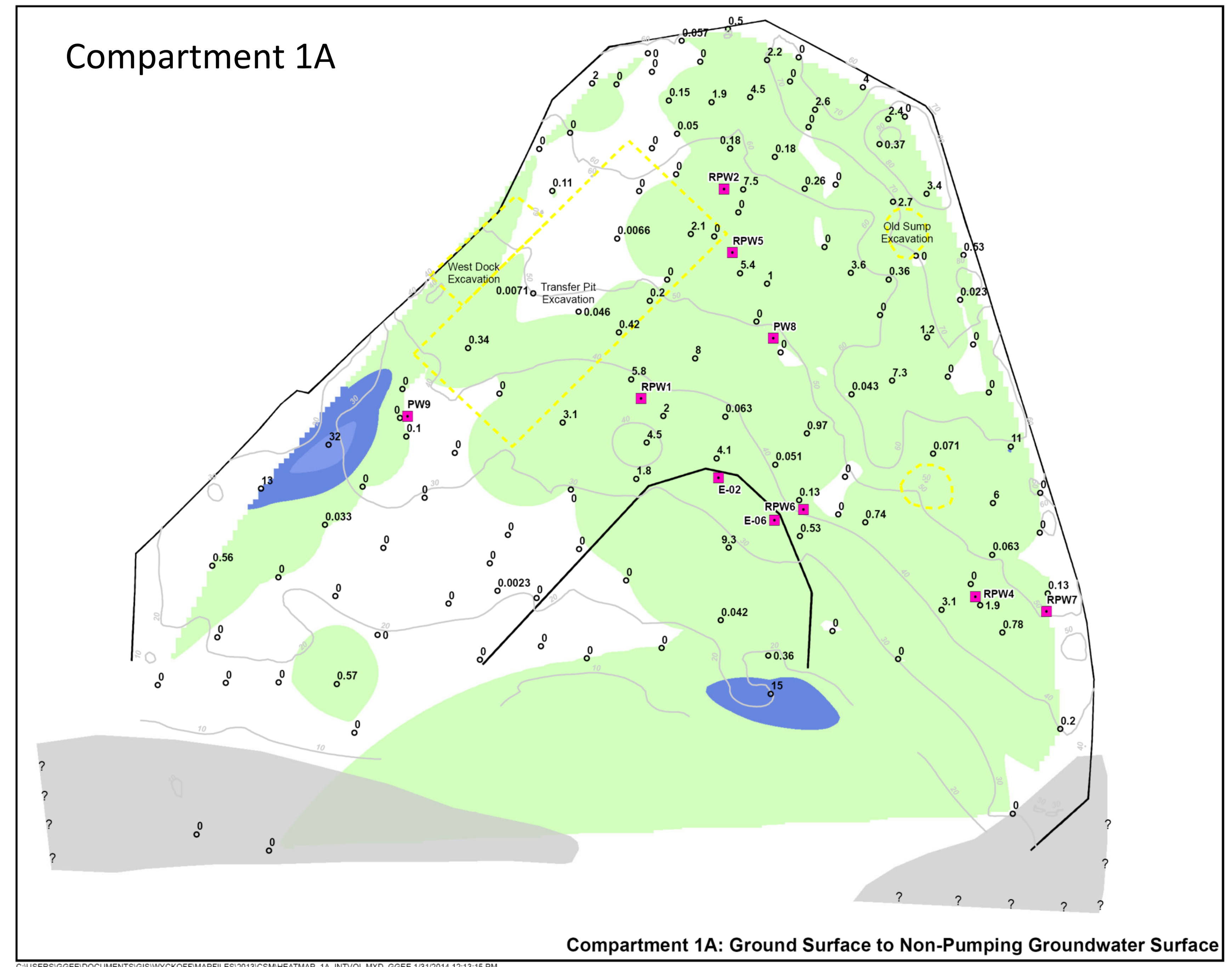
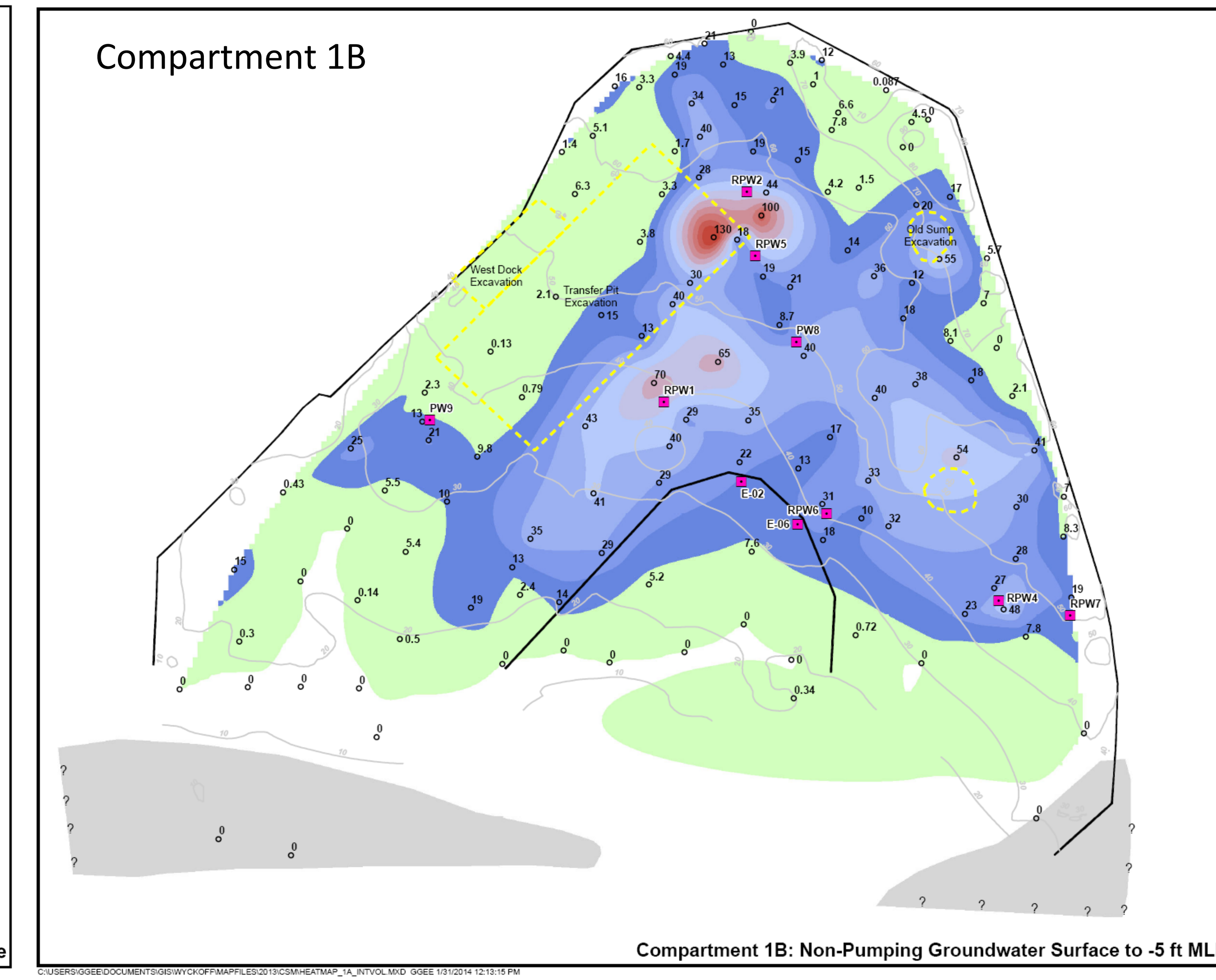
All Compartments



Compartment 1

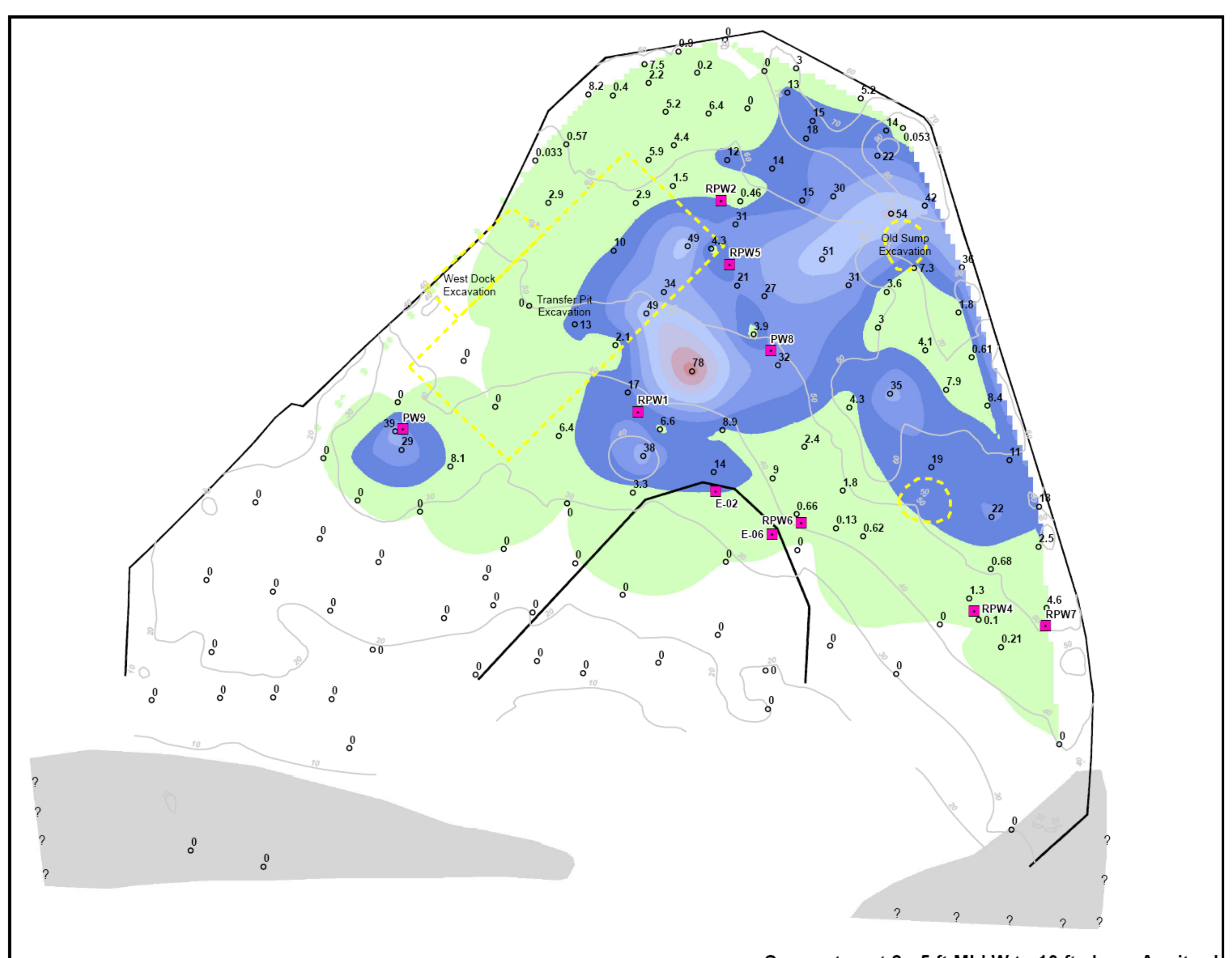


Compartment 1A: Ground Surface to Non-Pumping Groundwater Surface



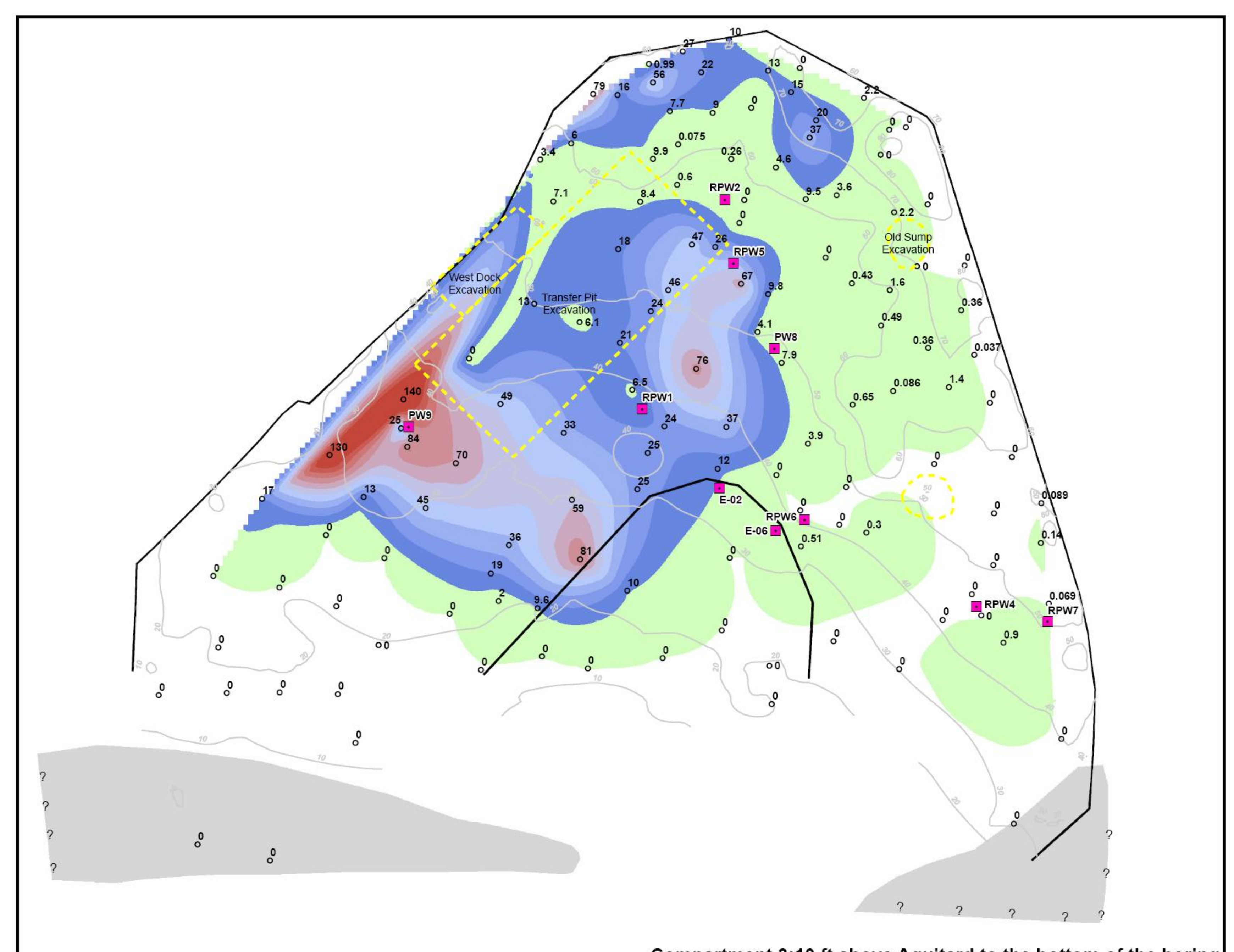
Compartment 1B: Non-Pumping Groundwater Surface to -5 ft MLLW

Compartment 2



Compartment 2: -5 ft MLLW to 10 ft above Aquitard

Compartment 3



Compartment 3:10 ft above Aquitard to the bottom of the boring

LEGEND

Integrated Volume of NAPL by Compartment (gallons)

- 0 - 0.1
- 0.1 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 60
- 60 - 70
- 70 - 80
- 80 - 90
- 90 - 100
- >100
- Extraction Wells
- Contours of Upper Aquifer Thickness (10 ft CI)
- Site Remediation Excavation Performed in 1992 through 1994
- Aquitard Thin (<4 ft) to Absent

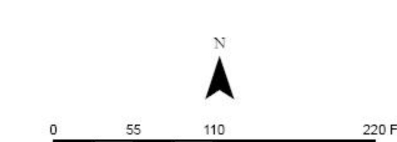


Plate 9

Integrated Volume of NAPL at Greater Than or Equal to 10%RE TarGOST Response
Upland Dataset

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