Draft Final Report

Draft Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

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Acronyms and Abbreviations

%RE	percent reference emitter (for TarGOST®)
µg/kg-w	micrograms per kilogram wet weight
µg/L	micrograms per liter
AC	activated carbon
AES	Architecture and Engineering Service
AET	Apparent Effects Threshold
ARAR	applicable or relevant and appropriate requirement
BAP	benzo(a)pyrene
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	contaminant of concern
CPAH	carcinogenic polycyclic aromatic hydrocarbon
CPT	cone-penetrometer
CSM	conceptual site model
CWA	Clean Water Act
CY	cubic yard
DNAPL	dense nonaqueous-phase liquid
DO	dissolved oxygen
EBS	exposure barrier system
Ecology	Washington State Department of Ecology
EHOU	East Harbor Operable Unit (OU-1)
ENR	enhanced natural recovery
EPA	U.S. Environmental Protection Agency
FALCON	Fingerprint Analysis of Leachate Contaminants
FFS	focused feasibility study
FS	feasibility study
ft/ft	feet per foot
gpm	gallons per minute
GRA	general response action
GWTP	groundwater treatment plant
HHRA	human health risk assessment
HI	hazard index
HOT	highest observable tide
HPAH	high-molecular-weight polycyclic aromatic hydrocarbon
ISCO	in-site chemical oxidation
ISS	in situ stabilization and solidification
LAET	Lowest Apparent Effects Threshold
LF	lineal feet
LIF	laser-induced fluorescence
LNAPL	light nonaqueous-phase liquid
LOT	lowest observable tide
LPAH	low-molecular-weight polycyclic aromatic hydrocarbon

MCUL	Minimum Cleanup Level
MDL	method detection limit
mg/kg-w	milligrams per kilogram wet weight
MHW	mean high water
MLLW	mean lower low water
MLW	mean low water
MNR	monitored natural recovery
MTCA	Model Toxics Control Action
NAPL	nonaqueous-phase liquid
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
ND	not detected
ng/L	nanogram per liter
NOAA	National Oceanic and Atmospheric Association
NPL	National Priorities List
O&M	operations and maintenance
OC	oleophilic clay
OMB	Office of Management and Budget
OSWER	Office of Solid Waste and Emergency Response
OU-1	Operable Unit OU-1 (East Harbor Operable Unit)
OU-2	Operable Unit OU-2 (Upland Soil Operable Unit)
OU-3	Operable Unit OU-3 (West Harbor Operable Unit)
OU-4	Operable Unit OU-4 (Upland Groundwater Operable Unit)
PAH	polycyclic aromatic hydrocarbon
PCP	pentachlorophenol
PQL	practical quantitation limit
PRG	Preliminary Remediation Goal
QAPP	Quality Assurance Project Plan
RAO	Remedial Action Objective
RAWP	Remedial Action Work Plan
RCM	reactive core mat
RCRA	Resource Conservation and Recovery Act of 1976
RI	remedial investigation
ROD	Record of Decision
RTA	remediation target area
S/S	stabilization/solidification
SCO	Sediment Cleanup Objective
SF	square feet
Site	Wyckoff/Eagle Harbor Superfund Site
SMS	Washington State Sediment Management Standards
SPME	solid phase micro-extraction
SQS	Sediment Quality Standard
SVOC	semivolatile organic compound
TarGOST®	Tar-Specific Green Optical Screening Technology
TBC	to be considered
TEF	toxicity equivalency factor
TEQ	toxicity equivalency quotients
TOC	total organic carbon

USACE	U.S. Army Corps of Engineers
UTA	University of Texas at Austin
VOC	volatile organic compound
WAC	Washington Administrative Code
WDOH	Washington State Department of Health
Wyckoff Site	Wyckoff/Eagle Harbor Superfund Site

SECTION 1

Introduction

This report presents a Focused Feasibility Study (FFS) for the Wyckoff/Eagle Harbor Superfund Site (Wyckoff Site, or Site) intertidal sediment portion of Operable Unit 1 (OU-1) located on Bainbridge Island, Washington. The FFS describes the process by which remedial action alternatives were developed and evaluated to assist in identifying a recommended alternative to address non-aqueous-phase liquid (NAPL) contaminated sediment present in the North Shoal and East Beach portions of OU-1. This FFS was prepared as one of the work scope items included under Task Order 077-RI-FS-10S1 of the U.S. Environmental Protection Agency (EPA) Region 10 and CH2M HILL Architecture and Engineering Services Contract No. 68-S7-04-01.

1.1 Purpose and Organization of Report

A feasibility study (FS) ensures that appropriate remedial action alternatives are developed and evaluated so that relevant information concerning the remedial action options can be presented and an appropriate remedy selected. This document is a FFS, rather than a FS, because it addresses a specific problem within OU-1; that is NAPL source material.

The 1994 *Record of Decision (1994 ROD) for Wyckoff Co./Eagle Harbor OU 01* (EPA, 1994) specified that remediation goals for the intertidal area must be met within 10 years after upland source control actions were completed. A sheet pile wall was constructed around the north and east perimeter of the upland area in 2001. The EPA and U.S. Army Corps of Engineers (USACE) conducted several OU-1 monitoring events in 2001, 2002-2003, and 2011 to assess the efficacy of the monitored natural recovery (MNR) remedy selected in the 1994 ROD and to assess the overall stability of the beaches following sheet pile wall installation. The *Final 2011 Year 17 Monitoring Report* (USACE, 2012) documented a general trend of improving sediment quality and fewer NAPL seeps than observed prior to sheet pile wall installation. However, contaminant of concern (COC) concentrations at several North Shoal and East Beach sediment sampling locations exceeded the cleanup goals established in the 1994 ROD. Additionally, NAPL seeps have persisted at several locations. Therefore, EPA commissioned this FFS to develop and evaluation remedial action alternatives to address NAPL source material present in the North Shoal and East Beach portions of OU-1 because this material is expected to pose a threat to human health and the environment that exceeds the upper bound of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) risk range.

As described in *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA, 1988), the FFS/FS consists of three phases:

1. Screening remedial technologies
2. Developing remedial action alternatives
3. Conducting a detailed analysis of the alternatives

The information associated with each of these three phases is presented in Sections 5, 6, and 7 of this FFS Report, respectively. Sections 1 through 4 provide background information that defines the problem to be addressed in the North Shoal and East Beach portions of OU-1 as follows:

- **Section 1, Introduction** briefly describes the purpose and organization of this FFS Report.
- **Section 2, Background Information** presents a brief site description and history, and describes previous remedial actions and investigations that have been performed at the Site since construction of the sheet pile wall was completed in 2001.
- **Section 3, Site Characteristics and Conceptual Site Model** (CSM) summarizes the results of the more recent Site investigations and presents a CSM for the FFS Project Area.

- **Section 4, Remedial Action Objectives** (RAOs) summarizes the basis for action and describes the RAOs, preliminary remediation goals (PRGs) and the area and depth of NAPL contaminated sediments to be addressed in this FFS.
- **Section 5, Identification and Screening of Remedial Technologies** identifies and describes a range of remedial approaches, technologies, and process options that could be used to address contaminated sediments in OU-1 and screens them based on effectiveness, implementability, and cost.
- **Section 6, Development of Remedial Alternatives** develops remedial alternatives for OU-1 sediments by combining the remedial approaches, technologies, and process options that were retained after the screening described in Section 5.
- **Section 7, Detailed and Comparative Analysis of Alternatives** presents a detailed and comparative analysis of the alternatives against the threshold and balancing criteria specified in CERCLA and the National Oil and Hazardous Substance Pollution Contingency Plan (NCP).
- **Section 8, References** lists the references cited in the report.

The tables and figures called out in this document are presented in separate sections that follow Section 8. This FFS Report also contains several appendixes that provide supporting information as follows:

- **Appendix A** presents the solid phase micro-extraction (SPME) sample analysis report from the University of Texas at Austin (UTA) to support evaluation of surface water quality in the FFS Project Area.
- **Appendix B** provides documentation for the cross-sectional groundwater flow model that informs interpretations of groundwater upwelling within the OU-1 intertidal sediments.
- **Appendix C** presents the technical memorandum describing analysis of wave-driven sediment transport at the FFS Project Area.
- **Appendix D** presents the technical memorandum describing review of intertidal sediment analytical data.
- **Appendix E** presents the technical memorandum describing the dewatering estimate for shallow excavations for remedial action alternatives that include placement of caps.
- **Appendix F** presents the cost estimates for the remedial action alternatives described in this FFS Report.

SECTION 2

Background Information

Numerous environmental investigations and remedial actions have been conducted at the Wyckoff/Eagle Harbor Superfund Site. This section provides an overview of investigations and remedial actions pertinent to the FFS Project Area. This summary includes investigations and monitoring activities performed just prior and subsequent to completing the sheet pile wall installation around the upland area in 2001. Data from these investigations provides context for Site conditions that are most relevant to this FFS. **Table 2-1** presents a chronology of remediation activities, investigations, and monitoring events.

2.1 Site Description and History

EPA added the Wyckoff/Eagle Harbor Superfund Site to the National Priorities List (NPL) in 1987. The Site is located on the east side of Bainbridge Island, Washington, in central Puget Sound (**Figure 2-1**). The Site encompasses the contaminated areas of Eagle Harbor and adjoining upland of the former 57-acre Wyckoff wood-treating facility. The Wyckoff/Eagle Harbor Superfund Site is comprised of the following OUs:

- **East Harbor Operable Unit (OU-1):** includes subtidal and intertidal sediments of the harbor next to the Wyckoff uplands ("The Point").
- **Soil Operable Unit (OU-2):** includes the soil underlying the former Wyckoff wood-treating process and storage area located on The Point.
- **West Harbor Operable Unit (OU-3):** includes sediments and uplands of a former shipyard facility.
- **Groundwater Operable Unit (OU-4):** includes the saturated zone (soil and groundwater) that lies beneath the Soil OU (OU-2).

2.1.1 Site Description

The FFS Project Area comprises 10.8 acres of OU-1 and includes intertidal portions of the East Beach, North Shoal, and a small portion of the West Beach adjacent to the Wyckoff uplands (**Figure 2-2**). The FFS Project Area limits are defined by current and historical NAPL product seeps and NAPL occurrences in intertidal sediments. The presence of NAPL poses potential exposure hazards to beach users, biota, and for potential future shellfish harvesting in the FFS Project Area.

The general marine setting of the FFS Project Area consists of beach and tide flat environments seaward of the existing sheet pile wall installed around the Wyckoff uplands. EPA and USACE installed the sheet pile between 1999 and 2001 as a measure to contain migration of NAPL from upland source areas. Surface elevations within the FFS Project Area generally range from approximately 0 foot mean lower low water (MLLW) to about +15 feet MLLW with the highest elevations present near the west end of the sheet pile wall.

2.1.2 Site History

Beginning in the early 1900s and lasting through 1988, several companies treated wood at the Wyckoff property for use as railroad ties and trestles, telephone poles, pilings, docks, and piers. Initially, poles were treated by wrapping them with burlap and asphalt, and, by 1910, pressure treatment with creosote and/or bunker oil had begun. The wood treatment operations involved using and storing creosote, pentachlorophenol (PCP), solvents, and petroleum products; generating solid process wastes and wastewater; and storing treated wood and other wood products. Former operational features in the Wyckoff upland area included storage tanks and process vessels (such as retorts), log peelers, and raw and treated log storage areas.

Historical operations resulted in releases of creosote product to the upland and nearshore areas. Creosote product, and diesel used as a carrier fluid for PCP based wood treating oil, occurs as a NAPL in soils and sediment and is a source of polycyclic aromatic hydrocarbon (PAH) constituents that are sorbed to soil and sediment and dissolved in groundwater. NAPL may occur as a light phase (LNAPL) or dense phase (DNAPL). LNAPL is less dense than water while DNAPL is heavier than water. LNAPL floats on the water table and thus distributes cross the zone of water table fluctuation while DNAPL migrates below the water table creating zones of residual (immobile DNAPL) and pools (mobile DNAPL). Pools generally form above zones of fine-grained material that represent a capillary barrier to downward migration. A majority of the NAPL present in the FFS Project Area is believed to be creosote DNAPL that was discharged as liquid waste or migrated through the subsurface from historic releases in the Site's former process area.

2.2 Prior Remedial Actions

Numerous remedial actions have been conducted at the Wyckoff/Eagle Harbor Superfund Site. Key studies relevant to FFS Project Area are listed in **Table 2-1** and summarized in the following subsections. Separate remedial investigations (RI) and feasibility studies (FS) were conducted, and separate decision documents issued for OU-1 and OU-2/OU-4.

Following work completed in the 1980s and early 1990s, EPA issued the 1994 ROD for OU-1 that identified capping and MNR as the selected remedial alternative (EPA, 1994). Capping of the subtidal and intertidal sediments was performed across much of the East Harbor area between 1994 and 2008 with MNR implemented across most of the North Shoal and East Beach areas. Approximately 275,000 cubic yards (CY) of sandy Snohomish River dredged material was placed in the East Harbor, covering more than 54 subtidal acres. The Phase I cap extended toward the northwest portion of the FFS Project Area (**Figure 2-3**). Many of the remaining in-water structures supporting previous operations at the Wyckoff facility, including the West Dock pier, were removed in 1998 and 1999. Pier pilings were cut off near the mudline; however, beach erosion has since exposed the tops of many pilings.

EPA and USACE completed a Phase II intertidal cap covering a portion of the North Shoal (**Figure 2-3**) in 2001. In 2002, a Phase III cap was placed to cover additional portions of the North Shoal and West Beach areas, with some partial overlap of the Phase II cap. The Phase II and Phase III subtidal caps within the western fringe of the FFS Project Area range in thickness up to approximately 12 feet and consist of quarry-run sand with "fish mix" gravel placed at the cap surface (EPA, 2002). Phase I, II, and III capping events, sheet pile wall construction, and other remedial activities are described in EPA's 2002 *Five-Year Review Report for the Wyckoff/Eagle Harbor Superfund Site* (EPA, 2002). An additional sand cover exposure barrier system (EBS) was placed along the West Beach in 2007 and 2008, as described in EPA's Third Five-Year Review Report (EPA, 2012a).

Following monitoring of the caps and other OU-1 areas by USACE in 2011, EPA concluded that, overall, the East Harbor remedy components are functioning as designed (EPA, 2012a). Additional details regarding remedial actions for OU-1, OU-2, and OU-4 are presented in EPA's Five-Year Review Reports (EPA, 2002, 2007, and 2012a).

Several remedial actions were also conducted in the OU-2 and OU-4 between 1988 and 1993, with some activities extending nearshore into the current FFS Project Area. Buried sludge near the former West Dock, an underground pipeline and associated product and sludge present at the North Shoal, and selected dock structures and pilings were removed as part of these earlier remedial actions (CH2M HILL, 1994). Groundwater extraction and treatment was initiated in OU-2/OU-4 in 1990 with construction of a replacement groundwater treatment plant completed in 2010 (EPA, 2012a). The current plant remains operational and provides hydraulic containment of upland groundwater and NAPL.

The sheet pile containment wall constructed around the northern and eastern portions of the Wyckoff upland facility between 1999 and 2001 was driven into glacial silt and clay aquitard soils at depths of up to about 90 feet below ground surface (bgs). The wall was intended to reduce, or prevent, additional NAPL migration into the intertidal areas from upland sources.

2.3 Previous OU-1 Investigations

This section provides an overview of the OU-1 investigations that are relevant to the FFS Project Area. The summary herein focuses on the investigations performed during and subsequent to the sheet pile wall installation in 2001, since the post-wall conditions represent the most pertinent baseline for this FFS. A more detailed compilation of the key studies and the associated results, activities, and other background information is provided in the Data Gaps Memorandum presented as an appendix to the project Quality Assurance Project Plan (QAPP) supporting CH2M HILL's 2012 OU-1 field investigations (CH2M HILL, 2012a). Sampling locations, explorations, historical seeps, and associated data are presented in tables and figures in the Data Gaps Memorandum.

Discussion of the findings from these investigations is summarized in Section 3, where results have been synthesized into the Site characteristics and CSM. Investigation findings and results are also incorporated as appropriate into the discussion establishing the remediation target area (RTA) in Section 4.

2.3.1 2000 Comprehensive Nonaqueous-Phase Liquid Field Exploration Report

The USACE completed deep direct-push explorations in 1999 to evaluate subsurface conditions along the general alignment of the planned sheet pile wall between the upland and nearshore areas (USACE, 2000). The direct push data supported sheet pile design and provided information on subsurface soil and sediment conditions and NAPL occurrence. Exploration objectives included assessing the general depth extent of NAPL near the upland edge of the current FFS Project Area. Several direct-push explorations were situated farther seaward in tide flat areas located near historical seep locations. As part of this work, USACE submitted selected subsurface sediment and soil samples for laboratory testing of PAHs to evaluate the extent of potential contamination. Uncertainty remained after the 1999 push probe investigation regarding the extent of subsurface NAPL zones, and NAPL flow and spreading mechanisms.

2.3.2 2001 Natural Recovery Study

Battelle conducted a natural attenuation investigation for Eagle Harbor that included two borings in the near-surface zone near the western edge of the FFS Project Area (Battelle, 2001). A third shallow boring was completed outside of the FFS Project Area to the northwest. Sediment samples were collected and analyzed for grain size, percent moisture, total organic carbon (TOC), PAHs, and radionuclides.

2.3.3 2002 East Beach Investigation Report

In August 2001, EPA and USACE conducted additional seep observations and direct-push explorations along a portion of East Beach after the sheet pile wall was completed (EPA and USACE, 2002). This investigation included a series of 21 direct-push borings advanced along an approximate 400-foot transect on East Beach. The sampling transect generally spanned the highest density of historical seeps along the East Beach. Sediment samples collected from various depth intervals were analyzed for TOC, total solids, and PAHs.

2.3.4 2004 Year 8 Environmental Monitoring Report

Integral Consulting collected near-surface and subsurface sediment samples in December 2002 as part of the Year 8 Site environmental monitoring for OU-1 (Integral Consulting, 2004). Integral also collected shellfish tissue samples during spring 2003 and conducted habitat surveys during winter and spring 2003. In addition to assessing cap performance elsewhere in OU-1, the Year 8 monitoring goals were to further define the physical extent of PAH contamination following sheet pile wall installation, confirm surface chemistry patterns in the North Shoal sediments, document PAH and lipids concentrations in shellfish tissue, and evaluate the success of habitat plantings. Shellfish tissue collection included two North Shoal locations sampled for horse clams (*Tresus capax*) and three East Beach locations sampled for butter clams (*Saxidomus gigantean*). Composited clam tissue samples from each location were analyzed for PAHs.

2.3.5 2011 Year 17 Monitoring Report

In October 2011, the USACE performed field sampling as part of the Year 17 monitoring investigation (USACE, 2012). Field explorations in the FFS Project Area included 15 sediment sampling locations on a grid on East Beach and 5 locations on North Shoal. Additionally, sediments were sampled at five locations previously identified during the 2002 monitoring adjacent to visible seeps on East Beach. Surface and subsurface sediment samples were submitted for grain size, TOC, total solids, PAH, semivolatile organic compounds (SVOCs), dibenzofuran, and PCP.

The Year 17 monitoring also included conducting habitat and biota surveys and collecting shellfish tissue for analytical testing of PAHs and PCP. Shellfish collection included three East Beach locations, three North Beach locations, and one “intertidal location” at the northwestern edge of North Shoal that were sampled for horse clams (*T. capax*). Composited clam tissue samples from each location were analyzed for PAHs.

2.3.6 2012-2013 Intertidal Investigations

CH2M HILL performed additional Site investigations in 2012 and 2013 to support the current OU-1 FFS. In May 2012, near-surface “pothole” excavations and pore water extractions were completed at 42 locations on East Beach and North Shoal. The pothole and pore water media collections were used to determine whether visual sheen was present and to confirm boring locations for Tar-Specific Green Optical Screening Technology (TarGOST®) deployment for subsurface laser-induced fluorescence (LIF) investigation of NAPL presence. The TarGOST® survey was performed in two phases during June and July 2013, with results from the first phase informing the TarGOST® probe locations for the second phase. TarGOST®-LIF vertical profiles were collected at 60 unique boring locations identified on **Figure 2-4**, as well as 19 field replicate borings. At six selected TarGOST® locations, direct-push sediment cores were advanced and the sediment logged for comparison with the TarGOST® results. The field activities and results are comprehensively described in the *Field Investigation Technical Memorandum – Wyckoff OU-1 Focused Feasibility Study* (CH2M HILL, 2012b).

SPME sampling devices were deployed late in 2013 to determine concentrations of dissolved-phase PAHs in sediment pore water and surface water (**Figure 2-5**). Field sampling, sample extraction, and laboratory testing were completed in accordance with the project QAPP (CH2M HILL, 2013a). CH2M HILL completed the fieldwork with assistance from its subcontractor, the University of Texas at Austin (UTA), and the EPA Region 10 dive team and vessel operators. The SPME samplers were deployed on November 13, 2013, at nine locations along three transects and at four surface water sampling locations.

The pore water samplers were deployed to depths of approximately 1 foot below the sediment surface. Each of the nine shallow subsurface pore water samplers was sectioned for samples at 3 to 5 centimeters, 5 to 7 centimeters, 13 to 15 centimeters, 15 to 17 centimeters , 23 to 25 centimeters , and 25 to 27 centimeters below sediment surface, for a total of 54 samples. The surface water sampling devices were anchored into the bottom sediment and positioned so that the top of the each sampler was approximately 1 foot above the sediment surface. The water column samplers were sectioned for samples at 3 to 5 centimeters, 5 to 7 centimeters, 13 to 15 centimeters, 15 to 17 centimeters, 23 to 25 centimeters, and 25 to 27 centimeters below the top of the sampler, for a total of 24 samples. Adjacent sample pairs at each deployment location served as field duplicates. The field team retrieved the samplers on December 5, 2013, and submitted SPME samples for analytical testing at the UTA laboratory. UTA field sampling efforts and laboratory analyses are presented in Appendix A and summarized in Section 3.2.3.

SECTION 3
Site Characteristics and Conceptual Site Model

This section describes the OU-1 generalized Site characteristics relevant to the development and evaluation of the remedial alternatives, as well as briefly summarizes the CSM. Information from previous Site environmental investigations and remedial actions summarized in Section 2 is incorporated, along with other sources of information as noted. Site characteristics are presented first in this section as background supporting the CSM.

3.1 Site Characteristics

This section discusses the current Site conditions for the FFS Project Area, including general Site setting, sediment stratigraphy, hydrogeologic conditions, coastal environment, and NAPL distribution.

3.1.1 General Site Setting

The general marine setting of the FFS Project Area consists of beach and tide flat environments seaward of the existing sheet pile containment wall (**Figure 2-2**). Surface elevations within the FFS Project Area range from approximately 15 feet MLLW near the base of the sheet pile wall to about -2 feet MLLW at the seaward extent of the FFS Project Area. The following additional tidal reference elevations derived from National Oceanic and Atmospheric Association (NOAA) data are referenced in the following discussions:

- Highest observable tide (HOT) elevation: +14.5 feet
- Mean high water (MHW) elevation: +10.5 feet
- Mean low low water (MLLW) elevation: 0.0 feet
- Mean low water (MLW) elevation: +2.8 feet
- Lowest observable tide (LOT) elevation: -5.0 feet

These values are relevant to the MLLW reference datum of elevation 0 feet. The beach face and tide flat compose a low-angle landform with extensive shoaling areas extending 200 to 300 feet nearshore. The intertidal sediments consist of variously bedded sands, gravels, and silts and the sediments support eelgrass beds, other macroalgae, and shellfish.

Pedestrians can physically enter the beach area through access points on the southern portion of East Beach and from West Beach; vessel access is possible. EPA policy is to discourage public beach use due to the presence of NAPL sheens and seeps, which represent potential exposure hazards; however, pet walking and other recreational activities are not uncommon. Signs in the West Beach area prohibiting trespass have been subject to vandalism, and EPA continues to upgrade posting methods.

The extent of the eelgrass beds, as mapped by Washington State Department of Ecology (Ecology) during a Site visit in June 2013 are illustrated in **Figure 3-1**. Eelgrass beds lie within the intertidal and subtidal portions of OU-1 where NAPL seeps and sheens have been detected. NAPL seep locations observed during the June 2103 Site visit are identified on **Figure 3-1**. EPA also noted NAPL seeps during a May 2014 site visit, along with an additional seep near the seaward edge of the North Shoal.

Eelgrass is an important resource. Eelgrass beds provide habitat and a food source for a variety of marine organisms. They also filter pollutants, stabilize intertidal areas against erosion, and are an indicator of environmental stress. NOAA and Suquamish Tribes recently completed 3 acres of eelgrass restoration in the vicinity of the Wyckoff site near the Milwaukie Dock (Puget Sound Acquisition and Restoration Fund, 2015).

3.1.2 Sediments and General Stratigraphy

The Site sediments are divided into lithologic units consistent with criteria developed by CH2M HILL during the *Final Remedial Investigation Report for the Wyckoff Soil and Groundwater Operable Units*

(CH2M HILL, 1997), and the USACE for the *Off-Shore Field Investigation Report for the Barrier Wall Design Project* (EPA and USACE, 1998). These geologic units were subsequently described with minor modifications in the USACE's *Comprehensive Report, Wyckoff NAPL Field Exploration, Soil and Groundwater Operable Units, Wyckoff/Eagle Harbor Superfund Site* (USACE, 2000); and in CH2M HILL's *Soil Boring and Monitoring Well Construction Summary* (CH2M HILL, 2009).

Following are the sediment lithologic units and associated descriptions for the FFS Project Area:

- **Fill—**Brown, fine sand containing wood debris, anthropogenic debris, and infrequent shell fragments. Fill materials may be associated with historical shoreline development and modification activities. Fill is locally present on upper portions of the western portion of the North Shoal area but is not extensive.
- **Surficial marine sediment—**Dark olive, harbor bottom silt and clay, commonly with abundant wood chips and wood and plant debris.
- **Marine silt—**Olive-gray silty sand with thin layers of gravel to silt or clay and containing abundant shell fragments.
- **Marine sand and gravel—**Gray to dark gray, loose to dense sand and gravel with local cobbles and low silt content and common shell fragments.
- **Marine sand and gravel (gravel zones) —**Marine sand and gravel zones with dominant gravel and local cobbles, transitioning into less coarse sediments.
- **Marine sand—**Dark greenish gray to medium dark, dense to very dense sand with little silt or gravel. Zones of dominantly wood pulp and wood debris were also added as OU-1 units. These zones are characterized by dark gray and brown to black decomposing fibrous or pulpy wood.

The general occurrence and distribution of sediment types observed during the 2012 OU-1 investigation were consistent with the stratigraphy documented in previous studies. Within the FFS Project Area, the upper portion of the sediment profile, approximately 40 feet of sediment, is dominated by marine sand and gravel with coarser gravel zones and localized cobbles. Limited occurrences of other sediment types, including marine silt and surficial marine sediments consisting of silt and clay with local wood chips and plant debris, have been observed during recent and historical field investigations. The distribution of these minor units is somewhat chaotic, consistent with the variable-energy, marine depositional environment. As noted above, fill areas are limited to uppermost elevations and localized occurrence in the western portion of the North Shoal.

3.1.3 Hydrogeology

Hydraulic forces in the OU-1 intertidal area are influenced by tidal conditions, the sheet pile wall between the upland and nearshore areas, and other factors. Tidal forces represent the dominant dynamic force controlling groundwater flow within the marine sands, gravels, and other sediment lithologies present in the intertidal area. The tidally influenced zone occurs between elevations of -10 to +12 feet MLLW. Tidal forces create cyclical horizontal and vertical gradients within the intertidal and shallow subtidal zones.

Although Site tidal studies or other investigations have not been conducted to evaluate groundwater flow and gradients, previous groundwater modeling indicated that net vertical gradients (steady state) are likely upward outside of the sheet pile wall (CH2M HILL, 2004). CH2M HILL completed additional cross-sectional groundwater flow modeling for the OU-1 FFS to evaluate gradient changes over a typical tidal cycle (see Appendix B). The model incorporated three hydrostratigraphic units that include in descending order: the upper aquifer, the aquitard, and the lower aquifer. The upper aquifer extends to a depth of about 50 feet below the beach surface and includes the tidally affected zone where NAPL is present. An underlying lower aquifer unit lies about 75 below the beach surface and is separated from the upper aquifer by a dense, fine-grained glacial till that functions as an aquitard. Hydraulic properties of the hydrostratigraphic units and other modeling assumptions are discussed further in Appendix B. The *Groundwater Conceptual Site Model*

Update Report for the Former Process Area (CH2M HILL, 2007) presents additional details and assumptions regarding the hydrostratigraphic units.

Vertical groundwater flow gradient changes predicted by the cross-sectional groundwater model in the tidally influenced upper aquifer are presented in **Figures 3-2** and **3-3**. Within the upper aquifer, **Figure 3-2** illustrates upward vertical gradients ranging from 0.0005 to 0.001 foot per foot (ft/ft) approaching high tide and 0.001 to 0.04 ft/ft approaching low tide (**Figure 3-3**). Mid-tide gradients ranges are expected to vary between these ranges. Vertical hydraulic gradients are a key factor affecting NAPL migration, as discussed further in Section 3.2.

The sheet pile wall between the Wyckoff upland and nearshore areas is a major feature that limits hydraulic interaction and mixing of freshwater and marine water between the upper aquifer and intertidal area. CH2M HILL evaluated sheet pile wall conditions in 2013, as reported in *Wyckoff Sheet Pile Wall – Nonaqueous Phase Liquid and Plume Migration Barrier Effectiveness Evaluation* (CH2M HILL, 2013b). The evaluation concluded that there is some hydraulic flux through the sheet pile seams (i.e., the wall is locally "leaky"); however, comparison of current and historical tidal efficiency factor measurements, combined with the sheet pile wall construction information, indicates that the current hydraulic flux between the upland and nearshore areas is significantly less than during pre-wall conditions. Groundwater within the FFS Project Area is saline, with potential influx of freshwater from the upland expected to be localized and limited.

3.1.4 General Coastal Environment and Sediment Stability

Wave dynamics and coastal processes influence the depositional and erosional environment of the FFS Project Area. Existing coastal conditions also provide a baseline for comparing potential impacts of remedial alternatives on the stability of intertidal landforms. The intertidal area ranges from approximately elevation 0 feet to + 15 feet MLLW and is influenced by wave action and tidal forces, including wakes from ferries and other vessels. The mean diurnal tidal range in Eagle Harbor is 7.7 feet (USACE, 2012), and the tidal currents are weak and are usually less than 1 knot (approximately 1.7 feet per second). Unlike East Beach, the North Shoal is fairly sheltered from wind-generated waves due to the harbor geometry.

The current understanding of coastal conditions in nearshore areas of the Wyckoff/Eagle Harbor Superfund Site is based on bathymetric elevation surveys and sediment mobility modeling conducted by USACE as part of 2011 monitoring activities (USACE, 2012). As an extension of this work, CH2M HILL performed further wave and sediment transport analysis to model the effects of wave break and longshore transport on sediment stability within the FFS Project Areas (CH2M HILL, 2013c). The CH2M HILL evaluation is presented as Appendix C to this FFS.

Conclusions of the USACE coastal evaluation relevant to the FFS Project Area include the following findings on bathymetric changes to the beach profile and wind-generated shear stresses on bed sediments:

- The intertidal areas of North Shoal and East Beach appear to be physically stable based on comparison of bathymetric data from 1999 and 2011. However, comparison of 2005 and 2011 bathymetry indicated apparent localized accretion of up to about 2 feet along upper intertidal portions of northeastern North Shoal and along northern and central East Beach. The conclusion was that there was no net loss or gain of sediment for North Shoal or East Beach since 1999. Localized areas adjacent to the sheet pile wall showed apparent losses (erosion) of less than approximately 1 foot of material; however, the apparent accretions and losses may be an artifact of the accuracy of the bathymetric survey.
- Maximum bed shear stresses from wind-generated waves were not found to exceed the critical shear stress of sediment cover materials compromising the existing Eagle Harbor caps. These caps include subtidal Phase I and Phase II caps and intertidal Phase III cap (**Figure 2-3**). Vessel wakes did result in marginal exceedances of the critical shear stress of the capping materials, indicating that these higher shear stresses could potentially mobilize the finer fractions of the cap material.

The USACE sediment transport analysis did not evaluate the existing intertidal sediment grain size, but coarse gravel to cobble-sized material on upper beach areas appear to be in a state of dynamic equilibrium. The sorting and distribution of this coarser material are the result of frequent wave exposure and relatively high-wave energy acting on the shoreline and wave reflection from the sheet pile wall.

Building on the USACE sediment transport modeling, CH2M HILL performed further analysis to model the effects of wave breaking and longshore transporting on sediment stability (CH2M HILL, 2013d). Following are the key findings of the CH2M HILL evaluation:

- Surface sediment within and around the FFS Project Area can be mobilized through wave transformation and wave breaking, as well as from wave-driven currents. Sediment can be mobilized during weak or strong wave forcing, although entrained sediment concentrations are greater when larger waves are present. However, the modeling results do not indicate significant erosion in the FFS Project Area promoted by wave breaking.
- Wave-driven longshore transport also carries material into the FFS Project Area from the south and drives sediment transport northward along East Beach. The longshore transport follows the approximate shoreline curvature of North Shoal.
- The USACE sediment mobility study found that tidal currents within the FFS Project Area are not sufficient to move material. However, the CH2M HILL analysis determined that wave-induced currents and wave-breaking processes result in surface sediment transport.
- Waves generated by winds from the south to southeast control the longshore currents and surface sediment transport. This is the result of stronger winds from southerly directions, greater fetch length, location of the FFS Project Area relative to these directions, and exposure of the shoreline to waves arriving from the south and southeast. The FFS Project Area is relatively sheltered from waves arriving from the north, and as a result, these waves have little effect on the FFS Project Area.
- Predicted rates of beach and seafloor morphology change in the FFS Project Area are relatively low, even under 100-year extreme wind and wave forcing. Under normal conditions associated with more typical wind and wave conditions, morphology change is likely insignificant.
- Because of uncertainty associated with modeling results based on the current bathymetry, some uncertainty is also associated with the rates of morphology change.

Overall findings of the USACE and CH2M HILL coastal evaluations indicate that the FFS Project Area is in dynamic equilibrium, with longshore transport of sediment from the south balancing transport of surficial material northward across the area from wave-induced currents and wave breaking. Wave breaking on the upper shoreline and against the sheet pile wall continues to sort and distribute coarser gravel to cobbles in a band extending approximately 30 to 50 feet seaward of the wall.

3.1.5 Biota and Habitat

The USACE habitat and biological surveys conducted during 2011 and 2012 identified a variety of habitats and species associated with the intertidal setting of the FFS Project Area and vicinity (USACE, 2012). Habitat types identified included the following:

- Unvegetated foreshore present throughout the FFS Project Area adjacent to the sheet pile wall
- Low-gradient terrace at the lower end of East Beach foreshore, distinguished by the presence of macroalgae and eelgrass
- Beach terrace in the upper intertidal portion of the western part of North Shoal, with sparse native and nonnative plant species, including seashore lupine, beach pea, sea rocket, yellow abronia, Scot’s broom, Queen Anne’s lace, and chickweed.

The USACE monitoring report noted that riparian and beach restoration near the south end of East Beach has a well-established shrub understory that includes native and nonnative plant species.

The USACE also completed invertebrate, macroalgae, and substrate surveys along several transects. General observations included common occurrence of *Ulva spp.*, eelgrass (*zostera spp.*) and other brown and red alga macroalgae in the lower intertidal areas. Ecology completed preliminary mapping of general eelgrass areas during a June 2013 site visit (**Figure 3-1**).

Various amphipod, anemone, barnacle, limpet, bivalve, gastropod, polycheate, and shrimp species were also noted. Shellfish tissue sampling completed as part of site monitoring in 2003 and 2011 included horse clams (*T. capax*), and also geoduck (*Panopea* generosa), native littleneck clams (*Protothaca stamina*) in 2003. Other clam species including *T. nuttallii* species and *Macoma nasuta* have also been identified by USACE and others.

Forage fish surveys included observations along several transects west of the North Shoal but not in the FFS Project Area. Sand lance and surf smelt eggs were identified along with sand lance larvae and surf smelt in the West Beach and adjacent intertidal areas.

Other observations from the USACE biological surveys included the following bird species:

- **Shallow nearshore areas—**double-crested cormorant, bufflehead, surf scoter, white-winged scoter, red-necked grebe, and Barrow's goldeneye
- **Point count surveys—**double-crested cormorant, great blue heron, rock dove, glaucous-winged gull, house finch, red-necked grebe, barn swallow, violet-green swallow, belted kingfisher, American crow, western sandpiper, killdeer, surf scoter, white-winged scoter, bufflehead, mallard, Barrow's goldeneye, common loon, Canada goose, pigeon guillemot, American robin, song sparrow, white-crowned sparrow, dark-eyed junco, Bewick's wren, American goldfinch, bald eagle, and sharp-shinned hawk

Signs of river otter use were also observed along with human use and dog walking in the beach areas at low tide. Deer and feral dogs are also known to be present nearby, including the Wyckoff upland area.

The relatively healthy appearance of the intertidal area and presence of diverse biota including eelgrass are positive indications of an improved ecological setting relative to the conditions that were present before upland containment measures were implemented. Prior to installation of the sheet pile wall, various reports supported by photographs and videos showed extensive oily seep areas with odor; conditions that are unfavorable for a healthy ecosystem. Although earlier biological data is limited, current conditions indicate a diverse and robust ecosystem demonstrating significant post sheet pile wall recovery.

3.2 Nonaqueous-Phase Liquid Characteristics

The physical and chemical characteristics of NAPL released from historic activities at the Site affect its distribution and mobility in the intertidal environment of the FFS Project Area. Physical and chemical characteristics of resident NAPL have not been measured because of the difficulty in obtaining sufficient sample volume from NAPL beach seeps. These seeps tend to quickly dissipate and mix with near-surface water, diluting the product content of the samples. Alternatively, CH2M HILL evaluated the physical and chemical composition of NAPL product from Wyckoff upland sources collected during the USACE 1999 preremedial design field exploration for the Wyckoff/Eagle Harbor Superfund Site (USACE, 2000).

NAPL data from the 1999 upland field investigation include chemical composition, density, oil-water interfacial tension, and solubility measurements. The 1999 NAPL samples were collected from upland Site extraction and monitoring wells with accumulated NAPL. The results from testing of these samples provide comparative information for assessing chemical composition and weathering of NAPL originating from upland sources, although NAPL properties may change with subsurface transport from the upland to the intertidal area. Changes can result from geochemical interaction with the soil or sediment and constituent weathering. Although physical properties and chemical composition of upland NAPL may vary somewhat from NAPL in the FFS Project Area, these differences are expected to be minor in the context of developing the OU-1 FFS CSM and evaluating OU-1 FFS alternatives.

Although physical and chemical characteristics of NAPL from the FFS Project Area are not available, the chemical compositions of historical upland NAPL from seven upland wells sampled during the 1999 field investigation are presented in **Table 3-1** and illustrated on **Figure 3-4**. These data were analyzed using the EPA Fingerprint Analysis of Leachate Contaminants (FALCON; EPA, 2004) to identify the chemical signature of the NAPL samples. PAH constituents exhibit limited variability and establish a consistent pattern of PAH composition that is dominated by naphthalene, 2-methylnaphthalene, low-molecular-weight polycyclic aromatic hydrocarbons (LPAHs), with much lower concentrations of high-molecular-weight polycyclic aromatic hydrocarbons (HPAHs). A 2001 investigation conducted by Battelle concluded that the characteristics of total petroleum hydrocarbons in the Wyckoff sediment samples are typical of various coal-derived liquid products formed during the heating and conversion of coal, most consistent with creosote (Battelle, 2001).

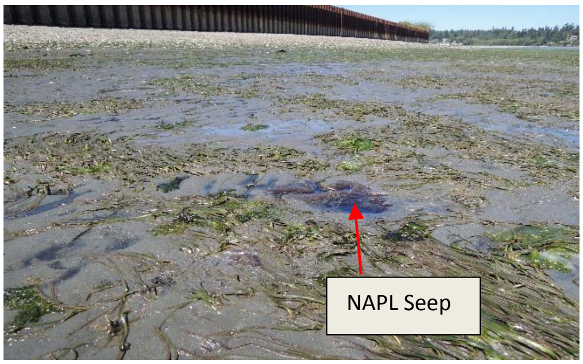
Limited NAPL density, interfacial tension, and viscosity data from upland samples are available from various historical sources. The density measurements can be used to estimate density gradients relative to freshwater and saltwater and indicate that NAPL in the FFS Project Area is likely to be LNAPL and neutral-buoyancy LNAPL. Interfacial tension measurements are used to estimate surface tension and the spreading coefficient to evaluate potential sheening. Viscosity measurements are used to estimate the conductivity of the NAPL relative to water.

3.2.1 Nonaqueous-Phase Liquid Distribution in Sediment

The extent of NAPL in the FFS Project Area is based on the 2012 OU-1 investigation, which utilized the Tar-specific Green Optical Scanning Technology (TarGOST®) to detect the presence of PAHs indicative of NAPL-derived from creosote. The scope of the TarGOST® investigation was summarized in Section 2.2.6, with additional details provided in the *Field Investigation Technical Memorandum* (CH2M HILL, 2013e). TarGOST® probe locations are shown on **Figure 2-4**.

All TarGOST® NAPL detections occur within the upper aquifer, which consists primarily of marine sand and gravel. NAPL predominantly resides within the coarser-grained beach sediments at elevations between -10 and +2.8 feet MLLW (depths of 0 to 13 feet below the mudline). These occurrences represent about 89 percent of the total NAPL detections, based on the vertical length of TarGOST® probes over which NAPL was present. In general, NAPL was not detected at depths greater than 20 feet below the beach surface in the borings that were drilled to greater depths. NAPL occurrences are consistent with the presence of a LNAPL and neutral-buoyancy NAPL types that are resident in the intertidal zone of the FFS Project Area.

Review of the TarGOST® findings, as well as boring logs from previous events, indicate a relatively complex distribution of NAPL with no strong spatial preference for particular sediment horizons. NAPL was most commonly observed in the marine sand and gravel unit and associated gravel zones. This is not unexpected, because these zones are the most prevalent sediment lithologies in the area. NAPL was less commonly observed in other fine-grained sediment units.



3.2.1.1 TarGOST® Response and Nonaqueous-Phase Liquid Occurrence and Mobility

The TarGOST® technology uses a simulated NAPL reference material to calibrate the unit's signal response. The calibration step is performed several times per day. As described in the *Field Investigation Technical Memorandum* (CH2M HILL, 2013e), the threshold response for detecting PAHs associated with NAPL was established at 10 percent reference emitter (%RE). This value provides a balance between NAPL detection sensitivity and potential for false positive detections above this threshold. TarGOST® measurements above the 10%RE threshold were identified as detections even though there is no correlation between this threshold and the degree of NAPL saturation present at the measurement location and depth. However, for the purposes of the TarGOST® investigation, four sediment samples were spiked with different amounts of creosote to define a TarGOST® response versus creosote concentration correlation. Based on the correlation, a TarGOST® 10%RE response correlates to a 5,000 parts per million (0.5 percent) creosote concentration in sediment.

NAPL mobility in the FFS Project Area has not been characterized through NAPL density, viscosity, interfacial surface tension, sediment grain size, pore fluid saturation, or other parameter measurements. Rather, a TarGOST® response of 50 %RE and greater was defined as an indicator of potentially mobile NAPL being present. This threshold is based on experience at other NAPL sites and the professional judgement of Dakota Technologies, Inc., the TarGOST® subcontractor.

Figure 3-5 illustrates the interpreted distribution of NAPL in subsurface sediments within the North Shoal and East Beach portions of OU-1 based on the 10%RE (e.g. NAPL present) and 50% RE (e.g. mobile NAPL present) TarGOST® thresholds.

3.2.1.2 Nonaqueous-Phase Liquid Occurrence and Probability

The TarGOST® data provide representative coverage over the FFS Project Area, but they do not conform to a regular statistical distribution, leading to challenges in depicting kriging results. A probabilistic approach was applied to the TarGOST® dataset to address uncertainties inherent in depicting the distribution of NAPL and to evaluate spatial variability. Using this approach, the likelihood of encountering NAPL at a given location was determined based on kriging and spatial variability analysis methods described in Isaaks and Srivastava (1989). The kriging results only indicate whether NAPL is present at a given location and do not account for the intensity of the TarGOST® signal. These estimates do not represent the actual volume of NAPL impacted sediment or indicate whether NAPL may or may not be contiguous between detected locations.

Figure 3-6 presents a plan view depiction showing the likelihood that NAPL would be present at levels of 10 and 90 percent probability. The 90 percent probability level represents the highest degree of certainty that NAPL would be present with a relatively low potential for nondetects. The 90 percent probability areas are near known or suspected sources of historical contamination associated with the former Wyckoff wood treatment facility. The 10 percent probability level shows a much smaller area over which NAPL could be present, but with a higher degree of uncertainty. The 50 percent probability is an intermediate case depicting a moderate degree of lateral continuity from kriging (**Figure 3-7**).

Representative cross-sections are presented for North Shoal and East Beach on **Figures 3-8**, **3-9**, and **3-10**, respectively, for the 50 percent NAPL probability distribution. In addition, **Figure 3-11** presents the estimated percent distribution of NAPL probability occurrences between various tidal elevation intervals. The probability of encountering NAPL is highest between the LOT elevation of -5.0 feet MLLW and the MLW elevation of 2.8 feet MLLW. The elevation range between about -10 feet (LOT -5 feet) and 2.8 feet (MLW) contains approximately 89 percent of the observed NAPL distribution at the 50 percent probability level (**Figure 3-11**). These elevation intervals include the lower to mid-portions of the tidally affected zone in the FFS Project Area.

3.2.2 Sediment Chemical Quality Trends (Post-Sheet Pile Wall Installation)

Several OU-1 monitoring events were completed following installation of the sheet pile wall around the upland area in 2001. These events were conducted in 2001, 2002-2003, and 2011 and included collecting sediment samples from East Beach and North Shoal for PAH analysis. The complete results are reported in the *East Beach Investigation Report* (EPA and USACE, 2002), *2002–2003 Year 8 Environmental Monitoring Report* (Integral Consulting, 2004), and the *Third Five-Year Review Report* (EPA, 2012a), and the *Final 2011 Year 17 Monitoring Report* (USACE, 2012). EPA's *Third Five-Year Review Report* (2012) summarized and compared sediment sample testing results from the 2002-2003 and 2011 monitoring events. CH2M HILL completed additional review of the analytical data from sediment monitoring, as presented in Appendix D (CH2M HILL, 2013d) and summarized below.

CH2M HILL's review of sediment monitoring data compared PAH analytical results against the cleanup goals established in the 1994 ROD, including Sediment Quality Standards (SQS) for protection of benthic organisms. The SQS are listed in the Washington State Sediment Management Standards (SMS; WAC 173-204) and represent chemical concentrations that pose no adverse effect on biological resources and correspond to no significant health risk to humans (Washington Administrative Code [WAC] 173-204-300, last updated 2013). For samples with TOC concentrations at or exceeding 0.5 percent, the data were organic carbon normalized and screened against Ecology's SQS. For sediment samples with TOC less than 0.5 percent, the dry weight PAH data were screened against the Apparent Effects Threshold (AET) values for each PAH compound. Using the AET criteria for samples with TOC concentrations outside the 0.5 to 3.5 percent range is consistent with Ecology's current practice and guidance (Ecology, 2015). The 1994 ROD also specified a sediment-based human health objective of 1,200 micrograms per kilogram (µg/kg) (dry weight) for HPAHs that was based on the 90th percentile of background Puget Sound subtidal sediments.

Review of the sediment quality data indicates that PAH concentrations generally declined in surface sediment samples between the 2002-2003 monitoring event and the 2011 event. Concentrations of naphthalene, LPAHs, and HPAHs were substantially lower at 11 of the 21 surface locations sampled during the 2011 event. At other locations, some parameter concentrations decreased but others increased. Regardless, concentrations of indicator parameters detected during the 2011 event were consistently below their associated AETs except at one North Shoal location. Naphthalene concentrations ranged up to 2,000 µg/kg dry weight in one North Shoal sample, with LPAH and HPAH concentrations ranging up to 4,435 and 9,094 µg/kg dry weight, respectively, in the same sample. HPAH concentrations were in the 1,000 to 5,000 µg/kg dry weight range in several other samples.

Elevated concentrations of PAHs in several of the 2011 samples collected at deeper intervals up to about 2 feet below the mudline indicated impacts with AET criteria exceeded at two locations. Naphthalene concentrations ranged up to 3,700 µg/kg dry weight in one East Beach sample, with LPAH and HPAH concentrations ranging up to 16,630 and 62,720 µg/kg dry weight, respectively, in the same sample. HPAH concentrations ranged up to about 31,000 µg/kg dry weight in several other samples. The sampling density for the deeper intervals was sparser during the 2011 event than in previous events.

General declines in PAH concentrations from East Beach and North Shoal samples indicate that natural recovery is occurring, likely through physical "washout" of near-surface NAPL sheen and entrained contaminants from wave and tidal action, winnowing and redistribution of the uppermost beach sediments from long-shore coastal transport, and aerobic biodegradation in the uppermost sediment horizon. As shown on **Figure 3-12**, sediment samples collected in 2011 at two North Shoal locations and at four East Beach locations contained PAH concentrations exceeding SQS and/or the 1994 ROD human health criteria. **Appendix D** discusses of the sediment quality monitoring data results in detail.

3.2.3 2012 Solid Phase Micro-Extraction Analytical Results

Laboratory analytical testing results for the SPME samples deployed in late 2013 are presented in **Table 3-1**, and results for total PAHs summarized on **Figure 3-13**. Results are reported for 54 SPME pore water samples collected at six discrete depth intervals between 3 centimeters and 27 centimeters below the mudline at each sampling location. Results also include 24 SPME surface water samples collected at six discrete water column intervals between 3 and 27 centimeters above the mudline at each sampling location. Adjacent sample pairs at the pore water and surface water sampler deployment locations served as field duplicates.

Concentrations of dissolved PAHs were calculated in accordance with the project QAPP (CH2M HILL, 2013a) and EPA's *Guidelines for Using Passive Samplers to Monitor Organic Contaminants at Superfund Sediment Sites* (EPA, 2012b). Additional analytical and quality assurance protocols are described *Technology User's Manual: Demonstration and Evaluation of Solid Phase Microextraction for the Assessment of Bioavailability and Contaminant Mobility* (Reible and Lotufo, 2012). Based on these guidelines, concentrations for specific PAH constituents detected in the SPME sampling media were converted to pore water and surface water PAH concentrations using sampling media-dissolved phase partitioning coefficients. Analytical results were also adjusted to calculate concentrations at equilibrium conditions for the sampling media and pore water or surface water. CH2M HILL's review of the data and quality assurance/quality control samples determined that all data were acceptable without qualification for screening level use as intended. The project QAPP and referenced guidance documents provide further details on analytical protocols and determination of equilibrium concentrations. General findings and data trends from the analytical testing are summarized below.

3.2.3.1 Pore Water Results

Total PAH concentrations in pore water ranged from 347 nanograms per liter (ng/L) in sample PW-B2 (5 to 7 centimeters deep) to 79,949 ng/L in sample PW-C2 (25 to 27 centimeters deep). Concentrations for individual PAH constituents detected ranged from less than 1 ng/L to 8,516 ng/L, except for the deeper sample intervals at pore water location PW-C2. The PW-C2 samples (23- to 25-centimeter and 25- to 27-centimeter depths) had naphthalene pore water concentrations of 26,144 and 79,273 ng/L, respectively.

Naphthalene was the dominant PAH constituent detected at many of the pore water locations, with a wide range of concentrations from about 100 ng/L to nearly 80,000 ng/L. The highest naphthalene concentrations in pore water were detected at North Shoal location PW-A1 (all depths) and PW-B1 (3 to 5 centimeters and 5 to 7 centimeters), and East Beach location PW-C2 (5 to 7 centimeters and below).

Total PAH concentrations exhibited limited variability between different depth intervals at five of the nine pore water sampling locations (PW-A3, PW-B2, PW-B3, PW-C1, and PW-C3). PAH concentrations increased with depth at locations PW-A1, PW-A2, and PW-C2. PAH concentrations decreased with depth somewhat at location PW-B1. For comparison, naphthalene trends tended to mimic total PAHs or tended to be less variable over a narrower range of concentrations.

General factors influencing these trends could include the following:

- **Tidal dilution in shallow subsurface sediments**—Tidal dilution through the entire sampled depth (less than 1 foot below mudline) would tend to homogenize results, as observed in most of the pore water sample locations. Similar trends were observed for all but the deepest sampling intervals at locations PW-A1, PW-A2, and PW-C2.
- **Partitioning of PAHs from nearby NAPL to pore water**—Increases in concentrations with depth at locations PW-A1, PW-A2, and PW-C2 could conceivably be affected by underlying NAPL as a source of PAHs to the dissolved phase. Locations PW-A1 and PW-A2 are near an active seep on the North Shoal, including one of the seeps noted in June 2012.
- **Sheening on falling surface water during receding tide**— Sheening could promote lateral transport of PAHs on the tidal water surface water film, causing contamination from the top down rather than below. An increase in total PAH concentrations was noted in the shallowest sample (3- to 5-centimeter depth) at location PW-B1, although this location is not near an area where sheening was observed.

Relatively low concentrations of detected PAHs in many samples could be further influenced from a variety of short-term sources, such as oil and gas from local vessel traffic, making definitive source conclusions difficult. Contamination from external sources could float in with rising tide, affecting SPME results from the bottom up. Conversely, external sampling sources could affect sampling intervals from the top down during a falling tide.

As a preliminary screening comparison, benzo[a]anthracene and chrysene marginally exceeded applicable surface water quality criteria, based on Clean Water Act Section 304 Human Health Criteria for Consumption of Organisms as follows (**Figure 3-13**):

- Benzo[a]anthracene in deeper sampling intervals 23 to 25 centimeters and 25 to 27 centimeters at locations PW-A1 and PW-A2, and in the 25 to 27 centimeters interval at PW-B2.
- Chrysene in the 25- to 27-centimeter intervals at BW-A2 and PW-B2.

No exceedances were noted in any of the shallower sampling intervals, including the uppermost sample at 3- to 5-centimeter depth near the interface with surface water at the beach surface. No exceedances of comparative criteria listed in **Table 3-1** for naphthalene or other PAH constituents were observed in any of the other pore water samples at any depth.

3.2.3.2 Surface Water Results

Total PAH concentrations for SPME surface water samples were comparatively consistent between different sampling intervals and between locations. Total PAH concentrations in surface water ranged from 293 ng/L in sample SW-C (3 to 5 centimeters above the sediment surface) to 522 ng/L in the sample SW-D (23 to 25 centimeters above the sediment surface).

As observed in the pore water samples, naphthalene was the dominant PAH constituent in surface water samples, ranging in concentration from 258 ng/L in sample SW-C (3 to 5 centimeters above the sediment surface) to 505 ng/L in sample SW-D (23 to 25 centimeters above the sediment surface), with fairly even distribution. PAH concentrations in surface water were well below comparative water quality screening criteria.

As for many of the SPME pore water samples, the surface water samples contain relatively low concentrations of PAHs that could be influenced by a variety of short-term sources such as vessel traffic, making definitive source conclusions difficult.

3.2.4 Shellfish Tissue Polycyclic Aromatic Hydrocarbon Testing Results

Figure 3-14 identifies clam collection locations for tissue sampling from the 2003 and 2011 sampling events (USACE, 2012; Integral, 2004). The 2003 samples included horse clams (*T. capax*) from North Shoal locations, and butter clams (*Saxidomus gigantean*) and horse clams (*T. capax*) from the East Beach locations. The 2011 samples included horse clams (*T. capax*) from all locations including North Shoal, East Beach, and one intertidal location at the northwestern edge of North Shoal.

The USACE concluded that quantitation limit for the 2003 study precluded direct comparison of PAH concentrations between the 2003 and 2011 sampling events. PAHs were undetected in all samples from the 2003 event, with a few detected PAH values less than the quantitation limit.

For the 2011 sampling event, analytical results for PAH constituents and total PAHs were reported as micrograms per kilogram wet weight (µg/kg-w) and as lipid-normalized milligrams per kilogram wet weight (mg/kg-w). The USACE reported the following results:

- Total PAH concentrations ranging from 38.31 to 86.41 µg/kg-w, including nondetects at the reporting limit value
- Lipid-normalized PAH values ranged from 7.09 to 16.3 mg/kg-w
- Total carcinogenic PAH (CPAH) concentrations expressed as toxicity equivalency quotient (TEQ) values ranged from 2.98 to 5.64 µg-TEQ/kg-w. For CPAH constituents with nondetect results, a concentration equal to one-half of the reporting limit was used to calculate the total CPAH TEQ concentration.

The USACE further reported that a comparison of CPAH results with the lipid fraction found no correlation, but the clams were reportedly not collected at their maximum lipid content.

The USACE also reported numerous holes with “contamination present,” including NAPL at one location in the western part of North Shoal. The two locations towards the northern portion of East Beach had lesser sheens than observed at the North Shoal locations with no NAPL observed.

EPA, the Suquamish Tribe, USACE, and Ecology completed additional shellfish sampling on May 16, 2014, to collect horse clams (*T. capax*) for PAH tissue testing. Analytical testing results are presented in *Clam Tissue Collection Report Wyckoff/Eagle Harbor Superfund Site EPA ID: WAD009248295* (USACE, 2015).

3.3 Nonaqueous-Phase Liquid Fate and Transport Processes

This section first describes the different types of forces affecting NAPL movement in a subsurface environment. The forces are described with respect to dense, light, and neutrally buoyant NAPL. The different mechanisms by which NAPL may be exposed at the sediment or water surface are also described in this section.

3.3.1 Forces Acting Upon Nonaqueous-Phase Liquid

The theory and equations describing NAPL fate and transport in saturated sediment have been developed based on the *DNAPL Site Evaluation* (EPA, 1993). Subsurface NAPL in the saturated zone is acted upon by three forces:

- **Gravity**—The buoyancy difference between the water and NAPL can create a directional force for migration. DNAPL will move downward, and an upward force would influence LNAPL migration. In the case of neutrally buoyant NAPL, there is no buoyancy difference between water and NAPL, and gravity is not a driving force for migration.
- **Capillary pressure—**The capillary pressure holding the wetting fluid (water) within soil or sediment pore spaces must be overcome for NAPL (nonwetting fluid) migration to occur. Where present, LNAPL rests on top of the water table, resulting in a three-phase system (air, water, and LNAPL). Changes in capillary pressure gradients are the primary mechanism for lateral LNAPL migration (American Petroleum Institute, 2007).
- **Hydrodynamic pressure**—Groundwater movement through NAPL zones creates a hydrodynamic force that can influence the migration of NAPL. Hydrodynamic pressure is usually minor compared with the force of gravity or capillary pressure for the movement of DNAPL or neutrally buoyant NAPL. Hydrodynamic forces do contribute to LNAPL migration.

Tidal effects, wave action, and the interaction of NAPL with saltwater are other key factors affecting NAPL migration in the OU-1 FFS. Saltwater has a greater density than freshwater; therefore, freshwater discharge from the upland can affect gravitational forces on neutrally buoyant NAPL and DNAPL.

3.3.2 Nonaqueous-Phase Liquid Transport Mechanisms

This subsection further describes the transport mechanisms commonly responsible for NAPL movement.

3.3.2.1 Nonaqueous-Phase Liquid Migration due to Groundwater Advection and Buoyancy

NAPL migration due to groundwater advection occurs when hydrodynamic forces from upward moving groundwater exceeds the gravity and capillary force of NAPL. Where the specific gravity of NAPL is near that of the surrounding groundwater, a smaller upward hydraulic gradient is needed for NAPL migration. The intertidal area is also subject to transient groundwater gradients during the tidal cycle. Generalized numerical simulations of tide-induced seawater-groundwater circulation in shallow-beach aquifers, presented by Li et al. (2008), demonstrate that the maximum Darcy velocity occurs at the intersection of the water table and the beach surface at ebb tide. Nearshore beach groundwater is almost stagnant compared with onshore groundwater flow. This tidal exchange cycle results in filling and draining of the interstitial water in the sediments between high and low tide elevations.

3.3.2.2 Seep Migration

A NAPL seep is defined as a discharge where the NAPL saturations are above residual (i.e., disconnected, immobile globules within larger pore spaces) and a NAPL-wetted pathway exists or where NAPL can move under a sustained gradient and overcome the capillary forces of water-wetted sediment. A NAPL gradient provides the driving force for NAPL discharge and seeps are typically associated with a recent or ongoing NAPL release is typically associated with seep discharges.

NAPL seeps can more readily migrate through previously impacted sediments where NAPL is the wetting fluid (Cohen and Mercer, 1993). NAPL migrates when the NAPL head pressure exceeds the pore entry capillary pressure of the groundwater. Once the NAPL displaces the water, it can become the new wetting phase, allowing NAPL migration to previously unaffected areas. Once established through current or historical seep migration, NAPL-wetted pathways can become preferential pathways or sustained conduits for continued NAPL migration because entry pressure inhibiting migration are no longer present and NAPL movement can be initiated by lower head pressures. The NAPL may manifest as seeps or sheens. This seep migration process appears to be locally active in the FFS Project Area, although prevalence of NAPL product seeps has diminished substantially since the sheet pile wall was completed in 2001.

3.3.2.3 Sheen Migration

NAPL sheen occurs when NAPL is released along the air-water surface. NAPL sheens migrate by surface tension differentials that result in the spreading on the water surface (Sale, 2011, personal communication). In subsurface sediments, NAPL spreads on the groundwater surface in the same manner as sheening on exposed surface water, and NAPL sheen can spontaneously enter water-coated, air-filled pores through capillary forces. Interfacial tension measurements from NAPL samples collected from upland extraction wells indicate that a positive spreading coefficient and spontaneous sheening is predicted to occur as NAPL moves from an oil-water system (two-phase) to an oil-water-air system (three-phase). Once formed, sheen can migrate laterally along water table and discharge where the water table intersects with surface water. With each tidal cycle, sheen migration can continue to create NAPL discharges considerable distances from the actual NAPL-impacted sediment. This sheening process appears to be active in the OU-1 intertidal area.

3.3.2.4 Ebullition

Ebullition is the production of gas due to anaerobic biological activity in sediment. Mineralization of organic matter in sediment by bacteria generates methane, nitrogen, carbon dioxide, and other gases. The bubbles produced during ebullition tend to accumulate hydrophobic contaminants and colloids, such as NAPL sheen, on their surfaces. When the gas bubbles migrate upwards through the water column, this NAPL can travel out of the sediment and manifest on the water surface as a sheen. The degree to which ebullition affects NAPL migration in the intertidal area of the Wyckoff Site is unknown, although observation of ebullition has not been reported. Given the dynamic exchange of seawater during the tidal cycle, evidence of ebullition may be difficult to observe (Viana et al., 2007a and 2007b; Reible, 2004).

3.4 Conceptual Site Model

This section presents a CSM describing the Site-specific features and physical processes that influence the potential exposure pathways for NAPL within the FFS Project Area. The CSM was developed based on the currently available Site information and the estimated extent of NAPL. The CSM describes the predominant forces affecting NAPL migration prior to and after implementing upland source control removal actions and hydraulic controls and installing the sheet pile wall between the upland and nearshore areas. This CSM is used as the basis for developing and evaluating the remedial alternatives.

3.4.1 Conditions Prior to Remedial Actions

The NAPL fate and transport mechanisms that occurred prior to installation of the sheet pile wall and source control measures are illustrated in **Figure 3-15**. The left of the figure illustrates the following:

- NAPL releases from upland operations migrated downward through the vadose zone into the saturated zone of the upper aquifer located within fill and marine sediments comprising upland soils.
- NAPL reaching the water table must overcome the entry pressure of the water in the lower formation to continue to migrate vertically.
- Much of the NAPL in the upland area migrated horizontally along water table or in shallow groundwater and was the likely the primary NAPL transport mechanism to OU-1.
- Some NAPL in upland area has migrated to the aquitard and along the stratigraphic gradient into OU-1
- NAPL releases directly to the intertidal area have also been documented. These releases would have been controlled by the saturated zone transport mechanisms described above.

The right side of **Figure 3-15** illustrates the fate and transport of NAPL in context of the freshwater discharge from the upland area to the saltwater intertidal environment throughout the tidal cycle. The conceptualized tidal exchange cycle was adapted from “Tidal Effects on Ground Water Discharge through a Sandy Marine Beach” (Urish and McKenna, 2004). NAPL fate and transport is summarized in context of the four primary tidal stages—high, ebb, low, and flood tide—that are described as follows:

- **High tide—**Groundwater (freshwater) discharge was suspended, and the hydraulic gradient is influenced by inundation of the shallow subsurface with tidal saltwater. The saltwater infiltrated into beach sediments, generally overriding and mixing with shallow fresh groundwater.
- **Ebb tide—**The hydraulic gradient reversed and groundwater flow moved seaward as discharge began. Tidal seeps from bank storage water begin to appear.
- **Low tide—**Groundwater discharge continued, both as discharge from the exposed beach face and as subaqueous discharge to surface water at lower elevations.
- **Flood tide—**The hydraulic gradient again reversed due to the incoming tide and groundwater discharge ceases.

NAPL migration was driven by strong upland NAPL gradients, because the NAPL pressure head was potentially as high as the original upland source elevation. This situation was observed in the 1980s where NAPL seep discharges were observed over a widespread area of the FFS Project Area. The upland investigations have documented DNAPL that has accumulated on the upper surface of the aquitard hydrostratigraphic unit beyond the wall in several locations. This NAPL could migrate along the stratigraphic gradient. The 2012 OU-1 TarGOST® borings did not indicate prevalent NAPL zones below about 20 to 25 feet depth, suggesting that deeper DNAPL, if present, has limited potential for vertical migration. The TarGOST® data also indicate little, if any, downward migration of the shallower LNAPL and neutrally buoyant NAPL.

3.4.2 Current Conditions

The sheet pile wall acts as a physical and hydraulic barrier between the upland and the OU-1 and restricts large-scale hydraulic flux and NAPL migration into the intertidal area. The upland groundwater pump-and-treat system also provides hydraulic containment. The NAPL remaining in the subsurface of the OU-1 intertidal zone is dominantly product that either migrated from the upland prior to implementation of upland remedial measures and sheet pile wall installation or is remnant from historical spills in the intertidal zone. The fate and transport of this stranded NAPL is controlled by hydraulic forces and physical properties (i.e., buoyancy and the capillary pressures of the NAPL impacted media). NAPL fate and transport mechanisms under current conditions are presented in **Figure 3-16**.

The sheet pile wall effectiveness evaluation (CH2M HILL, 2013b) did note that the presence of NAPL observed in the sheet pile wall seam channels suggests that localized, small-scale NAPL migration through the seams is possible. This limited NAPL migration is not expected to alter substantially the quantity or distribution of NAPL in the intertidal area. However, NAPL migration pathways through the sheet pile wall could provide the NAPL head needed for small NAPL seep releases in OU-1 to persist. Seawater is now expected to infiltrate the intertidal sediments to the sheet pile wall.

Two-dimensional groundwater modeling characterizing the presence of the sheet pile wall indicated the steady state gradient is very small from the deeper aquitard into the upper aquifer of intertidal zone (CH2M HILL, 2004). Additional modeling conducted by CH2M HILL for the OU-1 FFS further characterized predicted gradient changes over a typical tidal cycle (**Figures 3-2** and **3-3**, and Appendix B). The predicted upward hydraulic gradient, shown on the left side block of **Figure 3-16**, may be sufficient to mobilize NAPL toward the active tidal zone. Also, seawater (i.e., saline) has a higher density than freshwater, creating greater potential for upward NAPL movement due to buoyancy differences in the intertidal zone following construction of the sheet pile wall.

3.4.3 Nonaqueous-Phase Liquid Fate and Transport in Operable Unit 1

The following pathways are the NAPL transport mechanisms for NAPL affecting the beach surface at the Wyckoff FFS Project Area, both historically and under current conditions:

- **Seep migration—**Historical NAPL seeps were noted at many locations in previous investigations before the sheet pile wall was installed; observations of the seeps decreased following sheet pile wall installation. Seep migration is likely still active in some locations. Field observations in 2011, 2012, and 2013 identified limited occurrences of near-surface product in shallow core samples, hand-dug holes, and product seeps on the beach face (USACE, 2012; CH2M HILL, 2013e). The most recent product seeps observed during low tide Site visits in June 2013 and May 2014 are identified on **Figure 3-13**. In 2012, elevated TarGOST® readings of up to approximately 250%RE were observed at depths of less than 2 feet at five East Beach locations and two North Shoal locations. The magnitude of these readings may represent shallow, mobile NAPL zones that could contribute to product seeps. Active seep migration may still be occurring to the beach face, although pure product blebs appear to dilute quickly upon contact with surface water and beach exposure.
- **Sheen migration—**Groundwater contacting NAPL during the tidal cycle can create sheen on the falling groundwater table during the ebb tide. Sheens generated in this manner can migrate on the groundwater table or across the tide flat considerable distances from NAPL product sources closer to shore. During 2012 low tide field visits, CH2M HILL observed NAPL sheens at locations along the East Beach and North Shoal between about 0 and 2 feet elevation MLLW (CH2M HILL, 2013e). The prevalence and intensity of the sheening varied with tidal stage and was typically most pronounced as the outgoing tide exposed the elevations noted, the sheening dissipated somewhat as discharge from tidal bank storage diminished. Tidal flux is likely the primary factor controlling the intertidal sheening and this transport mechanism is active at elevations between low and high tide where an air-water interface is present.
- **Groundwater advection and NAPL buoyancy—**Upward hydraulic gradients in the intertidal area coupled with the increased groundwater density (due to seawater infiltration to the sheet pile wall) can alter the density gradient and move the NAPL upward. In many locations, sediment is likely NAPL wetted from previous head-driven NAPL seeps from the upland. NAPL wetted sediment have low (or zero) capillary pressure to overcome for upward migration.

Tidal exchange plays an important role in controlling the fate and transport of NAPL within the intertidal area. The transient groundwater gradient is much greater than the steady state gradient. During the ebb tide, the transient gradient likely forces NAPL upward along a historical seep pathway with or without a NAPL head driving the migration.

The beach topography and tidal cycle create a large discharge area for groundwater during the ebb tide. If groundwater contacts NAPL during the flood tide, then the discharge areas associated with this groundwater could present NAPL sheen.

SECTION 4

Remedial Action Objectives

This section presents the remedial action objectives (RAOs) and preliminary remediation goals (PRGs) for the Wyckoff OU-1 FFS Project Area. This information is used to define the area where remedial action will be performed, and to guide the technology screening (Section 5) and assembly of remedial action alternatives (Section 6).

4.1 Basis for Action

The NCP defines the acceptable risk range for Superfund sites as an excess lifetime cancer risk for an individual ranging from 1 in 10,000 (10^{-4}) to 1 in 1 million (10^{-6}). This represents the incremental (beyond cancers expected from other causes) chance of developing cancer because of exposure to site-related carcinogenic contaminants. Noncancer effects are evaluated by calculating the ratio between the estimated intake of a contaminant and its corresponding reference dose (the intake level at which no adverse health effects are expected to occur). If this ratio, called a hazard index (HI), is less than 1, noncancer health effects are not expected to be present at the Site. A HI greater than 1 suggests the potential for adverse effects may occur, especially in sensitive subpopulations.

Key findings from the earlier risk assessments that evaluated site risks associated with actual or threatened releases of hazardous substances to OU-1 sediments are briefly summarized below.

4.1.1 Human Health Risks

Historical human health risk assessment (HHRA) data are summarized below. A HHRA that incorporates updated PAH toxicity factors and other exposure assumptions including Tribal shellfish consumption rates revealed excess lifetime cancer risks exceeding the upper bound of the CERCLA 1 x 10^{-6} to 1 x 10^{-4} risk range. Alternatively, PRGs associated with the shellfish consumption exposure pathway are developed based on natural background PAH concentrations in sediment, as discussed in Section 4.4. EPA will also develop risk-based criteria for dermal contact and incidental ingestion of contaminated sediments for inclusion in the Proposed Plan.

4.1.1.1 1991 Human Health Risk Assessment

A baseline HHRA was conducted in 1991 to evaluate the potential human health risks for both the OU-2, OU-4, and adjacent intertidal sediments if no remedial action was performed. Results of the HHRA are summarized in the 2000 ROD for OU-2 and OU-4 (EPA, 2000a). The complete Eagle Harbor risk assessments can be found in the Site's Administrative Record. The HHRA identified and characterized the toxicity of chemicals of potential concern, possible exposure pathways, potential human receptors, and the associated potential human health risks at the Site. Risks were evaluated for cancer-causing and noncancer-causing toxic effects.

Chemicals evaluated in the 1991 HHRA included 3 SVOCs, 12 PAHs, 2 nitrogen-containing aromatic compounds, 2 volatile organic compounds (VOCs), and 10 metals. Three exposure scenarios were used to complete the risk assessment, including ingestion of clams based on assumed consumption rates at that time, ingestion of intertidal sediments, and dermal contact with intertidal sediments. Calculated noncancer HIs for dermal exposure using reasonable maximum exposure concentrations did not exceed the threshold of 1. Cancer risk for dermal contact was not calculated because dermal toxicity values were not available to quantify risks. Cancer risks for PAHs from ingestion of clams based on a reasonable maximum exposure scenario ranged from 1 x 10^{-3} to 8 x 10^{-4}. Cancer risks for PAHs from ingestion of sediments based on a reasonable maximum exposure scenario ranged from 1 x 10^{-5} to 6 x 10^{-6}.

4.1.2 Ecological Risks

As summarized in EPA's 2000 ROD for OU-2 and OU-4, an ecological assessment of the marine area adjacent to OU-2 was conducted as part of the Eagle Harbor risk assessment (complete risk assessments can be found in Administrative Record). Adverse biological effects were documented in much of the East Harbor. Most of the biological effects previously observed were associated with sediment contamination near the former Wyckoff facility. The risk assessments concluded that unacceptable risks existed in the intertidal and subtidal areas for a wide variety of animals and that these problems were largely a result of releases from the Wyckoff Site. In samples obtained from the eastern portion of Eagle Harbor, closest to the Wyckoff facility, sediments exceeded applicable 1988 Puget Sound benthic AETs for at least two PAHs at numerous stations. At several locations, all 16 PAH compounds exceeded their benthic AETs. Based on the comparison of the concentrations in Eagle Harbor samples with the 1988 benthic AETs for Puget Sound, EPA selected mercury and 16 PAHs as COCs in OU-1. As stated previously, the source of PAHs to East Harbor is believed to be primarily releases from the Wyckoff facility. The source of mercury may not be related to the Wyckoff facility but shipbuilding activities conducted in OU-3 or a Puget Sound anthropogenic sources.

Bioassays conducted for acute toxicity indicated that sediments from many sampled locations in the East Harbor were toxic to amphipods, oyster larvae, or both. The bioassay responses were most severe in the areas of high PAH contamination, such as areas of the East Harbor north of the Wyckoff facility. Other studies conducted in the East Harbor suggested that, while sediment contamination is present above the benthic AET for large areas of the harbor, adverse effects on benthic communities at the level of major taxa (polycheata, mollusks, and crustaceans) may not be occurring except in more heavily PAH-contaminated areas close to the Wyckoff facility.

4.2 Proposed Remedial Action Objectives

A RAO describes what a remedy is expected to accomplish by media and identifies site-specific goals for protecting human health and the environment. They provide a basis for evaluating the ability of a specific remedial alternative to achieve compliance with potential ARARs and to meet the target risk thresholds per the NCP (Code of Federal Regulations [CFR], Title 40, Part 300), Section 430(e)(2)(i), Remedial Investigation/Feasibility Study and Selection of Remedy, and CERCLA RI/FS guidance (EPA/540/G-89/004).

Remedial action to address NAPL contaminated sediment in the FFS Project Area is required to reduce unacceptable risks. These risks include direct exposure to NAPL, direct exposure to and/or ingestion of contaminated sediments, and consumption of contaminated marine shellfish. As described in Section 2, historical NAPL releases from the former Wyckoff facility consisted of creosote product, PCP, and/or aromatic carrier oils (e.g. diesel). The primary COCs for the FFS Project Area include PAHs, which are associated with mobile and immobile NAPL, and PCP. PAHs and PCP are also present in the dissolved phase in sediment pore water and groundwater that upwells through the sediment. Other SVOC constituents, including heterocyclic aromatic hydrocarbons (dibenzofuran, carbazole, and methylnaphthalene), are collocated with NAPL and PAH constituents.

The source of contamination is LNAPL and neutral-buoyancy NAPL remaining in subsurface sediments in the intertidal zone, to depths of about 20 feet below the beach surface, following construction of the sheet pile wall around the upland. The primary human health exposure pathways within the FFS Project Area are direct contact with NAPL present on the beach surface and in the intertidal sediments, and ingestion of potentially contaminated shellfish tissue. The primary ecological exposure pathways are direct contact with NAPL and NAPL contaminated sediment and PAH uptake through sediment and pore water.

Based on these receptors and exposure pathways, the following RAOs were developed for the FFS Project Area:

- **RAO 1—Prevent risk to human health posed by direct contact with NAPL in surface sediments (defined as the top 10 centimeters) of intertidal beach areas.** Once this RAO is achieved, the beaches could be opened for limited recreational use (with no shellfish collection) until such time as the other RAOs are achieved.

Meeting RAO 1 would require visual monitoring of the beaches on low tides during daylight hours. RAO1 would be met when no NAPL is observed during three consecutive annual low tide inspections. EPA expects this RAO could be met within 3 years after initial construction, but if additional seeps appear post construction, additional focused cleanup actions and MNR may be needed.

- **RAO 2—Reduce to protective levels the risk to human health posed by dermal contact and incidental ingestion of contaminated sediments in the top 2 feet of intertidal areas that provide habitat for shellfish.** Meeting this RAO will ensure that people can collect shellfish safely.

  COC concentrations in surface sediments are expected to be at or below levels protective of recreational beach users soon after construction of the selected remedy, but a period of MNR may be required to achieve protective concentrations to a depth of 2 feet, which is the depth to which shellfish harvesters may be exposed. RAO 2 would be met when the average COC concentrations in the top 2 feet of sediment in North Shoal and East Beach do not exceed cleanup levels that are based on direct contact during clamming or beach play.

- **RAO 3—Reduce levels of COCs in the top 10 centimeters of sediments to concentrations that protect benthic community health.** Meeting this RAO will protect worms, clams, and other sediment-dwelling organisms.

  This RAO would be met when point-by-point COC concentrations in the upper 10 centimeters of the sediment horizon do not exceed the remedial goals defined in the CERCLA decision document.

- **RAO 4—Reduce levels of COCs in shellfish tissue to concentrations that protect Tribal shellfish consumers.** This RAO will be met through the removal of contaminated sediments, capping, and MNR. Contaminant concentrations in shellfish tissue are expected to decline over time in response to lowered exposure concentrations.

  This RAO would be met when the average COC concentrations in the edible tissue of horse clams collected from the intertidal area are at or below levels protective of Tribal shellfish consumers. If this RAO cannot be achieved or cannot be achieved for all COCs, then the RAO will be met when the sitewide average concentration of COCs in the upper 2 feet of sediment does not exceed the sediment background concentration. Horse clams have been selected as the target species for this RAO because of the following:

  - The cleanup area is small relative to the home range of most fish species, so clams are more highly exposed than fish to PAHs in the cleanup area.
  - Clams do not metabolize PAHs as readily as fish, and are therefore more likely accumulate PAHs in their tissues.
  - Horse clams occur on all the beaches at the Site, occur in sufficient numbers to support regular collection for monitoring, and are a highly targeted species for collection.

  Post-construction monitoring will include monitoring the concentration of PAHs in horse clam tissue as well as sediment and pore water.

- **RAO 5—Prevent risks from consumption of shellfish until protective levels are achieved.**

  Institutional controls including consumption advisories or beach closures, as appropriate, will be used to prevent exposure until protective levels are achieved.

4.3 Potential Applicable or Relevant and Appropriate Requirements and To-Be-Considered Criteria

The ARARs evaluation prepared for the Wyckoff OU-1 FFS was conducted in accordance with the NCP as described in 40 CFR 300.430, *Remedial Investigation/Feasibility Study and Selection of Remedy*. Under CERCLA, ARARs consist of two sets of requirements: (1) those promulgated substantive standards that would be applicable requirements if the remediation were not being conducted under authority of CERCLA (CERCLA response actions are exempt from permitting requirements by authority of Section 121[e][1]); and (2) those substantive standards that are relevant and appropriate requirements of promulgated environmental regulations. CERCLA also provides for the identification of to-be-considered (TBC) standards, which are not legally enforceable and are not ARARs.

Only the substantive requirements (e.g., use of control/containment equipment or compliance with numerical standards) associated with ARARs apply to CERCLA onsite activities. According to CERCLA, Section 121(e)(1), Permits and Enforcement, administrative and procedural requirements of a regulation, such as permitting and enforcement, are not applicable to CERCLA onsite activities. In general, the CERCLA permitting exemption will be extended to all remedial activities conducted in the FFS Project Area.

ARAR and TBC elements include the following:

- Applicable requirements are substantive standards that specifically address the situation at a CERCLA site and would legally apply to remedial actions in the absence of CERCLA authority. All jurisdictional prerequisites of the requirement must be met in order for the requirement to be applicable, including specific application to federal agencies (e.g., through a waiver of federal sovereign immunity).
- "Relevant and appropriate" requirements mean those environmental requirements such as cleanup standards that address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well-suited to the particular site [40 CFR 300.400(g)(2)]. A requirement that is relevant and appropriate may not meet one or more jurisdictional prerequisites for applicability but still make sense at the site, given the circumstances of the site and the release.
- TBC criteria are advisories, criteria, or guidance developed by EPA, other federal agencies, or states that may be useful in developing CERCLA remedies. They are neither promulgated nor enforceable; however, they may be useful for determining protectiveness or how a remedial action could be performed.

To qualify as an ARAR under CERCLA and the NCP, a state requirement must be the following:

1. A standard, requirement, criterion, or limitation under a state environmental or facility citing law;
2. Promulgated (of general applicability and legally enforceable);
3. Substantive (not procedural or administrative);
4. More stringent than the federal requirement;
5. Identified by the state in a timely manner; and
6. Consistently applied.

Another factor in identifying the requirements that must be addressed by remedial alternatives is whether the requirement is substantive or administrative. Onsite CERCLA response actions must comply with the substantive but not the administrative requirements of environmental laws and regulations. Substantive requirements are those pertaining directly to actions or conditions in the environment. Administrative requirements are mechanisms that facilitate the implementation of the substantive requirements of an environmental law or regulation. In general, administrative requirements prescribe methods and procedures (e.g., fees, permitting, inspections, reporting requirements) by which substantive requirements are made effective for a particular environmental or public health program. Offsite actions must comply with all legally applicable requirements, both substantive and administrative. Specifically, the onsite components of the developed remedial alternatives are evaluated for the OU-1 FFS on the basis of whether they can be designed to meet substantive requirements.

ARARs are identified by three types: chemical-specific, action-specific, and location-specific. **Table 4-1** provides the ARARs and TBCs that may apply to remedial actions in FFS Project Area. Chemical-specific ARARs include laws and requirements that define health- or risk-based numerical values or methodologies applied to site-specific conditions that can be used to establish remediation goals. Many potential ARARs associated with specific remedial actions (i.e., discharges are also characterized as action-specific requirements. Action-specific ARARs apply to specific types of action or technologies under consideration, including features of the selected remedial design; outcomes, consultations, and reviews that specify additional actions; and the management of regulated materials and waste. Remedial action alternatives proposed in this FFS may have specific elements that must be designed and approved after the ROD has been finalized. As such, all action-specific ARARs may not be represented in **Table 4-1** For example, if the selected alternative can generate airborne emissions, then the associated air monitoring requirements must be added as needed in the remedial design/removal action work plan that is submitted for approval following remedy selection in the subsequent ROD. Location-specific ARARs are requirements that relate to the geographical position of the site. State and federal laws and regulations that apply to the protection of wetlands, construction in floodplains, and protection of endangered species are examples of location-specific ARARs.

4.4 Preliminary Remediation Goals

A preliminary remediation goal (PRG) represents the allowable COC concentration in an environmental media that is protective of human health and the environment (EPA, 1997). PRGs are typically aligned with chemical-specific ARARs that represent the numerical concentration or range of concentrations that protect a particular receptor(s) from unacceptable exposure. Non-numeric or narrative PRGs may be appropriate for sites that employ containment or engineered barrier technologies or where COCs may pose an adverse aesthetic effect.

4.4.1 Approach

The development of PRGs is an important step in the FFS process. PRGs serve as a benchmark to support technology screening, to define the area and volume of contaminated media to be addressed, and to support the development and evaluation of remedial action alternatives.

This section presents PRGs for the primary COCs that contribute a majority of risk to human health and the environment. Remedial actions that address the primary COCs are expected to address other site-related contaminants because they are co-located. Mercury, which was identified as a COC in the 1994 ROD, has not been identified as a COC for this FFS nor have dioxins/furans. EPA will identify the final COCs and remedial goals (cleanup levels) for OU-1 intertidal sediment in a future CERCLA decision document.

Based on the receptors and exposure pathways described for the RAOs presented in Section 4.2, PRGs are needed for the following:

- Human health exposure to NAPL present in sediment (RAO 1) and COCs present in sediment (RAO 2).
- Benthic invertebrate exposure to COCs present in sediment (RAO 3).
- Tribal and public exposure to COCs present in shellfish tissue (RAO 4).

PRGs are not necessary for RAO 5 because they would be the same as defined for RAO 4.

The 1994 ROD identified a sediment cleanup level for HPAHs of 1,200 µg/kg (dry weight). This cleanup level corresponded to the 90th percentile, Puget Sound subtidal sediment background HPAH concentration.

Since issuing the 1994 ROD, Ecology has developed risk-based concentrations for a range of exposure scenarios and environmental media. These risk-based concentrations are defined in the Model Toxics

Control Action (MTCA) under WAC 173-340-700 and in SMS under WAC 173-204. Based on the RAOs presented in Section 4.2, and the risk-based concentrations specified in Ecology MTCA and SMS regulations, the narrative and numerical PRGs for intertidal sediments include the following:

1. **RAO 1**. No visible NAPL.
2. **RAO 2**. MTCA Method B soil concentrations for unrestricted use (**Table 4-2**). These concentrations are based on residential exposure to contaminated surface soil; therefore, they would be protective for recreational exposure to contaminated sediments because recreational exposure would occur at a much lower frequency and duration. For example, based on review of the 2015 tide tables, the Wyckoff OU-1 intertidal area above an elevation of 0.0 foot is exposed only 16 days per year and above elevation +2.8 feet for just 60 days. The MTCA Method B residential surface soil risk-based concentrations assume an exposure duration of 350 days per year. Therefore, the concentrations shown in **Table 4-1** could be adjusted upward to reflect a lower exposure frequency and duration. However, because there may be offsetting exposure assumptions, such as greater skin contact in more sensitive areas (e.g. bare feet), no upward adjustment of the residential surface soil PRGs shown in **Table 4-2** is proposed.
3. **RAO 3**. The PRGs for protection of benthic invertebrate exposure shown in **Table 4-1** are derived from the SMS described in WAC 173-204. PRGs based on a TOC concentration of 0.5 percent and were not normalized for site-specific TOC values.
4. **RAO 4**. The primary threat to Tribal and public health associated with ingestion of shellfish tissue is because of the presence of HPAHs. In lieu of specifying a PRG for each individual HPAH constituent, a total HPAH concentration expressed in benzo(a)pyrene (BAP) TEQ of 0.00022 milligrams per kilogram could be used. The BAP TEQ concentration corresponds to the summed concentration for the seven[1] CPAH constituents multiplied by their corresponding toxicity equivalency factor (TEF).

4.5 Remediation Target Area

This FFS was prepared to develop remedial action alternatives that address NAPL. The NAPL present in OU-1 intertidal sediment represents source material because it acts as a reservoir for release of hazardous substances to sediment and surface water. By containing or removing NAPL occurrences, COC concentrations in sediment and surface water will be reduced.

The NAPL present in OU-1 sediment is also characterized as a principal threat waste. Principal threat wastes are those source materials considered highly toxic or highly mobile that generally cannot be reliably contained or would present a significant risk to human health or the environment should exposure occur.

As described in Section 3.2.1, NAPL distribution in sediment was defined based on TarGOST® response thresholds of 10% RE and 50% RE. The 10%RE and greater threshold indicates that NAPL is present, while the 50% RE and greater threshold indicates that the NAPL present may be mobile. Based on these thresholds, and the RAOs defined in Section 4.1, the RTA (**Figure 4-1**) was defined based on the following considerations:

- Areas with TarGOST® readings of 50% RE or higher in the top 3 feet of sediment should be included in the RTA.
- Areas with significant NAPL contamination below a depth of 3 feet should be included in the RTA because they could be a source of contamination to the overlying layers. By including these areas within the RTA, contaminant transport to the surface will be reduced. In defining areas of deeper NAPL contamination, consideration was given to the depth of the NAPL occurrence, thickness of the NAPL layer, and the strength of the TarGOST® %RE response as follows:

[1] Benzo(g,h,i)perylene is also identified as a CPAH. However, because its TEF is zero, it is not included in the BAP equivalent determination.

  - NAPL that occurs at depths between 3 and 5 feet should be included in the RTA if the TarGOST® %RE is greater than 100 or the NAPL has a thickness of 1 foot or more.
  - NAPL that occurs at depths between 5 and 10 feet should be included in the RTA if it has a thickness greater than 1 foot and a %RE greater than 150.
  - NAPL present at depths of 10 feet and greater does not need to be addressed.
- Areas with persistent NAPL seeps at the surface should be capped regardless of the TarGOST® results.
- If a co-located confirmatory sediment core contains NAPL or oil-coated sediment in the top 3 feet, the area should be included in the RTA regardless of the TarGOST® results.
- The likelihood of human exposure should be considered. On East Beach, the area exposed on most days (except during unusually low tides) is a fairly narrow strip next to the sheet pile wall. This factor was used to move some borderline stations (for example, with %RE just barely below 50 in the top 3 feet) into the cleanup area boundary.

In evaluating NAPL occurrence and distribution based on the considerations described above, it was recognized that further characterization during implementation of the selected remedy would increase the confidence that the RTA has been adequately defined. Based on the number and spatial distribution of TarGOST® borings, further characterization on East Beach is not needed. The RTAs are bounded by clean TarGOST® borings (**Figure 4-1**) to provide a clear and well-justified boundary. However, on North Shoal, further characterization is needed to refine the boundaries as shown on **Figure 4-1**.

SECTION 5

Identification and Screening of Remedial Technologies

This section presents the process by which potential remedial technologies for addressing NAPL-contaminated sediment in the OU-1 FFS Project Area are identified and screened. The following three-step process was used:

1. Identify general response actions (GRAs) that could accomplish the RAOs identified in Section 4.0.
2. Establish the process for initial screening of potential remedial technologies and evaluation criteria.
3. Identify and screen potential remedial technologies against the evaluation criteria and in consideration of the nature and extent of contamination and other Site-specific factors.

5.1 General Response Actions

General response actions are media-specific actions that are appropriate for the site conditions, COCs, and RAOs. GRAs may include either individual or combinations of the following:

- No action
- Access restrictions, including institutional controls (ICs) and engineering controls (ECs)
- Containment
- Removal and disposal (onsite and offsite)
- Ex situ treatment
- In situ treatment including natural recovery

Each GRA is briefly described in more detail in the following subsections.

5.1.1 No Action

This GRA is required as a baseline for comparison against other GRAs as specified under the NCP (40 CFR 300.430[e][6]). Under this GRA, no further action is taken at a site. If interim or final actions have been completed or are underway at the time of remedy selection, they are terminated following issuance of the CERCLA decision document.

5.1.2 Access Restrictions

This GRA includes ICs and ECs. Institutional controls are non-engineered measures, such as legal or administrative controls, that help minimize the potential for human exposure to contamination and/or protect the integrity of the remedy. Institutional controls are generally divided into the four general categories (EPA, 2005a):

- **Government controls** include local laws and permits (e.g., zoning, local ordinance, and building permits).
- **Proprietary controls** include property use restrictions based on private property law (e.g., easements and covenants).
- **Enforcement and permit tools** include administrative agreements (e.g., agreed orders and consent decrees) that require individuals or companies to conduct or prohibit specific actions.
- **Informational devices** include deed notices or public advisories (e.g., fish consumption advisories) that alert and educate people about a site.

The NCP emphasizes that ICs are meant to supplement ECs and that ICs will rarely be the sole remedy at a site. The future use of the Site and surrounding area should be considered when developing ICs. Access

The NCP emphasizes that ICs are meant to supplement ECs and that ICs will rarely be the sole remedy at a site. The future use of the Site and surrounding area should be considered when developing ICs. Access restrictions that conflict with Native American usual and accustomed harvest areas will be avoided to the extent practicable.

The Bremerton-Kitsap County Health District continues to maintain a fish and shellfish harvesting closure advisory for the entire area of Eagle Harbor, including the FFS Project Area, due to bacterial and chemical contamination of seafood in the harbor area. Recreational fishing in Eagle Harbor is not advised, and commercial harvest of shellfish near the mouth of Eagle Harbor is prohibited because of chemical contamination and a nearby municipal sewage outfall. The Washington State Department of Health (WDOH) maintains a one meal per week advisory (WDOH - Seafood Eating Advisory) for flatfish harvested from the harbor.

ECs generally include fences and signs to protect against exposure. Signs are posted on fences around the Wyckoff upland area and at several beach locations to warn against harvesting and consumption of contaminated fish and shellfish. In addition, the Washington State Department of Health has recommended limiting consumption of Puget Sound English sole and other flatfish in Eagle Harbor to no more than one meal (8 ounces) per week (WDOH, 2006).

Areas that have been previously capped are currently subject to the restrictions listed in 33 CFR Chapter 1: 165.1309. The restrictions state "All vessels and persons are prohibited from anchoring, dredging, laying cable, dragging, seining, bottom fishing conducting salvage operations, or any other activity which could potentially disturb the seabed in the designated area. Vessels may otherwise transit or navigate this area without reservation."

5.1.3 Containment

Containment technologies include both isolation capping and vertical barriers. Isolation capping (or engineered capping) involves placing a subaqueous cap of clean material over contaminated sediment that remains in place. Caps are generally constructed of naturally occurring granular material, such as clean sediment, sand, or gravel; however, designs that are more complex can include geotextiles, liners, and other permeable or impermeable elements in multiple layers. Engineered caps may also contain amendments to attenuate contaminant flux (e.g., reactive or sorbent layers with organic carbon or oleophilic clays) when COCs warrant chemical as well as physical isolation. Depending on the contaminants and sediment environment, a cap is designed to reduce risk through one or more of the following mechanisms:

- **Physical isolation** of the contaminated sediment by placing a layer of clean material of sufficient thickness to reduce potential for direct contact exposure and to reduce the ability of burrowing organisms to be exposed to or move contaminants to the surface
- **Physical isolation** to prevent erosion and/or transport of contaminated sediment, as well as sufficient protection of the sediment and cap against erosion
- **Chemical isolation of contaminated sediment** to reduce exposure from dissolved and colloidally bound contaminants in the pore water of the biologically active zone and overlying surface water

Caps may be designed with different layers and/or liners to perform these functions, or in some cases, a single layer may serve multiple functions (EPA, 2005b). Cap layers can be designed to achieve specific permeabilities to control groundwater flow, NAPL flux, and migration of other chemical constituents. A cap could also be designed to enhance intertidal habitat and create beneficial shoreline features, such as upper intertidal shelves and perched beach segments. The cap design could also include components such as protective berms and armoring in areas susceptible to wave erosion (e.g., near the existing sheet pile wall). The addition of beach features and erosion protection typically results in thicker caps that could provide additional physical and chemical isolation but potentially at the trade-off of influencing ongoing coastal

Vertical barriers include sheet pile or soil/bentonite walls. These structures can be designed as low permeability (no-flow) or as flow-through structures. No-flow structures isolate areas of contamination to prevent lateral movement. Flow-through structures typically use low permeability segments that funnel contaminants through a treatment gate consisting of reactive material, such as oleophilic clay (OC) or activated carbon (AC). Vertical barriers have been successfully installed at NAPL sites to prevent NAPL movement. Primary design considerations include wall location, embedment depth, composition (i.e., permanence of materials of construction for impermeable structures and adsorption capacity for flow-through systems), installation and/or trenching methods, hydraulic exchange, and long-term performance and maintenance.

Vertical barriers can alter wave dynamics and groundwater flow so hydrodynamic modeling or another form of assessment is needed to confirm that there is no adverse consequence. Alternatively, the vertical barrier design may be amended from conventional installation to accommodate hydrodynamics. For example, based on coastal analysis modeling (CH2M HILL, 2013c), buried vertical structures are unlikely to create changes in wave dynamics that would promote deposition or erosion. Consequently, maintaining the top of a barrier below the beach surface at Wyckoff minimizes the potential for changing near-surface sediment transport processes.

5.1.4 Removal and Disposal

Removal refers to dredging or excavating contaminated sediments from a site. Dredging typically involves removing sediments in water using mechanical or hydraulic methods. Excavation may include removing sediments using conventional construction equipment operated in the dry. Work in the dry could be performed during low tide or it could involve constructing isolation cells using temporary sheet pile or cofferdams and dewatering the cell to create relatively dry conditions.

Sediment removed using dredging or excavation methods is often dewatered, stabilized, or treated before it is disposed or reused. Because of the presence of NAPL, residual water generated from OU-1 sediment dredging/excavation would require containment, handling, and treatment with treatment potentially performed using the existing groundwater treatment plant located in the upland rea. Hydraulic dredging would generate larger amounts of water than mechanical dredging and would require careful planning to configure the discharge lines and pumps conveying dredge slurry to the upland area.

Examples of offsite disposal technologies include in-water units such as confined disposal facilities, confined aquatic disposal cells, or dry disposal units located onsite or offsite. Onsite disposal would include dewatering, stabilizing, and consolidating the material in the upland portion of the Site. Offsite disposal involves transporting and placing removed sediment into a Resource Conservation and Recovery Act of 1976 (RCRA) Subtitle C (hazardous waste) treatment, storage, or disposal (TSD) facility or a RCRA Subtitle D (non-hazardous waste) landfill.

Beneficial reuse of dredged material depends on the type and level of contamination, but placement options can include beach nourishment, habitat enhancement, upland soil supplements, and engineered fills. However, because of the presence of NAPL in the FFS Project Area sediment, disposal at an offsite Subtitle C or Subtitle D facility, or ex situ treatment and beneficial reuse in the upland area represent the most probable end state for OU-1 sediment.

5.1.5 Ex Situ Treatment

Ex situ treatment involves post-removal treatment to transform, destroy, or immobilize contaminants in the dredged or excavated material. Examples of ex situ treatment include stabilization, separation, solidification, thermal destruction, and vitrification. Thermal destruction (i.e., medium temperature thermal desorption [MTTD]) separates VOCs and SVOCs from soil or sediment by heating to temperatures upward of 1,000 degrees Fahrenheit (°F). Treatment temperatures are not typically high enough to oxidize or destroy the contaminants; instead, they are converted into a vapor that is captured in the offgas that is subsequently treated using thermal oxidation. This technology is well established to treat oily and organicrich soil and sediments. Contaminated sediment would require dewatering, particle size separation or reduction, and moisture control to optimize treatment effectiveness and energy consumption.

5.1.6 In Situ Treatment

In situ treatment involves biologically, chemically, or physically treating contaminated sediment in place to reduce contaminant concentrations, mobility, or toxicity. Examples of in situ treatment include the following:

- **Biological treatment** involves enhancing microbial degradation of contaminants by adding materials such as oxygen, nitrate, sulfate, hydrogen, nutrients, substrate (e.g., organic carbon), or microorganisms into the sediment or a reactive cap.
- **Chemical treatment** involves destruction of contaminants through oxidation by providing chemical reagents, such as permanganate, hydrogen peroxide, or potassium hydroxide, into the sediment or into a reactive cap.
- **Stabilization/solidification (S/S)** includes sequestering contaminants by adding coal, coke breeze, Portland cement, fly ash, limestone, pozzolans, OC, or other additives to the sediment to encapsulate the contaminants in a solid matrix and/or chemically alter them to convert them into a less bioavailable, mobile, or toxic form(s).
- **Adsorption** involves adding OC or AC, in powder or granular form, to the sediment to decrease contaminant toxicity and/or mobility. A number of commercially available products have been developed for this application.

Limited-scale testing of S/S using cementitious materials has been completed in a few cases, such as the Rutgers University 2004-2005 pilot study completed in Newark Bay near the mouth of the Passaic River (Maher et al., 2005). This study concluded that using deep soil mixing methods to deliver a pozzolanic slurry to stabilize contaminated sediments was feasible for increasing the sediment strength and improving material engineering properties to facilitate potential dredging. The effectiveness of S/S for immobilizing NAPL in an intertidal marine environment is unknown because there are limited analogous sites for comparison. Other S/S methods, such as jet grouting, may also be feasible as a delivery method.

Potential short-term and long-term disruption to the beach and marine environment is a concern for several in situ methods. In particular, oxidizers and other reagents associated with chemical and S/S treatment could be difficult to introduce to subsurface targets and apply in a controlled manner. EPA, Ecology, and other stakeholders have also raised concerns regarding S/S application in the intertidal area, particularly related to managing swell and potential habitat impacts. Swell would need to be contained and rehandled for disposal outside of the FFS Project Area. Temporary sheet piles or other containment would likely be needed to control in situ methods, adding additional cost and effort. S/S, and potentially in situ chemical treatment, would also create low-permeability zones that permanently alter groundwater flow patterns, requiring careful analysis of long-term impacts.

5.1.6.1 Natural Recovery and Enhanced Natural Recovery

Another form of in situ treatment involves monitored natural recovery (MNR) and enhanced natural recovery (ENR). MNR uses naturally occurring processes to contain, destroy, or reduce the bioavailability or toxicity of contaminants in sediment. The success of MNR as a risk reduction approach typically depends upon understanding the fate and mobility of the contaminant in that environment (EPA, 2005b). MNR relies on naturally occurring processes to reduce potential unacceptable human health and ecological risks to acceptable levels, while monitoring recovery over time to determine the progress towards achieving RAOs.

MNR was include as a component of the remedy selected in the 1994 ROD for North Shoal and East Beach intertidal sediments. As indicated in the *2011 Year 17 Monitoring Report East Harbor Operable Unit Wyckoff/Eagle Harbor Superfund Site* (USACE, 2012), MNR has achieved an estimated 97 percent reduction in COC concentrations in the 10-year period (2001 to 2011) following completion of source control measures (installation of the upland sheet pile wall).

ENR involves accelerating the natural recovery process through engineering, typically by placing a thin layer of clean sediment over contaminated sediment; this approach is sometimes referred to as “thin-layer capping.” Accelerated recovery can occur through several processes, including increased dilution through mixing clean sediment with underlying contaminated sediment. Although thin-layer capping is not necessarily intended to isolate and stabilize underlying contaminated sediments, layers of approximately 2 to 6 inches in thickness can suffice to separate and isolate (typically non-NAPL) contaminants from the benthic macroinvertebrates (National Research Council, 2003). ENR includes long-term performance monitoring to determine progress towards achieving RAOs. Thin-layer caps may be amended with AC, OC, or other sequestration agents to enhance further effectiveness and long-term performance to achieve RAOs related to surface water protection.

5.2 Technology Screening Approach

Technology screening was conducted following the guidance described in EPA’s *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA, 1988) and consistent with EPA’s *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (EPA, 2005b). In addition, a review of current literature and recent feasibility study documents from other contaminated sediment sites was conducted to identify potential candidate remedial technologies and process options. Potential remedial technologies and process options were screened according to the following three established criteria:

- Effectiveness
- Implementability
- Relative cost

Each technology was evaluated on a scale of 1 to 4 for each criterion, with 1 being the lowest ranking and 4 being the highest ranking relative to the OU-1 site characteristics, and the RAOs and PRGs established for the RTA. The overall screening results, which are presented in **Table 5-1**, provide the basis for retaining or eliminating a technology or process option. Additional information of the screening criteria and the evaluation process is presented in the following subsections. The technologies retained from the screening are assembled into an array of remedial action alternatives in Section 6.

5.2.1 Effectiveness

The effectiveness of a technology and/or process option is evaluated based on its ability to meet the project RAOs under Site conditions and constraints. The effectiveness criterion was used to determine which remedial technologies would be effective based on the nature and extent of contamination, Site characteristics, and other engineering considerations. The effectiveness evaluation considers the following three objectives:

- The potential effectiveness of candidate technologies and process options in meeting the remediation goals identified in the RAO
- The potential impacts to human health and the environment during the construction and implementation phase
- How proven and reliable the process is for the contaminants and conditions at the site based on documented experience at other locations with comparable conditions

Remedial technologies that are not likely to address effectively sediment contamination within the FFS Project Area are not retained for further evaluation.

5.2.2 Implementability

Implementability refers to the relative degree of difficulty anticipated in implementing a particular technology and/or process option under the regulatory and technical constraints posed within the FFS Project Area. Implementability is evaluated in terms of the technical and administrative feasibility of constructing, operating, and maintaining the technology and/or process option, as well as the availability of services and materials (EPA, 1988). Technical feasibility refers to the ability to construct, reliably operate, and comply with regulatory requirements during implementation of the technology and/or process option. Technical feasibility also refers to the future operation, maintenance, and monitoring after the technology and/or process option has been completed. Administrative feasibility refers to the ability to coordinate with and obtain appropriate approvals, permits, and CERCLA substantive compliance concurrence from EPA and other regulatory agencies. Availability of services and materials may include the availability and capacity of treatment, storage, transportation, and disposal services; the availability of bulk materials; and the requirements for and availability of specialized equipment and technicians. The implementability evaluation for this FFS further considers protection of eelgrass, shellfish, and other intertidal habitat and resources. Technologies that minimize short-term and long-term impacts provide benefit over those that are potentially more destructive or result in changes to beach morphology. Remedial technologies that are not implementable at the Site are not retained for further evaluation.

5.2.3 Relative Cost

The primary purpose of the cost-screening criterion is to allow comparison of the rough cost ranges typically associated with the technologies and/or process options considered. The cost criterion addresses anticipated costs to implement the technology and/or process option as well as associated long-term operations and maintenance (O&M) costs. This comparative evaluation excludes assigning actual dollar values at the technology and/or process option screening level. The evaluation is used for rough comparative purposes only. The no action alternative is used as a basis of cost comparison and is assigned a ranking level of “4.”

5.3 Technology Screening Results

The remedial technologies and process options that were identified to address the contaminated sediment at OU-1 are summarized in **Table 5-2**. GRAs may be addressed by several types of remedial technologies and process options. Remedial technologies (e.g., removal, capping, and disposal) are general categories of technologies, with more specific process options (e.g., dredging, reactive cap, and landfilling) identified as specific processes within a remedial technology category. Technologies were qualitatively evaluated on their relative effectiveness, implementability, and cost and were retained or discarded based on the degree to which they satisfied each criterion. The retained process options are each considered to be implementable and potentially be effective for remediating NAPL-contaminated sediments within OU-1. Remedial technologies and/or process options that are retained after screening are then combined into potential remedial alternatives for the site. **Table 5-2** describes the technologies and process options identified, and it includes the results of the screening evaluation.

5.3.1 Retained Technologies

The screening process evaluated the remedial technologies and process options for effectiveness, implementability, and cost. Remedial technologies and process options that would not effectively address sediment contamination or be implementable within the FFS Project Area were eliminated. **Table 5-3** summarizes the retained technologies and process options, and the remainder of this section briefly describes the retained technologies and process options for each GRA.

5.3.1.1 No Action

No action is retained as a comparative baseline for evaluation against other technologies in accordance with the NCP (40 CFR 300.430 (e) (6)).

5.3.1.2 Access Controls

The following access controls were retained:

- Government Controls: notification of waterway use, commercial fishing bans, regulated navigation areas
- Enforcement and Permit Tools: consent decrees and permits
- Informational Devices: education and public outreach, deed notices, seafood consumption advisories, and Site registry

These access controls are potentially applicable as components of remedial alternatives that include other remedial technologies. These actions would not reduce NAPL volumes or contain NAPL, nor would they be effective as stand-along remedial actions. The need for continued fish advisories and their effectiveness requires evaluation as part of institutional controls.

5.3.1.3 Containment

Containment technologies retained include engineered capping and vertical barriers. Each technology type includes more than one potential process option for alternative development. Engineered caps and vertical barriers can be effective in reducing migration of and exposure to NAPL-contaminated sediments. Cap construction would temporarily impact intertidal habitat and aquatic organisms during placement, but the cap can be designed so that habitat is restored upon completion. The following section lists the retained process options and provides rationale for choosing a representative process option for remedial action alternative development.

Engineered Capping

Following are the engineered capping process options that were retained:

- Permeable cap
- Reactive or sorbent cap

Permeable caps are typically constructed of sand and are designed to provide a physical barrier between the contaminated sediment and the biologically active sediment zone and overlying water column. Physical – contaminant isolation occurs because the thickness of the cap prevents contaminant movement from the impacted sediment to the water column. Permeable caps may be amended to include a low permeability layer consisting of synthetic or natural materials that impede vertical - upward contaminant movement.

Permeable caps constructed without an amendment layer or component that actively sequesters/absorbs NAPL and associated COCs may, over time, allow breakthrough and contaminant release to the water column. In reactive caps, commercially available media can be incorporated into the cap as an individual reactive layer or mixed with other cap material to sequester NAPL and slow breakthrough. The sorbent media is available in a pelletized form that is adhered to a gravel core (i.e., AquaGate), or as a granular adsorbent (i.e., bulk media). The media may also be incorporated into a geotextile blanket or "envelope" such as a reactive core mat (RCM). The RCM is deployed as a permeable, engineered liner whereas the sorbent bulk media is generally placed similar to sand or gravel. The efficacy of NAPL adsorption depends on selecting appropriate media and the media having adequate available sorption sites. Sorption depends on the rate at which NAPL seeps into the media, source volume, and the sorbent media. The sorbent media is typically selected during design evaluation following literature and project reviews, and/or bench top laboratory tests and pilot tests. Sorbent materials are typically expensive and must consider key factors for availability and acquisition, placement ease, potential erosion, expected performance, and habitat restoration needs.

The sorbent media must also remain in contact with the NAPL during tidal flux to maintain sequestration. The degree of contact is a function of the type and quantity of sorbent media, along with the elements of cap design to resist lateral bypass of NAPL. Optimally, the cap construction materials should have similar physical characteristics to the existing sediment to maintain comparable hydraulic conditions. The current estimate for the hydraulic conductivity of the upper aquifer within the FFS Project Area is roughly 26 feet per day (Appendix B). For comparison the hydraulic conductivity of OC blankets was estimated by the University of Colorado (Olsta, 2013) at approximately $1x10^{-6}$ meters per second or 0.3 feet per day, or roughly two orders of magnitude less permeable than marine sand and gravel sediments. However, the permeability of bulk OC can be adjusted by mixing with sandy substrate and related commercial products. Testing performed by the CH2M Applied Sciences Laboratory showed significant swelling and flow blockage in test columns packed with 100 percent OC and a 50 percent OC and 50 percent sand mixture within several days of creosote NAPL contact.

The efficacy of NAPL sorbent media depends on selecting appropriate media and developing a cap design to prevent the NAPL from bypassing the media. In the longer term, the efficacy of the cap depends on the degree of saturation of the sorbent media and if reduced permeability redirects NAPL around the media to the beach surface. Adequate available media depends on the rate at which NAPL seeps into the media.

The development of a cap design that promotes a high level of NAPL adsorption over its design life, while permitting upward groundwater flow, will require bench scale testing during remedial design. The overall testing may need to include assessment (**Table 5-4**) of the following:

- Adsorptive layer thickness and mix percentage with other reactive media or inert material
- Reactive media particle size for consistency with native materials
- Material quality assurance/quality control
- Deployment ease
- Permeability and density

A key consideration is the speed of installation given the tidal fluctuation in the FFS Project Area. However, solutions to installation issues can be engineered for either the RCM or bulk media products. Long-term performance is determined by the ability of the sorption media to sequester NAPL in the intertidal environment and minimize potential for changing hydraulic flow patterns with the goal of avoiding short-circuiting and diversion of NAPL around the reactive cap. For purposes of this FFS, OC is retained as the representative amendment for development of alternatives.

Vertical Barriers

As described in Section 3, the NAPL transport mechanisms promoting seep migration in the OU-1 FFS Project Area include groundwater advection and buoyancy. Lateral containment prevents further migration of NAPL to downslope beach areas when sheen may be generated from mobile NAPL areas and migrate laterally during the receding tide.

Impermeable barriers for lateral containment are typically constructed from steel sheet piles, soil bentonite, or other low permeability material. If the NAPL is not migrating downward, then barrier walls of limited vertical height that are not keyed into a deeper, lower permeability unit are applicable. Wall heights spanning roughly the tidal range (20 feet below beach grade) are expected to provide sufficient vertical containment within this zone of NAPL. Selection of construction materials generally depends on the subsurface conditions including sediment type and density, potential subsurface obstructions/debris, and the overall length and dimensions required for the barrier.

Table 5-5 compares steel/fiberglass sheet piles and soil bentonite cutoff wall process options for vertical barriers. Steel/fiberglass sheets can be installed with the top of wall below the beach surface. The marine sands and gravels are expected to be conducive to installation of sheet piles using vibratory or direct push methods, minimizing the ground disturbance. These materials are resistant to NAPL degradation and, in the case of steel, can be epoxy-coated to be resistant to seawater. Steel sheets can also be over-thickened to account for corrosive thinning. Whereas bentonite-based slurry wall performance in a marine environment is uncertain. Additionally, a slurry wall would generate large amounts of sediment, some potentially contaminated, that would have to be managed and disposed.

In consideration of these site-specific conditions in the intertidal zone, the use of steel or fiberglass sheet piles is expected to be a more suitable process options than bentonite-amended soil. For the purpose of this FFS, steel sheets are retained for development of alternatives. Selection of the barrier material would be further evaluated during the design phase. Key characteristics for comparison include substrate conditions, degree of beach surface disturbance, subsurface obstruction concerns, groundwater chemical effects, and potential NAPL mobilization during installation.

5.3.1.4 Removal

Removal technologies were categorized as in-water dredging and dry excavation as follows:

- In-water Dredging - mechanical
- Dry Excavation - mechanical excavation at low tide; mechanical excavation using dewatering pumps; and mechanical excavation using sheet piling and/or cofferdams to isolate and dewater excavation cells

Removal technologies would effectively exhume contaminated sediments, thereby reducing risks of exposure to NAPL. Mechanical dredging equipment must be matched to tidal conditions depending on whether water- or land-based staging platforms are used and whether dredging is performed through the water column (in-water) or at low tide.

Mechanical excavation process options using conventional excavation equipment has proven to be feasible in similar tidal in environments in Puget Sound, but in the dry, implementation becomes progressively challenging with increasing excavation depth and at lower intertidal elevations. The associated dewatering technologies and effluent treatment can also be relatively expensive to implement, but are feasible for the OU-1 FFS. Land-based excavation using conventional equipment and mechanical dredging using water-based equipment are retained for FFS alternatives analysis.

5.3.1.5 Transportation and Disposal

The following disposal process options were retained:

- Transportation using a conveyor (onsite) and truck (onsite and offsite)
- Onsite disposal with upland placement
- Offsite disposal at a permitted landfill

Transportation and disposal are ancillary technologies that would be implemented in combination with removal. Onsite disposal would be limited by available capacity to dewater and stabilize NAPL-contaminated materials in the upland portion of the Site. For the purposes of this FFS, offsite disposal of dewatered and stabilized dredged materials and drainage water are assumed to require transportation from the upland using truck to a permitted landfill as RCRA Subtitle D wastes. This would require EPA approval under the NCP Offsite Disposal Rule (40 CFR 300.440) and potentially a Contained-In Policy determination.

5.3.1.6 Ex Situ Treatment

Physical and/or Chemical Treatment

If sediment were removed through dredging or dry excavation, excess water would need to be removed prior to treatment or disposal. Dewatering can be performed using passive (e.g., slack drying) chemical (e.g., pozzolon or superabsorbent polymer), or mechanical (e.g., filter press) means. Ex situ dewatering would be implemented as an ancillary technology in combination with removal technologies. Ex situ treatment could involve multiple technologies to dewater and stabilize dredged and/or excavated materials onsite prior to transport, with additional offsite stabilization, if needed, to further address NAPL presence and potential waste designation status.

Solidification and stabilization refers to mixing dredged or excavated sediment with cementing or stabilization agents. The reagents would react with the sediment to absorb excess water, increase the material strength, and immobilize some classes of contaminants through chemical or physical reactions.

For the purpose of this FFS, sediment dewatering and stabilization would be performed in the upland portion of the Site.

5.3.1.7 In Situ Treatment

Monitored Natural Recovery and Enhanced Natural Recovery

Monitoring by the USACE (USACE, 2012), indicates improved environmental conditions in the FFS Project Area because upland source control measures were completed in 2001. The primary natural recovery mechanisms are likely a combination of wave washout of NAPL near surface sheens and dispersal of contaminated particulate material, as well as deposition of clean sediment. The coastal engineering analysis concluded that surface sediment transport is in a state of dynamic equilibrium, and that while there is sediment transport occurring, there is no net erosion or deposition (CH2M HILL, 2013c). Therefore, these natural recovery mechanisms are expected to continue to reduce NAPL volume slowly over time.

Natural recovery is retained for further consideration during alternative development and analysis. MNR alone may not effectively address active NAPL migration pathways in a beach environment; however, this technology may be combined with other remedial measures to achieve RAOs.

ENR using thin-layer capping is also expected to be an effective technology not envisioned as providing sufficient protectiveness to address NAPL contamination at the beach surface and deeper sources. A thin cover of sandy material would also be expected to become mobile and redistribute in the intertidal area.

SECTION 6

Development of Remedial Alternatives

This section assembles the technologies retained from the screening presented in Section 5 into an array of NAPL source control remedial alternatives and presents a conceptual design and cost estimate for each alternative.

6.1 Development of Alternatives

The NCP ("Remedial Investigation/Feasibility Study and Selection of Remedy," 40 CFR 300.430[e][3]) sets forth the following expectations for development of source control alternatives:

- *"A range of alternatives in which treatment that reduces the toxicity, mobility, or volume of the hazardous substances, pollutants, or contaminants is a principal element. As appropriate, this range shall include an alternative that removes or destroys hazardous substances, pollutants, or contaminants to the maximum extent feasible, eliminating or minimizing, to the degree possible, the need for long-term management.*
- *Alternatives, as appropriate, which, at a minimum, treat the principal threats posed by the site but vary in the degree of treatment employed and the quantities and characteristics of the treatment residuals and untreated waste that must be managed.*
- *One or more alternatives that involve little or no treatment, but provide protection of human health and the environment primarily by preventing or controlling exposure to hazardous substances, pollutants, or contaminants, through engineering controls, for example, containment, and, as necessary, institutional controls to protect human health and the environment and to assure continued effectiveness of the response action."*

Based on the RAOs presented in Section 4.2, remedial alternatives were developed to target mobile NAPL in sediment while relying on MNR to address non-mobile NAPL in areas not targeted for active remediation. The reliance on MNR to address areas with non-mobile NAPL reflects the effectiveness of this technology based on the evaluations presented in the Year 17 Report (USACE, 2012). None of the alternatives includes an active component to remediate pore water or shellfish tissue. COC concentrations in these media are expected to decline with the elimination of active NAPL seeps and reduction of COC concentrations in sediment.

Based on the technology screening results and proposed RAOs, the following alternatives were developed:

- Alternative 1—No Action (retained as the baseline for comparison to other alternatives per NCP requirements)
- Alternative 2—Seep Capping and MNR
- Alternative 3—Partial Excavation and Capping
- Alternative 4—Vertical Containment with Partial Excavation and Capping
- Alternative 5—Dredging

These alternatives were developed to provide a range of remedial actions incorporating various containment, treatment, and removal technologies identified and screened in Section 5. The alternatives are arranged in general order of complexity and site disturbance. All alternatives include an MNR component that would occur following construction and implementation of active element.

Table 6-1 presents the key components of each alternative. Section 6.2 provides a description of each alternative and lists the assumptions used in developing the conceptual design and cost estimates.

6.1.1 Conceptual Design

The level of engineering performed for the alternatives presented in this section varies and is estimated to range from 3 to 15 percent of that required to prepare a fully biddable and constructible remedial design.

The conceptual design for each alternative is based on the area and volume of NAPL contaminated sediment present in each of the remedial action target zones shown on **Figure 4-1**. The actual areas and volumes of NAPL contaminated media addressed by the selected alternative will be refined during the remedial design using new information obtained from predesign investigations and more detailed evaluation of existing information. Additionally, the actual volumes of NAPL contaminated media treated and/or volumes of NAPL removed by the selected alternative will also likely differ from that estimated in this FFS.

6.1.2 Cost Estimates

The estimates presented for the Wyckoff OU-1 FFS are order-of-magnitude cost estimates that provide nominal accuracy of +50 percent to -30 percent. They were prepared using USEPA's *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* (USEPA, 2000b). The cost estimates were prepared using vendor quotes, technology reference documents, and estimates based on other sediment remediation projects, and engineering experience available at the time of preparation of this report. Labor costs have been estimated by using regional prevailing wages. This estimate is limited to the conditions existing at its issuance and is not a guaranty of actual price or cost. Uncertain market conditions such as, but not limited to, local labor or contractor availability, wages, other work, material market fluctuations, price escalations, force majeure events, and developing bidding conditions, may affect the accuracy of this estimate.

Based on the collected additional information, technology components and material volumes would be further refined to support design for the selected alternative. Additional process options may be also evaluated during the remedial design, and incorporated if determined to be advantageously effective and implementable.

The actual cost of the selected remedial alternative will depend on a number of factors, including:

- Final sediment volumes removed
- Final cap design and associated material volumes
- Inclusion of potential additional emerging technologies that are not currently identified
- Competitive market conditions
- Actual labor and material costs

Although these factors will affect the cost of each remedial action alternative, they are not expected to affect the relative cost differences between alternatives for comparing alternatives. However, the final costs will vary from the estimates presented in this report, so funding needs must be carefully reviewed before specific financial decisions are made or final budget is established.

6.1.2.1 Capital and Long-Term Operations and Maintenance Cost

The cost summary tables include capital costs and long-term O&M costs. Capital costs include nominal labor estimates, contractor markups, overhead, and profit, as well as the following:

- Pre-design sampling and testing
- Pre-remediation site work
- Installation of vertical barrier for Alternative 4, and installation and removal of temporary sheet piles for Alternative 5
- Sediment removal and dewatering

- Cap placement
- Construction (short-term) monitoring and confirmation surveys
- Excavated or dredged material stabilization and disposal
- Institutional controls

All capital costs include a 30 percent contingency. Mobilization, construction management/oversight, remedial design, and project management are estimated at nominal percentages of summed capital cost pay items.

Long-term O&M costs are the post-construction costs required to ensure or verify the continued effectiveness of the remedy. The Appendix F cost tables identify O&M costs over a 100-year total life-cycle term based on direction from EPA. These costs include periodic costs for monitoring, reporting, and nominal cap maintenance expenditures assumed to occur at various times and frequencies as noted.

Long-term cap O&M expenditures apply to Alternatives 2, 3, and 4, where replacement of portions of the caps is assumed to be required if containment of NAPL reduces the effectiveness of the caps over time. The actual need and frequencies of potential cap replacement are challenging to predict, and would be determined based on post-construction monitoring results. Cap replacement assumes that expended capping materials would be removed from the beach area, and temporarily stockpiled, dewatered, and stabilized in a dedicated storage area at the southwestern corner of the upland (see **Figure 6-1**). The stabilized material and collected drainage water would be transported and for offsite disposal, and new cap sections would be placed using the same methods described for capital construction. Although the timing for implementing a selected remedy for the Wyckoff upland area is uncertain, the storage pad area at the southwestern corner of the upland can be dedicated for future OU-1 O&M needs.

6.1.2.2 Present Worth Analysis

Long-term O&M expenditures that occur over different periods were analyzed using present-worth, which discounts all future costs to a base year. Present-worth analysis allows the cost of remedial action alternatives to be compared based on a single figure representing the amount of money that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the life of the remedial project. All present worth values are based on the 7-percent discount factor cited in *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* (EPA, 2000). Present worth values were also estimated using the 1.4 percent real discount rate published in *Appendix C - Discount Rates for Cost Effectiveness, Lease Purchase, and Related Analyses*, *Guidelines and Discount Rates for Benefit Cost Analysis of Federal Programs* (Office of Management and Budget Circular A-94, 2015). **Table 6-7** also provides non-discounted O&M estimates for comparative purposes.

The cost estimates are in 2014 dollars and were prepared based on the site information available at the time of preparation of this report and the components of the conceptual remedial alternatives presented herein. Additional investigation activities and evaluations would be performed during the remedial design.

6.2 Common Elements and General Assumptions

There are a number of elements common to Alternatives 2 through 4, and these elements are described in the following section. Some elements are also applicable to Alternative 5 and are called out where applicable.

6.2.1 Timing and Coordination of OU-1 and OU-2/OU-4 Remediation

A separate FFS was prepared for the remediation of NAPL-contaminated soil and groundwater present in OU-2/OU-4. Technologies for remedial alternatives under consideration for the upland could preclude access and extensive use of the upland area for stockpiling and staging to support OU-1 remediation without advanced planning. For this reason, a working assumption is that construction for active elements of any of the alternatives developed for the OU-1 FFS must be completed before upland remediation begins. Given current uncertainty regarding the selection of an upland remedy, it is further assumed that remedial actions for OU-1 would be conducted independently, including offsite disposal of excavated/dredged material for OU-1 rather than disposal in the upland area. In addition, upgrades to the upland sheet pile wall would be completed prior to implementation of an OU-1 remedy. Additional OU-1 and OU-2/OU-4 coordination will occur during the remedy implementation phase.

6.2.2 Control of Upland NAPL Sources

The existing sheet pile wall around the upland continues to contain NAPL migration from upland sources. Implementation of a remedy for the OU-1 FFS Project Area assumes that upland sources would continue to be controlled, and the sources would not result in recontamination of intertidal areas once OU-1 remedial action is complete. Potential sealing, upgrading, replacement, or reinforcement of portions the sheet pile wall and additional actions taken as necessary to control of upland NAPL migration would be completed separate from OU-1 activities. Such actions could be substantial and would need to occur prior to implementing OU-1 remedial actions. Careful coordination and planning would be required to avoid interference with implementation of the alternatives evaluated in this FFS.

6.2.3 Institutional Controls

The use of anchors, moorings, and other physical means of securing vessels can damage cap layers. In areas that would be managed using MNR, anchors and moorings could release NAPL at the beach surface. There are existing anchoring restrictions in North Shoal and Phase III cap; these restrictions would be expanded to include the East Beach.

There are existing Eagle Harbor ICs for fish and shellfish harvesting closure and flat fish consumption. Until monitoring data indicate that habitat is restored to meet RAOs, these ICs would be maintained. As post-remediation monitoring is performed, evaluations would be conducted to assess the need for continued application of fishing advisories in the FFS Project Area.

ICs are applicable to Alternatives 2 through 5.

6.2.4 Predesign Investigation

The OU-1 FFS assumes a number of predesign data collection activities would be required to complete the remedial design for Alternatives 2 through 5. These include: a North Shoal TarGOST® investigation as shown on **Figure 4-1,** waste characterization; additional physical characterization of sediments; determination of NAPL properties and cap amendment testing; determination of NAPL seep expression rates; and establishing baseline surveys for bathymetry, habitat conditions, and NAPL distribution. Alternatives 4 and 5 would also require additional geotechnical investigations to support the design of the vertical barrier or the sheet pile excavation cells, respectively.

6.2.5 Pre-remediation Site Work

Alternatives 2 through 5 would require pre-remediation site work to provide the infrastructure needed to support remedial action construction. Temporary access roads, office areas, parking areas, and equipment storage areas would need to be constructed. Additionally, stockpile and dewatering pads would need to be identified and constructed, and security fencing around staging area(s) would need to be installed. The amount of staging area required varies by alternative and is primarily based on the amount of material (dredged sediment or capping/backfill materials) that would need to be handled. **Figure 6-1** illustrates the locations of the existing upland groundwater treatment plant (GWTP), roadways, decontamination pad, available area for staging equipment, as well as the locations and sizes of areas for material stockpiling and sediment dewatering. There are approximately 2 acres of available space, plus a 0.5 acre improved area shown as “Asphalt Parking.”

The FFS also assumes that a high-resolution preconstruction bathymetry survey would be performed to confirm site conditions and that survey control points and tide gages would be established. Additional surveys would be required for Alternatives 4 and 5; these are described in the respective subsections below.

6.2.6 Excavated/Dredged Material Removal and Transport to the Upland

Alternatives 2 through 4 all include varying degrees of sediment removal using mechanical excavation to construct engineered capping sections approximately 30-inches deep into the beach face without changing the existing grade. Alternative 5 includes deeper mechanical excavation and a significant dredging component. For Alternatives 2 through 4, the FFS assumes enclosed 'environmental buckets' would be used to control turbidity and sheening during excavation. Excavation would be limited to working intertidal beach areas from the landside in dry conditions when the beach face is exposed during lower tide periods. Estimated construction durations assume a typical diurnal tidal cycle of approximately 5 hours and that two excavators would work simultaneously. Surveys would be performed to verify that removal depths are achieved. Additional assumptions have been made for the alternatives with greater amounts of sediment removal; these are called out in the descriptions below.

For Alternatives 2 through 4, sediment would be placed into dump trucks for transport to the upland area dewatering pad. A working assumption for the purposes of this FFS is that excavated and dredged material for all alternatives would require dewatering and stabilization in the upland part of the site, with truck shipment for offsite disposal at a RCRA Subtitle D facility as nonhazardous waste. Designation of dredged material wastes would likely require a Contained-In Policy determination by EPA.

6.2.7 Cap Design

Alternatives 2, 3, and 4 all include installation of a multilayer cap that combines an estimated 4 to 6-inch thick reactive layer, which sorbs and/or treats NAPL and dissolved NAPL constituents, with an overlying 24-inch thick habitat layer. An optional demarcation layer could also be installed between the reactive layer and the habitat layer to mark the boundary between the two and to protect the reactive layer from inadvertent intrusion.

The size of the cap footprint in Alternatives 3, 4, and 5 is comparable while Alternative 2 is much smaller. For the FFS, the cap design and installation means and methods are assumed to be intertidal. During remedial design, the cap layer thickness and composition will be refined based on site-specific hydrodynamic and NAPL upwelling expression rates. The cap footprint locations for Alternatives 2, 3, and 4 are provided in **Figures 6-2, 6-4, and 6-5**.

The reactive layer conceptually uses adsorbent material to intercept and immobilize NAPL and dissolved PAH constituents. The reactive layer may be overlain by a scour protection/demarcation layer before placing a suitable sand habitat for shellfish and other biota. A final determination on the adsorbent or other reactive material type(s), quantities, and thicknesses would be made during remedial design through laboratory testing of site-specific NAPL and various mix designs. The reactive layer is conceptually envisioned to be between 4 and 6 inches thick and constructed using OC-amended material (either engineered or a sand blended with OC), AquaGate+OC overlain by AC amended material (also engineered or a sand blend) or AquaGate+AC. If necessary, the reactive layer can be protected with a demarcation layer constructed of stone aggregate, which also serves as a structural template for the habitat layer. All materials are commercially available, although large quantities require advance order to ensure adequate stock in the timeframe needed. **Figure 6-3** provides a conceptual cross-section for the cap design.

Based on the results of the coastal model summarized in Section 3.1.2, surface armoring of the cap to prevent potential scour from storm-induced mechanical forces would not be required. If during remedial design new information is obtained indicating that armoring would be beneficial, an armor layer could be added.

Installation in the intertidal area will consist of a sequence of removal and backfill operations during the ebb tide cycle. The removal and backfill activities will use land-based equipment and establish areal extent of work each day based on projected tidal cycle. This method of intertidal cap installation has been used on several sites after trying alternative methods of construction in the wet to lengthen the workday period. Use of land-based equipment and optimizing work in the dry has been found to be cost effective and, with a decade of monitoring data, produces satisfactory quality assurance and quality control. Using mechanical excavators to remove sufficient sediment to permit cap construction and maintain existing beach grade, a multi-layer cap would be constructed.

For purposes of the FFS, the cost estimates assume that OC administered in bulk is the best media type for this project; however, the design would evaluate this concept in comparison to other process options such as reactive core mats (RCMs) or biobarriers prior to implementation.

Confirmation field surveys would be performed after sediment removal and cap placement to document that the required depth of sediment has been removed. Physical surveys would also be performed after placement of each of the cap layers to confirm that the materials are placed according to the design specifications.

6.2.8 100-Year Life-Cycle Term

EPA identified a 100-Year life-cycle term for remedial actions associated with the current OU-1 FFS, and with the upland FFS for OU-2/OU-4. The intent of the conceptual design assumptions for the OU-1 FFS is for there to be sufficient media to control NAPL for the design life of the alternative through a 100-year life-cycle term for remediation. NAPL seepage rates are not currently well quantified, and remedy performance is not easily predicted. Media replacement over the life of the caps is therefore assumed to be required as follows for Alternatives 2, 3, and 4:

- North Shoal – 25 percent of the capped area would be replaced at Year 9.
- East Beach – 25 percent of the capped area would be replaced in Year 9 and 25 percent in Year 30.

6.2.9 Dewatering of Shallow Beach Excavations

To facilitate removal of sediment material from the shallow beach excavations for Alternatives 2, 3, and 4, the FFS assumes excavation and capping for each excavated/capped grid area would be staged to occur in the dry at low tide. It is likely; however, that well points or sump pumps would be needed to keep the excavation(s) dry enough complete excavation and capping, and to confirm removal depths and place cap materials with sufficient survey accuracy.

The computer model AQTESOL was used to estimate the amount of water that would need to be removed to keep a dry or nearly dry excavation condition (Appendix E). This solution was applied assuming a constant head boundary at different distances from the excavation to represent the ocean tide and its effect on pumping rate. Based on the modeling, a pumping rate of 100 gallons per minute (gpm) was established for FFS concept development and costing purposes. This rate is expected to provide approximately 3 feet of drawdown at the edge of individual excavation cells 40 feet by 40 feet in area. The assumption is that this pumping rate would be applied throughout the excavation period, which is estimated to be approximately 3 hours. For each 40-foot by 40-foot excavation area, a volume of approximately 18,000 gallons would be removed over a period of up to about 5 hours.

Excess water from the buckets of excavated sediment would be permitted to drain into the excavation, but no other sediment dewatering would occur within the intertidal area. Sediment would be transported to the upland and dewatered using gravity drainage constructed pad located in the upland. No mechanically assisted dewatering is anticipated to be necessary. The FFS assumes that up to approximately 7 gallons of water would gravity drain from each cubic yard of excavated/dredged material.

Pumped and drained water would be piped directly to temporary containers located in the upland to allow solids to settle. Alternative 2 assumes that the water would be characterized and disposed offsite as non-hazardous liquid. Alternatives 3, 4, and 5 assume that that GWTP in the upland would be restarted and operated for the duration of the remediation.

6.2.10 Material Stabilization and Disposal

Excavated/dredged material would be stabilized if gravity dewatering does not reduce moisture to a suitable level for transport and disposal. The FFS assumes 5 percent by weight Portland cement would be used to stabilize the material to pass the paint filter test and to immobilize NAPL, as needed for transport and disposal. The actual amendment percentage may be lower, but 5 percent was selected as a relatively conservative concentration for FFS level planning and cost estimating.

Following stabilization, the excavated/dredged material would likely be transported by truck to an offsite RCRA Subtitle D disposal facility but some material may be suitable for upland use. Material-specific treatability testing would be conducted prior to implementation to assure cost-effective amendment selection and dosage. As noted above, the FFS assumes that 100 percent of the excavated/dredged material would require offsite disposal; however, it may be possible to segregate material on the dewatering pad for Alternatives 3, 4, and 5, because clean material could potentially be suitable for onsite reuse.

The assumption that stabilized material could be disposed offsite at a RCRA Subtitle D facility is based on the following:

- NAPL-contaminated sediment would not be classified as a listed hazardous waste. A generator must know the source of the creosote-based NAPL in order to determine if the F032, F034, or U051 waste code is applicable. If the facility owner or operator cannot make such a determination because documentation regarding a source of contamination, contaminant, or waste is unavailable or inconclusive, the owner or operator may assume the source, contaminant, or waste is not a listed hazardous waste (*Management of Remediation Waste under RCRA*, EPA 530-F-98-026).
- NAPL-contaminated sediment would not be classified as a characteristic hazardous waste based on the characteristic of ignitability, reactivity, corrosivity, and toxicity. Although detectable concentrations of PAHs and PCP may be present, they would not exceed the toxicity characteristic leaching procedure thresholds specified in 40 CFR 261.24.
- If a listed waste determination was previously made for contaminated environmental media present at the Wyckoff Site, a representative sample of stabilized sediment will be collected and tested for site-related constituents and the results compared with MTCA Method B cleanup levels for residential exposure. EPA and Ecology will review these results to make a Contained-In Policy determination that the environmental media no longer contains a listed hazardous waste.

For estimating purposes, it is assumed that the dewatered and stabilized excavated/dredged material would be transported approximately 20 miles by truck to an intermodal rail transfer facility and then approximately 200 miles by rail for landfill disposal. None the excavated and dredged materials is assumed to remain on site for incorporation into upland remediation activities or reuse.

Depending on the alternative, excavation and stockpile dewatering water would be either treated and discharged through the existing upland treatment facility, or stored and shipped for offsite reprocessing as nonhazardous waste.

6.2.11 Short-Term Monitoring During Construction

Environmental, health, and safety monitoring would be performed during construction activities. Sheens would be monitored visually and no water quality monitoring (e.g., turbidity, dissolved oxygen [DO], temperature) would be performed unless there was visual evidence that construction activities were resulting in water quality impacts. Habitat, fish, and cultural resource monitoring would be also be performed. Air monitoring would be performed within and on the perimeter of the work zone. The FFS assumes a limited amount of odor suppressing foam would needed during sediment excavation, upland dewatering, and stabilization. Short-term monitoring elements are assumed for Alternatives 2 through 5.

6.2.12 Monitored Natural Recovery

MNR would be used for remediation of suspected non-mobile NAPL-affected areas of OU-1 outside of the active remediation footprints established for Alternatives 2 through 5 (see **Figures 6-2, 6-4, 6-5, and 6-9**). The active remediation footprints target areas of suspected mobile NAPL, whereas MNR targets peripheral areas where NAPL is less likely to be mobile; however, areas delineated for active remediation also consider constructability. Monitoring would be conducted assess the efficacy of the remedy and overall site recovery. For the purposes of the FFS, it is assumed the monitoring described below would be applied to all four alternatives. The area to be managed using MNR ranges from approximately 8 to 10 acres, depending on the alternative.

6.2.13 Remedy Performance Monitoring

Following construction, performance monitoring would be conducted to confirm that the remedy is performing as expected. Monitoring activities would include:

- Visual inspection of intertidal beach area for evidence of NAPL and cap surface erosion
- Intertidal topographic surveys to confirm beach and cap stability
- Grain size analysis
- Off-cap sediment and shellfish tissue sampling with laboratory analysis for COCs
- Potential TarGOST® monitoring surveys to assess movement of NAPL in the subsurface

Post-construction sampling will establish the post-construction baseline conditions, against which future sampling results will be compared. It will also establish surveyed elevations across the capped areas and set survey markers for future assessment of the physical stability of the beach. It will include sampling and analysis of sediments and shellfish tissue in MNR areas (i.e., off-cap areas). Newly capped areas will not be sampled for sediment or clam tissue. In calculating the average sediment concentrations of contaminants on the beaches, the concentrations from a composite sample of the backfill source material will be used for the capped areas.

Tables 6-2 through 6-5 provide the assumptions for the numbers of samples and associated analytical schedules used to inform the cost estimate. The FFS assumes the same sampling schedule would be used for Alternatives 2 through 5; however, it is possible that the alternatives where more active remediation occur could require fewer samples and analyses. Monitoring plans would be fully developed during the remedial design process. The data collected to assess the remedy performance and site recovery would be provided to EPA to support development of the Five-Year Review Reports.

6.2.14 Long-Term Operations and Maintenance

Long-term O&M would be required for all four alternatives evaluated and the anticipated requirements are specific to each alternative. The FFS cost estimate assumes that the long-term O&M for all four alternatives would extend to 100 years as the life-cycle term of the project. Alternative-specific requirements are noted in the descriptions below and in **Tables 6-2 through 6-5**, respectively.

6.3 Remedial Alternative Descriptions

Summaries of each alternative are presented below, with additional details in **Tables 6-2 through 6-5** and in Appendix F cost estimation assumptions.

6.3.1 Alternative 1—No Further Action

Per the NCP requirement, the No Action alternative is carried through the FFS process as the baseline condition against which the performance of the remaining alternatives is evaluated. The No Action alternative does not include remediation of OU-1 and all existing monitoring and maintenance of access controls under the 1994 ROD would be discontinued as part of this alternative.

6.3.2 Alternative 2—Seep Capping and Monitored Natural Recovery

Alternative 2 consists of remediating four active NAPL seeps by placing a cap over an approximate 40-foot by 40-foot area centered over each seep location. Two other active seeps, located at an elevation of 0 foot or lower within the eelgrass beds, would be addressed by MNR. Beach sediments would be excavated at each seep location to a depth of 2.5 feet to construct the amended cap. The seep capping areas for Alternative 2 are shown on **Figure 6-2**.

Alternative 2 would actively remediate approximately 0.2 acre and the remaining 10.6 acres would be remediated through MNR. The estimated sediment excavation volume is approximately 900 CY, excluding bulking during removal. Additional information is summarized below and in **Table 6-2**.

The FFS assumes that a total of six seeps would be remediated during a single mobilization. The six seeps include three seeps observed in the East Beach area in 2013, one seep observed in the North Shoal area in 2013, and an allowance for two additional seeps to be identified in the North Shoal area during predesign investigations as described in Section 6.2.4. The two seeps observed in the eelgrass on the East Beach and North Shoal would be remediated using MNR to avoid disturbing the habitat in that area.

6.3.2.1 Shallow Excavations and Dewatering

Working in the dry during lower tide periods as discussed under in Section 6.2, sediment in each NAPL seep area would be removed to a depth of approximately 2.5 feet in a 40-foot by 40-foot area. Each excavation area would be dewatered as described in Section 6.2. Because of the relatively small volume of water generated for Alternative 2, the water would be pumped to a temporary tank storage for particulate removal and then blended with the existing GWTP inflow.

6.3.2.2 Capping

After removing sediments in each seep location, the cap would be placed as described in Section 6.2 and shown in **Figure 6-3**. The cap is intended to intercept and adsorb NAPL constituents upwelling to the surface along existing NAPL-wetted pathways. Groundwater and seawater would continue to discharge to the beach surface; however, the NAPL would be adsorbed to the media at the base of the cap.

6.3.2.3 Future Cap Replacement

Alternative 2 does not include routine maintenance of the cap areas; however, the sorptive properties of the reactive layer may require replenishing if breakthrough is observed during the 100-year performance monitoring period. For FFS cost estimating purposes, it is assumed that 25 percent of the capped area in the North Shoal (1,200 square feet [SF]) and 25 percent of the capped area in the East Beach (1,200 SF) would require replacement in Year 9. In addition, 25 percent of the capped area in the East Beach (1,200 SF) would require replacement in Year 30. The additional replacement event for the East Beach assumes that NAPL expression rates are greater in this area due to the greater number of seeps observed. The small stockpile storage area near the southwest corner of the upland facility would be maintained to handle the relatively small volume of seep cap material to be removed, stabilized, and shipped for offsite disposal during replacement. Water from dewatering would be temporarily stored and transported offsite for disposal.

6.3.3 Alternative 3—Partial Excavation and Capping

Alternative 3 consists of constructing a series of caps over portions of the North Shoal and East Beach with the greatest potential for NAPL seeps and near-surface mobile NAPL occurrences based on the TarGOST® data. The conceptual capping areas, which total approximately 1.6 acres (71,000 SF), are shown on **Figure 6-4**. Three other seeps, located near or within the eelgrass beds would be mitigated using MNR to avoid disturbing the habitat in that area. This alternative would actively remediate approximately 1.6 acres and the remaining 9.2 acres would be remediated through MNR. The estimated sediment excavation volume is approximately 6,600 CY, excluding bulking during removal. Additional information is summarized below and in **Table 6-3**.

6.3.3.1 Shallow Excavations, Dewatering, and Capping

The capping areas would be excavated, dewatered, and capped as described for Alternative 2 in Section 6.2. Daily tides will constrain construction such that caps will be constructed in 40-foot by 40-foot sections that are contiguous, with approximately 10 percent overlap, across the defined areas. In areas higher up on the beach, it is expected that the daily tidal cycle will allow for longer working periods and allow larger segments to be capped at any one time. Consequently, the approach to excavating sediment and placing the cap material is assumed to proceed in segments with comparable daily production rates as noted for Alternative 2. Work in successive segments would likely proceed up the beach to optimize construction productivity with the lowest tide sets. The presence or absence of NAPL in cap excavation areas would also affect productivity. While the intent is to excavate sand to install the cap, if NAPL is encountered at the bottom of the excavation, additional impacted sand volume may be removed, or the active media thickness may be increased to add additional sorptive capacity to the cap. The potential for encountering NAPL in excavated material is greater in the North Shoal near boreholes 127, 043 and 044 and at East Beach boreholes 002, 008, 010, and 027.

For Alternative 3, pumped water would be pumped to the upland and temporarily containerized to allow solids to settle and then treated and discharged through the GWTP. The duration of the construction for Alternative 4 is estimated to be 4 months.

6.3.3.2 Future Cap Replacement

As described for Alternative 2, the Alternative 3 caps do not require routine maintenance; however, the sorptive media and other cap materials may require replenishing over time if breakthrough is noted during the 100-year performance monitoring period. For FFS cost estimating purposes, it is assumed that 25 percent of the capped area in the North Shoal (18,000 SF) and 25 percent of the capped area in the East Beach (18,000 SF) would require replacement in Year 9. In addition, 25 percent of the capped area in the East Beach (18,000 SF) would require replacement in Year 30. The additional replacement event for the East Beach assumes that NAPL expression rates are greater in this area due to the greater number of seeps observed.

Excavated cap material for stabilization and offsite disposal would be managed as for Alternative 2, using the small pad area near the southwest corner of the upland facility. Reactivation of the GWTP for cap replacement events is not planned given the dewatering treatment volumes and uncertainty on whether the GWTP would be available. During each of the two-cap repair mobilizations, it is assumed that the water from dewatering would be containerized, settled, and disposed offsite.

6.3.4 Alternative 4—Vertical Containment with Partial Excavation and Capping

Alternative 4 consists of containing lateral NAPL migration in areas with the highest potential for NAPL surface seeps and near-surface mobile NAPL being present. The representative process option for vertical containment include permanent steel sheet pile wall sections hydraulically driven or vibrated from the beach surface using land-based equipment during low tide conditions. The conceptual layout for Alternative 4 is shown in plan-view in **Figure 6-5** and in cross-section on **Figure 6-6**.

The performance expectation of this alternative is that the vertical barrier would prevent lateral NAPL migration, seep formation, and sheening from occurring. The amended capping component is similar to Alternative 3 and uses the same concepts for tidal working durations, shallow excavation, dewatering, materials handling, and capping. This alternative would actively remediate approximately 1.6 acres with amended capping with the remaining 9.2 acres remediated using MNR. The vertical sheet pile walls would enclose an area slightly larger than the total capping footprint of 1.8 acres. The estimated sediment excavation volume is approximately 6,600 CY, excluding bulking during removal. Additional information is summarized below and in **Table 6-4**.

6.3.4.1 Sheet Piles for Vertical Containment

Permanent steel sheet piling, with a total estimated length of 2,200 feet, would be installed to contain mobile NAPL areas as shown on **Figure 6-5**. The vertical steel sheets would be installed to a depth of approximately 20 feet below grade to contain the LNAPL and buoyant-neutral NAPL identified from the TarGOST® data. The vertical containment sheets also intercept NAPL sheen generated on water surface during ebb tide. The sheet pile walls would be driven just below the beach surface to maintain the current topography and coastal shoreline processes. Construction sequencing assumes wall installation followed by cap installation, with details to be further developed during design. Alternative 4 includes a nominal 15 percent allowance for deformation/refusal of sheets during installation.

One-half inch to three-quarter inch steel sheet section thicknesses are assumed to provide some capacity for sacrificial corrosion over time, but the sheets may require replacement. Design life and alternative sheet materials would be further evaluated following remedial design based on strength, long-term durability, and cost effectiveness. Fiberglass or vinyl represents alternate materials for further evaluation during remedial design. These alternate materials may be susceptible to gouging during installation and must be evaluated carefully. The wall sections would be sealed with epoxy-coated bentonite sealant or other low-permeability joint compound. Wall sections may also be joined or sealed to the existing upland sheet pile wall, depending on further evaluation during remedial design.

Standard hydraulic push or vibratory methods are expected to be suitable for installing the sheet pile walls in marine sands and gravels within the FFS Project Area. The need for additional staging preparation, use of temporary pads, mats, or other protective features would be further evaluated during design. Additional subsurface characterization such as cone-penetration probes and auger borings along barrier alignment shown data would be needed to support the remedial design of the vertical barrier. Geophysical testing may also be appropriate. The data from these investigations would be used to confirm sheet pile type and inform installation means and methods.

6.3.4.2 Groundwater Modeling to Assess Hydraulic Conditions

The MicroFEM cross-sectional groundwater model was used to evaluate hydraulic conditions associated with vertical barriers and capping (Appendix B). The model evaluated gradient changes through time steps during a typical representative tidal cycle. Changes to gradient were assessed for base case conditions before construction, and then compare to hydraulic conditions following wall installation and capping. Capping assumed permeability conditions of 0.3 feet per day consistent with conceptual parameters for the cap performance.

Results of the cross-sectional modeling indicate the new wall construction would not substantially affect hydraulic conditions. The predicted groundwater elevation near the barrier exhibited minimal change, with highest variability occurring very close to the new sheet pile wall but quickly attenuating. The marine sands and gravels in the intertidal area have a relatively high hydraulic conductivity and help promote tidal flux beneath the barrier, minimizing potential hydraulic impacts. The amended cap placed on the shoreward side of the vertical barrier would further address NAPL migration toward the beach surface. Modeling conclusions indicate that the presence of the wall and cap would not induce further NAPL migration or bypass of the wall.

6.3.4.3 Future Vertical Barrier and Cap Replacement

The steel sheets assumed for the FFS evaluation would corrode and degrade over time and are expected to require replacement in about Year 30. As for Alternatives 2 and 3, 25 percent of the capped area in the North Shoal (18,000 SF) and 25 percent of the capped area in the East Beach (18,000 SF) would require replacement in Year 9, and 25 percent of the capped area in the East Beach (18,000 SF) would require replacement in Year 30. During each mobilization for cap repairs, assumptions for excavated materials management and offsite disposal are the same as described for Alternative 3.

6.3.5 Alternative 5—Dredging

Alternative 5 would reduce the source volume of NAPL by dredging and excavating contaminated sediment to a depth of 10 feet below grade in the identified portions of the North Shoal and East Beach areas. By excavating these areas, substantial NAPL source material would be removed from the intertidal area. Excavation and dredging would be accomplished within sheet pile cofferdam systems, with water retained inside the enclosure for wet dredging/excavation. Conventional mechanical dredging equipment would be used inside the North Shoal enclosures. Land-based excavators would be staged from the adjacent upland to remove sediment from the East Beach enclosure. Following sediment removal in each enclosure, OC-amended sand would be placed at the base of the dredging/excavation cuts, with clean gravelly sand capping material placed to the existing beach surface to reestablish habitat. AC-amended sand is not targeted in the concept because the depth of placement is approximately 10 feet and concern about reducing dissolved concentration for the habitat is not as relevant. The reason for placing OC-amended sand is to provide some sorption at the base of the excavation and reduce NAPL mobility. The conceptual layout for Alternative 5 is shown in plan-view in **Figure 6-9** and in cross-section on **Figure 6-10**.

Alternative 5 would actively remediate approximately 1.6 acres and the remaining 9.2 acres would be remediated using MNR. The estimated sediment excavation and dredging volume is approximately 26,000 CY, excluding bulking during removal. Additional information is summarized below and in **Table 6-5**.

6.3.5.1 Dredging and Excavation and Sheet Pile Enclosure Concepts

Removal of NAPL-contaminated sediments to 10 feet below grade in the intertidal area is challenging because tidal fluctuations of up to about 15 feet occur twice daily. Water-based and dry-excavation approaches each have significant issues for implementation, productivity, and environmental protection. To develop the concept for Alternative 5, multiple construction options were evaluated by assessing the practicality of means of water- and land-based equipment. Conclusions are as follows:

- Sheet pile enclosures dams are a practical approach for containment but present a number of logistical and structural challenges requiring significant design analysis if Alternative 5 is selected.
- Wet dredging/excavation inside sheet pile enclosures contains contaminated media and negates reliance on suitable tide levels to float dredging equipment ‘reaching in’ from outside the enclosures.
- Wet dredging/excavation with equipment inside sheet pile enclosures allows more-continuous production than with equipment staged outside of the enclosure.
- Environmental clamshell dredge buckets and/or enclosed excavator buckets are assumed but may not be strictly necessary working inside the enclosures.

Key FFS-level criteria for sheet pile enclosures include the following:

- Adequate embedment depth to maintain a safe, stable dredge/excavation prism.
- Adequate wall height to maintain safe freeboard at high tide and contingency storm events.
- Adequate sealing of sheet sections to prevent release of NAPL and contaminated water from inside the enclosure.
- Adequate structural rigidity to resist deformation from external loading during high tide conditions.
- Management of water column height inside the enclosure to facilitate dredging/excavation but not create adverse internal loading during low tide conditions.
- Management of water column height inside the enclosure to avoid hydraulic conditions creating potential heave conditions on the outside of the enclosure during low tide.
- Avoidance of actions that would potentially destabilize the existing sheet pile wall around the upland area.

A preliminary geotechnical analysis was completed for initial evaluation of general sheet pile dimensions and configuration. A minimum sheet height of 45 feet was identified along with a nominal embedment depth of approximately 25 feet below grade. This embedment depth is needed to support adequately a sheet height of 16 feet or more above grade in the water column. This sheet length and embedment account for varying tidal water loads on the exterior of the enclosure. This configuration also assumes maintaining (optimally) a 12-foot water column inside the enclosure, in part to counterbalance the external water pressure at high tide. A nominal identified sheet section of AZ 28-700 or stronger was also identified.

Figures 6-9 and 6-10 illustrate sheet pile enclosure concepts addressing the above requirements. General enclosure areas are shown on **Figure 6-9** for the North Shoal and East Beach:

- North Shoal: Three enclosure areas
- East Beach: Three enclosure areas
- Total estimated length of the sheet pile: 2,200 feet

The approximate 16-foot wall height through the water column provides nominal free board working height in the water column. Sheet section types, thicknesses, joints, and sealants would be specified during design. Several options exist for sealing seams, to be determined. The size and weight of the sheets require use of a crane and vibratory driver for installation and extraction. Sheet pile delivery could be from the waterside by barges or transfer from upland trucks.

6.3.5.2 Backfill

While substantial NAPL would be removed from the intertidal area, some NAPL would be left below the limits of the dredge/excavation cells. An approximate three-inch sand lift would be placed immediately after the excavation to settle residuals. A second 3-inch sand lift with OC amendment would then be placed as a sequestration layer for residual NAPL. Bench testing during design would be required to establish the appropriate amendment and ratio for the amended backfill. Remaining capping material would be placed to the beach surface using gravelly sand to restore suitable marine habitat.

6.3.5.3 Water Management Inside Enclosures

Maintaining optimal water levels inside the enclosures is a critical to maintain a functional, safe working environment. A working assumption is that maintaining a water column depth of approximately 12 feet inside the enclosure provides a balance for internal and external sheet pile loading, with appropriate sizing and installation of the sheets. A related assumption is that this water column height would not induce heaving of the adjacent, external beach surface at low tide. Additional geotechnical analysis would be needed to evaluate further assumptions for managing water column height inside the enclosures during design.

Once capping was complete in an enclosure, the contaminated standing water inside the enclosure would be extracted by pumping for transfer to the upland GWTP. Fresh seawater would enter the enclosure over the cap before removing the sheet piles.

6.3.5.4 General Construction Sequencing

Overall construction sequencing assumes that the enclosure cells would be dredged sequentially, with upland staging and stockpiling space being a key constraint for balancing production.

Conceptual work sequencing for the North Shoal dredging is as follows:

1. A crane and support barge equipment set (Set A) installs the first sheet pile enclosure.
2. A dredging and materials barge equipment set (Set B) completes sediment removal and capping in the first enclosure while sheet pile (Set A) equipment completes the second enclosure adjacent to a common wall of the first enclosure.
3. Dredging Set B equipment moves to the second enclosure to dredge and cap while sheet pile (Set A) equipment removes the first enclosure and constructs the third enclosure.

4. Work proceeds until all enclosures are dredged, ending with equipment Set B dredging and capping the last enclosure and equipment Set B then removing the last sheet pile enclosure.

Dredged material from material barges inside the enclosures would be transferred over the enclosure wall to transport barges or directly haul vehicles in the upland (over the upland sheet pile wall) for dewatering and stabilization. Alternatively, dredged materials could be transferred to haul vehicles on the exposed beach at low tide. These vehicles would transfer materials to the upland area return back empty to intertidal the area.

For the East Beach, the proximity of the impacted sediment to the existing sheet pile wall offers the opportunity to consider using a long-arm clamshell bucket excavator located in the upland to remove sediment. The size and weight of equipment requires adequate setback to preserve the stability of the existing sheet pile wall. Additional structural support or load-bearing support platform may require further analysis and is not currently included in the FFS planning assumptions. Conceptual work sequencing for the East Beach excavation is as follows:

1. Sheet pile equipment Set A would install the first enclosure from nearshore. Alternatively, some combination of nearshore and upland installation equipment could be used.
2. Upland-staged excavation equipment Set C would remove sediment from the first enclosure and then place capping material. Set C equipment would reach into the enclosure to remove sediment and place it into transfer vehicles, containers, or directly onto upland dewatering pads.
3. Sheet pile (Set A) equipment completes the second enclosure while Set C excavates and caps the first enclosure.
4. Equipment Set C excavates and caps the last enclosure, followed by removal of the second sheet pile enclosure with equipment Set A.

The final installation plan would be based on the most comprehensive and updated information regarding the location of NAPL in the subsurface and geotechnical information obtained during predesign activities. The selected contractor may further optimize the containment approach and dredge segment size to economize footage of steel sheet piles, or use of alternative techniques where determined to be suitable.

6.3.5.5 Protection of Upland Sheet Pile Wall

Although the extraction volume of approximately 26,000 CY for Alternative 5 assumes vertical box cuts within the enclosures, it would likely be necessary to leave a supportive wedge buffer of undredged or unexcavated material next to the existing upland sheet pile wall to preserve the stability of that structure. Further geotechnical analysis of this issue would be needed as an additional design consideration. Current cut surfaces and volume estimates for Alternative 5 do not exclude this wedge material. Related protection issues must be considered for sheet pile enclosures installed near the upland sheet pile wall to avoid damage from contact, undermining, etc.

6.3.5.6 Dredged/Excavated Material Handling and Disposal

Similar to Alternatives 2, 3, and 4, dredged/excavated material would be dewatered and stabilized on upland storage pads (**Figure 6-1**). Pre-remediation site work would include construction of these pads, including an asphalt base. The relatively large removal (and capping fill) volume approximately 26,000 CY yards for Alternative 5 requires greater design and planning scrutiny to optimize the use of these storage areas that are limited to about 2-1/2 acres. Specific design considerations must account for moisture content, residence time, sequence of dewatering and amendment addition, and stockpile configuration and drainage.

6.3.5.7 Pre-Design Characterization

Alternative 5 requires further subsurface characterization to confirm dredging/excavation means and methods, and to support design of the temporary sheet pile wall. For purposes of this FFS, it is assumed that subsurface characterization consists of cone-penetration probe, auger borings, and related physical characterization of the sediment (e.g., shear strength) near the removal cells and along the enclosure alignments.

6.3.5.8 Construction Monitoring

Short-term monitoring requirements for Alternatives 2 through 4 are also applicable to Alternative 5. Additional inspections of the sheet pile enclosure and water quality monitoring outside of the sheet pile enclosures would also be needed for Alternative 5.

6.3.5.9 Future Maintenance

The 10-foot cap section for Alternative 5 is expected to preclude the need to replace and replenish cap materials in the future. Using gravely sand fill material to fill to the existing beach grade is expected to provide a permanent, stable surface without concerns for erosion. Seep areas would be removed in mobile zones dredged/excavated for this alternative. No maintenance is therefore envisioned as necessary for the Alternative 5 remedy components, although the remedy would be monitored over the 100-year life-cycle term as for the other alternatives.

SECTION 7
Detailed and Comparative Evaluation of Alternatives

The NCP defines nine criteria—classified as threshold, balancing, or modifying—to be used for the evaluation and analysis of remedial alternatives. The definitions of these criteria from the EPA RI/FS guidance (EPA, 1988) are presented below. Sustainability and green remediation metrics were considered under short-term effectiveness.

For the alternatives developed, the detailed analysis was performed using a two-step process. During the first step, alternatives were evaluated individually against the NCP criteria. In the second step, a comparative analysis of the alternatives was performed relative to each criterion to identify key trade-offs between the alternatives.

7.1 National Contingency Plan Threshold Criteria

To be eligible for selection, an alternative must meet the threshold criteria described below, or in the case of compliance with ARARs, a waiver, if necessary, must be justified.

7.1.1 Overall Protection of Human Health and the Environment

This criterion evaluates whether an alternative can protect human health and the environment. This criterion draws on the analyses performed for other evaluation criteria, particularly long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs. Evaluation of overall protection of human health and the environment offered by each alternative focuses on the following:

- Determining whether an alternative achieves adequate protection
- Considering how site risks associated with each exposure pathway are either eliminated, reduced, or controlled through treatment, engineering, or institutional controls
- Determining if an alternative will result in any unacceptable short-term or cross-media effects

7.1.2 Compliance with Applicable or Relevant and Appropriate Requirements

This evaluation criterion is used to determine whether an alternative meets the substantive portions of the federal and state ARARs defined in Section 4. It must be noted that under CERCLA, permits are not required for actions conducted onsite; however, the substantive requirements of the associated ARARs must be met.

CERCLA authorizes the waiver of an ARAR with respect to a remedial alternative if any of the following bases exist (EPA, 1988):

- The alternative is an interim measure that will become part of a total remedial action that will attain the ARAR
- Compliance with the requirement will result in greater risk to human health and the environment than other alternatives
- Compliance with the requirement is technically impracticable from an engineering perspective
- The alternative would attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, or limitation through use of another method
- With respect to a state requirement, the state has not consistently applied, or demonstrated the intention to consistently apply, the promulgated requirement in similar circumstances at other remedial actions within the state

- For Superfund-financed response actions only (such as for the Wyckoff OU-1 FFS Project Area), an alternative that attains the ARAR would not provide a balance between the need for protection of human health and the environment at the site and the availability of Fund monies to respond to other sites.

7.2 National Contingency Plan Balancing Criteria

Alternatives meeting the threshold criteria are further evaluated using the following five balancing criteria.

7.2.1 Long-Term Effectiveness and Permanence

The assessment against this criterion evaluates the long-term effectiveness of the alternatives in maintaining consistent protection of human health and the environment after the RAOs have been met. A key component of this evaluation is to consider the extent and effectiveness of controls that may be required to manage risk posed by treatment residuals and/or untreated waste. The long-term effectiveness of an alternative is assessed by considering the following two factors:

- Magnitude of residual risk assesses the residual risk remaining from untreated waste or treatment residuals at the conclusion of the remedial activities.
- Adequacy and reliability of controls evaluates the capability and suitability of controls, if any, that are used to manage treatment residuals or untreated wastes that remain at the site.

7.2.2 Reduction of Toxicity, Mobility, or Volume through Treatment

This evaluation criterion addresses the statutory preference for selecting remedial actions that employ treatment technologies resulting in the permanent and significant reductions of toxicity, mobility, or volume of the hazardous substances as their principal element. This preference is satisfied when treatment is used to reduce the principal threats at a site through destruction of toxic contaminants, irreversible reduction in contaminant mobility, or reduction of total volume of contaminated media. The following six factors are considered when evaluating alternatives against this criterion:

- The treatment processes the remedy would employ and the materials they would treat
- The amount of hazardous materials that would be destroyed or treated (including how the principal threat(s) would be addressed)
- The degree of expected reduction in toxicity, mobility, or volume measured as a percentage of reduction (order of magnitude)
- The degree to which the treatment is irreversible
- The type and quantity of treatment residuals remaining following treatment
- Whether the alternative satisfies the statutory preference for treatment as a principal element

Of particular importance in evaluating this criterion is the assessment of whether treatment is used to reduce principal threats, including the extent to which toxicity, mobility, or volume is reduced either alone or in combination.

7.2.3 Short-Term Effectiveness

This criterion assesses the effects of the alternative during its construction and implementation until the RAOs are met. Alternatives are evaluated with respect to potential effects on human health and the environment during their implementation. The following factors are considered when evaluating alternatives against this criterion:

- Protection of the community during remedial actions addresses any risk resulting from the remedy implementation. Examples include dust from excavations, transportation of hazardous materials, and air-quality impacts.

- Protection of workers during remedial actions assesses threats potentially posed to workers and the effectiveness and reliability of protective measures that would need to be taken.
- Environmental impacts consider the environmental impacts potentially resulting from the construction and implementation of the alternative, and assess the reliability of available mitigation measures for preventing or reducing those impacts.

Time until RAOs are achieved includes an estimate of the time required to achieve protection for either the entire site or individual elements associated with specific site areas or threats.

7.2.4 Sustainability

The EPA Office of Solid Waste and Emergency Response (OSWER) has a goal to implement sustainable and/or green practices as part of remedial actions, where practicable. The OSWER and EPA Office of Superfund Remediation and Technology Innovation document titled *Superfund Green Remediation Strategy* (EPA, 2010) includes the following initiatives for green remediation practices during remediation:

- Maximize the use of renewable energy and identify methods for increasing energy efficiency.
- Reduce the use of natural resources and energy during remedial actions.
- Integrate clean, renewable, and innovative energy sources and advanced diesel technologies
- Encourage operational practices that minimize total emissions.
- Establish mechanisms to track and increase water conservation, reuse of treated water, and recharge of aquifers.
- Identify additional onsite or offsite uses of materials or energy otherwise considered waste.

EPA Region 10 also has a *Clean and Green Policy* (EPA, 2009), which directs the Region to “enhance the environmental benefits of federal cleanup programs by promoting technologies and practices that are sustainable.” The objectives of this policy are to:

- Protect human health and the environment by achieving remedial action goals
- Support sustainable human and ecological use and reuse of remediated land
- Minimize impacts to water quality and water resources
- Reduce air toxics emissions and greenhouse gas production
- Minimize material use and waste production
- Conserve natural resources and energy

The alternatives considered in this evaluation are considered qualitatively against a number of sustainability metrics that include these principal elements. The intent of this evaluation is to highlight differences among the alternatives with respect to sustainability and green practices or elements.

7.2.5 Implementability

The implementability criterion assesses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during the remedy implementation. The following factors are considered when evaluating alternatives against this criterion:

- Technical feasibility includes the following:
  - Construction and operation relates to the technical difficulties and unknowns associated with a technology.
  - Reliability of technology focuses on the likelihood that technical problems associated with the implementation would result in schedule delays.
  - Ease of undertaking additional remedial action includes a discussion of what, if any, future remedial actions may need to be performed and how difficult it would be to implement those actions.

  - Monitoring considerations addresses the ability to monitor the effectiveness of the remedy and includes an evaluation of exposure risk should monitoring be insufficient to detect a failure.

- Administrative feasibility assesses the activities required to coordinate with other offices and agencies (e.g., access, right-of-way).
- Availability of services and materials includes an evaluation of the availability of appropriate offsite treatment, storage capacity, and disposal services; necessary equipment and specialists; services and materials (including the potential for competitive bidding); and the availability of prospective technologies.

7.2.6 Cost

This criterion includes all the engineering, construction, and O&M costs incurred over the life of the project. The evaluation of cost includes three principal components:

- Capital costs includes direct (construction) and indirect (non-construction and overhead) costs. Equipment, labor, and materials required for the installation of the remedy are considered direct costs. Indirect costs consist of those expenses related to the engineering, financial, and other services that are necessary to complete the remedy installation but are not part of the actual installation or construction activities.
- Annual O&M costs refer to post-construction expenditures required to ensure continued effectiveness of the remedial action. Components of annual O&M costs include auxiliary materials, monitoring expenses, equipment or material replacement, and 5-year review reporting.
- Present worth analysis is a method of evaluating expenditures such as construction and O&M that occur over different lengths of time. This allows costs for remedial alternatives to be compared by discounting all costs to the year that the alternative is implemented. The present worth of a project represents the amount of money, which if invested in the initial year of the remedy and disbursed as needed, would be sufficient to cover all costs associated with the remedial action.

The level of detail required to analyze each alternative with respect to the cost criteria depends on the nature and complexity of the site, the types of technologies and alternatives being considered, and other project-specific considerations. The analysis is conducted in sufficient detail to understand the significant aspects of each alternative and to identify the uncertainties associated with the evaluation.

The cost estimates presented for each alternative have been developed for comparing the alternatives. The final costs of the selected remedy would depend on actual labor and material costs, competitive market conditions, final project scope, the implementation schedule, and other variables. The cost estimates are order-of-magnitude estimates with an intended accuracy range of plus 50 to minus 30 percent. The range applies only to the alternatives as they are described in this report and does not account for changes in the scope of the alternatives.

7.3 National Contingency Plan Modifying Criteria

The two modifying criteria are state acceptance and community acceptance. The evaluation of these criteria is typically not completed until state and public comments are received on the Proposed Plan. The State of Washington, Affected Tribes, and other stakeholders and regulatory agencies have been engaged and provided input for the Wyckoff/Eagle Harbor Superfund Site including OU-1 for many years. The involvement of these parties includes periodic review and input of investigation data for FFS Project Area, development of RAOs, and development of remedial technologies and alternatives.

7.4 Detailed Analysis of Alternatives

Detailed analyses of the alternatives against the NCP criteria are presented in **Table 6-6**. This table provides only the present-worth costs for comparison purposes. **Table 6-7** presents the summarized capital costs and present-worth O&M costs for each alternative calculated using the 7 percent discount rate specified by *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* (EPA, 2000b). In addition, **Table 6-7** provides a present worth cost estimate comparison made using the 1.4 percent rate published in *Appendix C - Discount Rates for Cost Effectiveness, Lease Purchase, and Related Analyses*, *Guidelines and Discount Rates for Benefit Cost Analysis of Federal Programs* (OMB Circular A-94), effective June 2015. Present worth costs calculated using the 7 percent discount rate are intended to show the sensitivity of each alternative's total present value cost to the discount rate. Appendix F contains the detailed cost estimates. Non-discounted O&M costs for each alternative are also presented for comparison.

7.5 Comparative Analysis

The comparative analysis of alternatives is provided in **Table 6-8**. The following sections explain the relative ranking of the alternatives for each of the seven NCP criteria and discusses sustainability considerations among the disposal options. The sub criteria within each of the seven NCP criteria were considered during the detailed and comparative evaluation; however, the following discussion focuses on the ranking of the alternatives with respect to the threshold and balancing criteria.

7.5.1 Overall Protection of Human Health and the Environment

All alternatives except Alternative 1 satisfy this threshold criterion, as noted in **Table 6-8**. Alternative 1, No Action, would not provide overall protection of human health and the environment and would not achieve the RAOs for the site. Exposure to the contaminated sediments would continue to pose human health and ecological risks and NAPL migration from the sediment to beach surface, and the associated potential for direct contact with NAPL, would remain. Natural recovery processes occurring at the site would continue to do so; however, there would be no associated monitoring to assess site recovery or notices maintained to inform the public or exposure risks.

Alternatives 2 through 5 would all provide overall protection of human health and the environment and would achieve the RAOs for the site. For each alternative, the RAOs would be met immediately upon completion in the actively remediated areas (i.e., those areas that are capped or dredged). The remainder of OU-1 would eventually meet the RAOs through MNR – it is expected that the timeframe for that to occur would be shortest for Alternative 5 and longest for Alternative 2, because the rate of recovery would be largely dependent upon the degree of source control and/or removal that is achieved in areas that are actively remediated.

7.5.2 Compliance with Applicable or Relevant and Appropriate Requirements

Because no action is taken, Alternative 1 would not comply with the chemical- or trigger compliance with action- and location-specific ARARs. Alternatives 2 through 5 are designed and would be implemented to comply with the substantive components of the ARARs.

7.5.3 Long-Term Effectiveness and Permanence

Alternative 1 would not result in any significant change in risk associated with contaminated sediment or NAPL exposure. This alternative receives a low ranking for this criterion. As presented in **Table 6-8**, performance with respect to long-term effectiveness and permanence increases from less well for Alternatives 1 and 2, to moderately well for Alternatives 3 and 4, to very well for Alternative 5.

Alternatives 3 and 4 are considered to have a moderate degree of long-term effectiveness and permanence. Both alternatives would meet RAOs and would be protective of human health and the environment, with Alternatives 3 and 4 meeting the RAOs over a larger area than Alternative 2. These two alternatives are ranked as performing moderate well compared to Alternative 5. The added degree of source control from the vertical barrier in Alternative 4 or the removal in Alternative 5, are expected to increase the recovery rate in the areas of the site managed using MNR. Alternative 5 is considered to have a high degree of effectiveness because a much greater volume of contaminated sediment and potentially mobile NAPL would be removed, considerably reducing the amount of source material remaining in OU-1.

7.5.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 1 does not include a treatment component; therefore, it is ranked low for this criterion. Capping under Alternatives 2, 3, and 4 are presented in **Table 6-8** as having increasing degrees of treatment capability achieved through progressively larger treatment areas. Alternative 5 incorporates OC amendments and treats the largest volume of NAPL contaminated sediment, and therefore, was ranked higher than the other alternatives.

The adsorbent components included in the conceptual cap designs in Alternatives 2 through 4, as well as the adsorbent component of the thicker cap in Alternative 5, reduce NAPL mobility and are considered treatment technologies. The overall reduction in NAPL mobility expected to be achieved by these amendments is considered to be high; the relative rankings are based on the areas capped under Alternatives 2, 3, and 4, and the reliance upon treatment through capping as a primary component of the remedy for Alternative 5. The area to be actively capped under Alternative 2 is the smallest, approximately 0.3 acre; therefore, this alternative is rated lower. Alternatives 3 and 4 would cap 1.6 acres each; therefore, they were rated as performing moderately well. Alternative 5 is assigned the highest ranking because overall it treats the highest volume of material (26,000 CY versus 6,600 CY for Alternatives 2 and 3) through removal, stabilization, and offsite disposal.

7.5.5 Short-Term Effectiveness

The potential risks to the community, workers, and the environment for Alternatives 2 through 5 are generally similar, except that Alternatives 4 and 5 also include potential vibration and noise concerns associated with the sheet pile installation. All four alternatives have been conceptualized to avoid any active remediation within the eelgrass and the magnitude of the short-term risks are a largely function of the amount of beach area that is disrupted and the anticipated construction duration.

The short-term effectiveness of Alternative 1 is considered high because no construction activities would occur. Alternative 2 also is ranked high with respect to short-term effectiveness due to a construction duration of possibly only about 2 months and comparatively small area of beach disrupted (estimated to be 0.3 acre).

Alternatives 3 and 4 are both ranked as having moderate short-term effectiveness. The estimated construction duration for both alternatives is approximately 4 months and the area disrupted is approximately 1.6 acres for both alternatives. Even though the area disrupted by Alternative 3 is slightly greater, the two alternatives are ranked the same because of the additional short-term risks to workers and the environment posed by the sheet pile installation required in Alternative 4.

Alternative 5 would also disrupt approximately 1.6 acres of beach habitat for an estimated 8 months; however, it is expected that because of the nature of the work (excavation to depth of 10 feet) the actual area of disturbance would be greater. This alternative removes substantial NAPL volume following construction and provides high short-term effectiveness. However, Alternative 5 also includes the risks associated with the installation (and subsequent removal) of sheet pile and includes greater potential risks for surface water impacts during the sheet pile installation and sediment removal, hence it was rated comparable to Alternatives 3 and 4.

Alternatives 3, 4, and 5 implement more aggressive remediation than Alternative 2 and they are expected to achieve the RAOs faster. As discussed in Section 4, EPA's goal is to achieve the RAOs within 10 years. Alternative 2 relies more heavily on MNR than the other alternatives, making the 10-year period for meeting the RAOs more difficult to achieve. The ability to fully achieve RAOs will depend on the time for MNR to complete remediation after active technologies are applied to each of their respective target areas.

7.5.6 Implementability

This comparison focuses on the expected key constraints to the implementability of the conceptual alternatives for OU-1. These include the limited working windows due to the tide cycle, the relatively small upland area available for material and equipment staging, the availability of materials, ability to manage and treat water, and the stability of the existing sheet pile wall around the upland area.

Alternative 1 is considered readily implementable (high ranking) because no remedial actions would be performed; however, this alternative would not be administratively feasible because it would not meet any of the RAOs for the site.

Alternative 2 is also considered readily implementable. The proposed seep areas can be remediated within the tidal window and a relatively small amount of sediment and capping material would require storage and management. Additionally, with the relatively small amount of capping materials required, availability of specialty reagents is not anticipated to be a constraint on production. Alternative 2 is also not expected to result in significant amounts of water requiring treatment – water would be containerized and disposed offsite. This alternative also does not include any excavation near the existing upland sheet pile wall, so the stability of that wall should not affect the implementation of Alternative 2.

Alternatives 3 and 4 are ranked has having moderate implementability. The areas to be remediated are larger than Alternative 2 and construction sequencing based on the tide cycles would be needed to maximize production and transportation of the dredged material to the staging area could limit production rates. The amount of water that could potentially be generated would also be greater and the onsite GWTP would be restarted and managed; however, the capacity of this system is limited and it is anticipated that water would need to be temporarily stored in the upland and slowly transferred to the GWTP. The availability of specialty reagents required for cap construction (i.e., AquaGate) could be limited and require advance coordination with appropriate vendors. This alternative includes relatively shallow excavation, approximately 3 feet, near the existing upland sheet pile wall, so the stability of the wall should not affect the implementation of these alternatives. Alternative 4 is considered to have a slightly lower implementability, relative to Alternative 3, because the sequencing and installation of the new sheet pile containment wall would result in slightly greater logistical complexity.

Alternative 5 is considered to have moderate implementability because the installation of the sheet pile dredge cells and associated logistical management would pose significant engineering challenges. Additionally, a large volume of sediment would need to be managed and the minimal amount of upland staging area available and a multiple step transport process from the work area are expected to limit production rates. The stability of the existing sheet pile wall around the upland is also a critical component of the overall implementability of this alternative – if the wall requires additional bracing or support during the removal action, the engineering and implementation challenges previously noted would be exacerbated.

7.5.7 Cost

A summary of the estimated costs for each alternative is provided in **Table 6-7**. Appendix F presents the detailed cost estimates and associated assumptions. The detailed components presented in **Tables 6-2 through 6-5** provide the basis of the cost estimate for each alternative. There were no estimated costs associated with Alternative 1.

Estimated total capital plus 7 percent discounted O&M costs ranged from $3.1 million for Alternative 2 to $29.4 million for Alternative 5. The total cost for Alternative 3 of $11.8 million is considerably lower than Alternative 4 at $15.2 million. Non-discounted O&M costs were also estimated, and they are substantially higher than discounted O&M costs.

7.5.8 Sustainability

The sustainability evaluation for Alternatives 2 through 5 is provided in **Table 6-9**. This qualitative evaluation was performed by considering five areas of potential sustainability impacts:

- Energy consumption and fossil fuel depletion
- Waste reduction, reuse, and recycling
- Greenhouse gas and other air emissions

- Transportation impacts
- Water requirements and impacts on water resources

The overall ranking of the sustainability impacts for each alternative is as follows:

- Alternative 1: Not evaluated, no action taken
- Alternative 2: Low
- Alternative 3: Moderate
- Alternative 4: Moderate
- Alternative 5: High

7.6 Remedial Design Considerations

The evaluations performed in this FFS have identified a number of elements that may require further consideration during the remedial design. The surveys, evaluations, and analyses listed below are not prescriptive or inclusive, but simply summarize possible data collection activities identified during the development and analysis of alternatives.

In addition to determining NAPL seepage rates and properties, other data collection activities and surveys performed during the remedial design may include high-resolution bathymetry, habitat, and TarGOST® surveys to refine volumes, footprints, and establish baseline conditions prior to remedial action. Data could also be collected to determine if it would be feasible and cost-effective to segregate clean and NAPL-impacted sediment during removal and handling in order to reduce the amount of material requiring offsite disposal.

Bench-scale testing would be needed to support the cap design and should be considered in order to determine the stabilization materials and dosages. These evaluations should also confirm that the stabilized materials meet the acceptance criteria of the disposal facilities.

Alternatives 4 and 5, if selected would both require collection of additional geotechnical data to establish the sheet pile specifications. Alternative 5 would also likely require additional evaluations of the existing upland sheet pile wall to determine the structural integrity of the wall and to determine what type of bracing or support would be required to prevent damage to the wall during sediment removal.

SECTION 7
References

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Tables

TABLE 2-1

Chronology of Events and Activities at the Wyckoff/Eagle Harbor Superfund Site

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Event/Activity	Date
The Wyckoff/Eagle Harbor site was added to the National Priority List (NPL)	1987
Completion of the Remedial Investigation (RI)	1989
Completion of the Feasibility Study (FS) for Eagle Harbor	1991
Removal Action – Placement of sand cap over 21.4 hectares of contaminated sediments	1993-1994
Construction monitoring of removal action	1993-1994
EPA completed ROD for the East Harbor OU, which included the following elements; (1) monitor and maintain the existing sediment cap, additional capping in remaining subtidal areas of concern; (2) monitor success of natural recovery in intertidal areas; (3) enhance existing institutional controls to reduce public exposure to contaminated fish and shellfish; (4) demolish in-water structures	1994
Final Focused RI for the Groundwater Operable Unit	1994
Baseline, Year 0 monitoring of subtidal cap	1994
Year 1 monitoring of subtidal cap	1995
Year 3 monitoring of subtidal cap	1997
RI for the Wyckoff Soil and Groundwater Operable Units	1997
Removal of in-water structures (e.g., piers and pilings)	1998-1999
1999 OMMP Addendum	1999
Year 5 monitoring of subtidal cap	1999
Installation of sheet pile wall around upland site	1999-2001
Intertidal investigation around the Wyckoff facility	1999-2002
Placement of Phase II subtidal cap	2000-2001
Placement of Phase III subtidal nearshore and intertidal cap	2001-2002
EPA created habitat Mitigation Beach at West Beach and placed Phase III subtidal nearshore and intertidal cap	2001-2002
2002 OMMP Addendum	2002
Year 8 monitoring of subtidal cap, intertidal cap, Mitigation Beach, and East Beach natural recovery	2002
First 5-Year Review	2002
Surface sediment samples in the visibly-contaminated areas of the West Beach Mitigation Beach	2005
West Beach intertidal sediment investigations	2005-2006
Second 5-Year Review	2007
Explanations of Significant Difference (ESD) for the West Beach Exposure Barrier System (EBS)	2007
Construction of the West Beach EBS	2007-2008
2011 OMMP Addendum	2011

TABLE 3-1

EPA Fingerprint Analysis of Contaminants for Wyckoff Historical Upland NAPL Samples

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Compound / Sample Name:	PW3 LNAPL	PW4 LNAPL	PW5 DNAPL	PW6 DNAPL	PW6 LNAPL	PW8 DNAPL	PW9 DNAPL	Average	Mass fraction (%)
Toluene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.000
Ethylbenzene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.000
m,p-Xylene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.000
o-Xylene	0.0	2.2	0.0	0.0	0.0	0.0	2.4	0.65	0.065
Phenol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.000
Naphthalene	305.7	335.3	400.6	376.3	298.0	333.7	385.7	347.9	34.790
2-Methylnaphthalene	148.1	166.9	74.9	70.7	135.8	128.2	156.4	125.9	12.587
Acenaphthylene	2.2	2.3	2.4	2.3	2.3	2.3	2.3	2.3	0.231
Acenaphthene	24.8	22.0	31.0	30.1	20.6	29.0	31.1	26.9	2.694
Dibenzofuran	13.4	10.7	23.0	24.4	10.7	20.5	26.1	18.4	1.841
Fluorene	12.4	9.4	25.7	27.6	10.0	22.1	25.6	19.0	1.896
Pentachlorophenol	2.4	0.0	2.5	0.0	2.4	2.4	0.0	1.4	0.138
Phenanthrene	25.7	19.4	61.8	0.0	20.7	27.6	63.7	31.3	3.128
Anthracene	4.1	4.0	6.8	7.0	4.2	5.9	8.2	5.8	0.575
Carbazole	0.0	0.0	4.9	4.7	2.7	4.2	6.6	3.3	0.329
Fluoranthene	12.0	8.1	26.9	26.4	9.1	23.7	21.7	18.3	1.828
Pyrene	7.1	5.1	14.8	14.3	5.6	13.0	11.3	10.2	1.016
Benz(a)anthracene	2.6	2.3	4.1	3.7	2.4	3.9	2.9	3.1	0.314
Chrysene	2.6	2.4	3.8	3.5	2.5	3.6	2.8	3.0	0.303
Benzo(b)fluranthene	2.4	2.3	2.8	2.6	2.4	2.7	2.4	2.5	0.250
Benzo(k)fluoranthene	2.3	2.2	2.6	2.4	2.3	2.5	2.3	2.4	0.238
Benzo(a)pyrene	2.4	2.3	2.7	2.5	2.4	2.6	2.4	2.5	0.246
Indeno(1,2,3-cd)pyrene	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.3	0.032
Dibenzo(a,h)anthracene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.000
Benzo(g,h,i)perylene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.000
Sum	570	597	691	599	534	630	754	625	62.501
Total PAH	568	595	684	594	529	624	745	620	125.001
non-PAH	432	405	316	406	471	376	255	380	37.499

Notes:

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

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

TABLE 3-2

Solid Phase Micro-Extraction Analytical Testing Results for Polycyclic Aromatic Hydrocarbons[1]

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

	Naphthalene	Fluorene	Acenaphthene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Chrysene	Benzo[a] anthracene	Benzo[b] fluoranthene	Benzo[k]f luoranthene	Benzo[a[pyrene	Dibenzo[ah] anthracene	Benzo[ghi]peryl ene + Indeno[1,2,3-cd]pyrene	Total PAHs [2]
Surface Water Quality Criteria in ng/L	**4.9×10^6 MTCA**	**3.46×10^6 MTCA**	**6.4×10^5 MTCA**	**Not Established**	**2.64×10^7 MTCA**	**9×10^4 MTCA**	**2.59×10^6 MTCA**	**18 CWA**	**18 CWA**	**18 CWA**	**18 CWA**	**18 CWA**	**18 CWA**	**18 CWA**	**Not Established**
Sample Designation and Interval in cm															
Pore Water Transect A Samples															
WYOU-PW-A1-3/5	669	ND	ND	ND	33	78	72	2.3	5.4	0.9	0.4	0.5	ND	ND	861
WYOU-PW-A1-5/7	1,212	ND	ND	ND	38	54	57	1.4	3.5	ND	0.3	0.3	ND	ND	1,366
WYOU-PW-A1-13/15	1,054	ND	192 J	ND	35	69	148	1.0	4.4	0.9	0.4	0.6	ND	ND	1,505
WYOU-PW-A1-15/17	1,083	ND	202 J	ND	100	95	213	2.0	6.2	1	0.5	0.7	ND	ND	1,703
WYOU-PW-A1-23/25	1,485	434	2,674	793	2,601	1,939	1,161	6.2	34	2.9	1.4	2.4	ND	ND	11,135
WYOU-PW-A1-25/27	994	656	3,467	1,742	4,882	4,188	2,231	14	87	11	3.9	7.7	ND	ND	18,283
WYOU-PW-A2-3/5	425	ND	ND	57 J	32	55	75	0.5	2.3	0.5	0.3	0.3	ND	ND	648
WYOU-PW-A2-5/7	410	ND	ND	60 J	34	81	92	0.8	2.6	0.6	0.3	0.4	ND	ND	681
WYOU-PW-A2-13/15	343 J	ND	ND	60 J	69	328	280	0.9	3.1	0.8	0.3	0.4	ND	ND	1,085
WYOU-PW-A2-15/17	269 J	ND	ND	48 J	131	1,261	883	2.5	7.5	1	0.3	0.4	ND	ND	2,603
WYOU-PW-A2-23/25	146 J	666	ND	ND	351	4,042	3,644	8.4	30	1.2	0.6	0.9	ND	ND	8,889
WYOU-PW-A2-25/27	113 J	932	ND	ND	498	8,516	6,887	23	85	3	1.2	2.1	ND	ND	17,059
WYOU-PW-A3-3/5	443	158 J	93 J	80 J	9 J	47	64	0.7	2.6	1.1	0.4	0.5	ND	ND	898
WYOU-PW-A3-5/7	416	ND	ND	98 J	15	35	63	0.9	2.9	1.4	0.5	0.6	ND	ND	634
WYOU-PW-A3-13/15	422	ND	ND	7 J	4 J	13	41	ND	1.5	1.3	0.4	0.6	ND	ND	492
WYOU-PW-A3-15/17	377 J	ND	ND	14 J	5 J	11	51	0.3 J	1.8	1.6	0.5	0.7	ND	ND	464
WYOU-PW-A3-23/25	446	ND	ND	23 J	ND	27	64	1.0	2.9	2.3	0.7	1.1	ND	ND	569
WYOU-PW-A3-25/27	597	ND	ND	ND	11	24	63	0.9	2.8	2.0	0.6	0.9	ND	ND	702
Pore Water Transect B Samples															
WYOU-PW-B1-3/5	1,895	369	491	121	39	50	135	1.6	3.4	0.9	0.4	0.5	ND	ND	3,107
WYOU-PW-B1-5/7	1,064	ND	133 J	57 J	26	85	182	0.9	2.4	0.8	0.3	0.4	ND	ND	1,552
WYOU-PW-B1-13/15	510	ND	ND	35 J	40	52	296	0.7	1.6	0.7	0.4	0.5	ND	ND	937
WYOU-PW-B1-15/17	624	ND	ND	31 J	60	41	374	1.0	2.0	0.9	0.4	0.6	ND	ND	1,135

TABLE 3-2

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Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

	Naphthalene	Fluorene	Acenaphthene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Chrysene	Benzo[a] anthracene	Benzo[b] fluoranthene	Benzo[k]f luoranthene	Benzo[a]pyrene	Dibenzo[ah] anthracene	Benzo[ghi]peryl ene + Indeno[1,2,3-cd]pyrene	Total PAHs [2]
Surface Water Quality Criteria in ng/L	**4.9×10^6 MTCA**	**3.46×10^6 MTCA**	**6.4×10^5 MTCA**	**Not Established**	**2.64×10^7 MTCA**	**9×10^4 MTCA**	**2.59×10^6 MTCA**	**18 CWA**	**18 CWA**	**18 CWA**	**18 CWA**	**18 CWA**	**18 CWA**	**18 CWA**	**Not Established**
WYOU-PW-B1-23/25	385 J	ND	ND	21 J	61	50	471	1	2.8	1.3	0.6	0.9	ND	ND	993
WYOU-PW-B1-25/27	359 J	ND	ND	25 J	67	73	662	2.2	4.8	2.1	0.8	1	ND	ND	1,198
WYOU-PW-B2-3/5	415	ND	ND	20 J	ND	8	16	0.5	0.9	0.5	0.2	0.2	ND	ND	461
WYOU-PW-B2-5/7	318 J	ND	ND	10 J	ND	4	13	0.5	0.8	0.5	0.2	0.3	ND	ND	347
WYOU-PW-B2-13/15	359 J	57 J	ND	30 J	7 J	3 J	10	0.3	0.4	0.3	0.1 J	0.2	ND	ND	467
WYOU-PW-B2-15/17	333 J	ND	ND	45 J	16	4 J	10	0.2 J	0.3	0.2	0.1 J	0.1	ND	ND	410
WYOU-PW-B2-23/25	371 J	ND	ND	78 J	212	29	98	16	13.2	3.4	1.0	1.3	ND	ND	823
WYOU-PW-B2-25/27	414	ND	ND	71 J	207	24	101	28	23	6.8	2.2	3.2	ND	ND	880
WYOU-PW-B3-3/5	315 J	ND	ND	44 J	17	55	57	1.9	5.2	1.7	0.5	0.7	ND	ND	499
WYOU-PW-B3-5/7	332 J	ND	ND	55 J	15	43	43	1.4	4	1.5	0.4	0.6	ND	ND	496
WYOU-PW-B3-13/15	417	ND	ND	17 J	3 J	20	30	0.9	3	1	0.3	0.4	ND	ND	492
WYOU-PW-B3-15/17	393	ND	ND	ND	6 J	19	36	0.8	2.7	1	0.3	0.5	ND	ND	460
WYOU-PW-B3-23/25	459	ND	ND	ND	8 J	15	39	0.9	2.5	1.4	0.4	0.7	ND	ND	526
WYOU-PW-B3-25/27	426	ND	ND	ND	6 J	13	38	0.7	2.4	1	0.3	0.5	ND	ND	488
Pore Water Transect C Samples															
WYOU-PW-C1-3/5	517	ND	221 J	94 J	15	45	45	1.8	3.8	0.57	0.27	0.29	ND	ND	943
WYOU-PW-C1-5/7	520	ND	565	125	25	42	60	1.4	3.2	0.57	0.21	0.24	ND	ND	1,342
WYOU-PW-C1-13/15	399	191 J	222 J	156	24	24	26	0.55	1.40	0.26	0.12	0.19	ND	ND	1,043
WYOU-PW-C1-15/17	423	ND	ND	43 J	ND	9	20	0.4	0.86	0.17	0.08 J	0.12 J	ND	ND	497
WYOU-PW-C1-23/25	349 J	ND	ND	25 J	ND	5 J	20	0.28 J	0.75	0.16	0.08 J	0.08 J	ND	ND	401
WYOU-PW-C1-25/27	464	ND	ND	27 J	ND	7	20	0.35	0.87	0.14 J	0.08 J	0.08 J	ND	ND	520
WYOU-PW-C2-3/5	615	ND	ND	21 J	ND	11	18	0.55	1.22	0.45	0.18	0.25	ND	ND	669
WYOU-PW-C2-5/7	1,072	ND	ND	17 J	ND	11	17	0.69	1.14	0.39	0.17	0.20	ND	ND	1,119
WYOU-PW-C2-13/15	2,347	ND	ND	22 J	ND	4	26	0.37	0.97	0.42	0.17	0.24	ND	ND	2,402
WYOU-PW-C2-15/17	3,444	ND	ND	17 J	ND	4 J	24	0.37	0.93	0.35	0.16	0.20	ND	ND	3,491

TABLE 3-2

Solid Phase Micro-Extraction Analytical Testing Results for Polycyclic Aromatic Hydrocarbons[1]

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Surface Water Quality Criteria in ng/L	Naphthalene	Fluorene	Acenaphthene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Chrysene	Benzo[a] anthracene	Benzo[b] fluoranthene	Benzo[k]f luoranthene	Benzo[a[pyrene	Dibenzo[ah] anthracene	Benzo[ghi]peryl ene + Indeno[1,2,3- cd]pyrene	Total PAHs ²
	4.9 x 10^6 MTCA	**3.46 x 10^6 MTCA**	**6.4 x 10^5 MTCA**	**Not Established**	**2.64 x 10^7 MTCA**	**9 x 10^4 MTCA**	**2.59 x 10^6 MTCA**	**18 CWA**	**18 CWA**	**18 CWA**	**18 CWA**	**18 CWA**	**18 CWA**	**18 CWA**	**Not Established**
WYOU-PW-C2-23/25	26,144	ND	ND	30 J	ND	6	46	0.18 J	1.02	0.52	0.21	0.24	ND	ND	26,228
WYOU-PW-C2-25/27	79,273	ND	587	30 J	ND	5 J	52	0.30 J	1.04	0.49	0.23	0.29	ND	ND	79,949
WYOU-PW-C3-3/5	402	ND	ND	18 J	ND	8	48	0.60	0.77	0.22	0.09	0.1	ND	ND	479
WYOU-PW-C3-5/7	419	ND	ND	18 J	ND	5	41	0.54	0.66	0.21	0.08	0.08	ND	ND	485
WYOU-PW-C3-13/15	533	ND	ND	24 J	ND	4 J	11	ND	0.57	0.25	0.10 J	0.11 J	ND	ND	573
WYOU-PW-C3-15/17	488	ND	ND	25 J	ND	3 J	9	ND	0.65	ND	0.11 J	0.11 J	ND	ND	526
WYOU-PW-C3-23/25	486	ND	ND	21 J	ND	3 J	7	0.21 J	0.56	0.22	0.09 J	0.07 J	ND	ND	517
WYOU-PW-C3-25/27	432	ND	ND	20 J	ND	ND	9	ND	0.48	0.23	0.09 J	0.10 J	ND	ND	461
Surface Water Location A Samples															
WYOU-SW-A-3/5	325 J	ND	ND	ND	2 J	14	11	0.39	1.07	0.30	0.13	0.13	ND	ND	355
WYOU-SW-A-5/7	327 J	ND	ND	ND	ND	13	11	0.33	0.95	0.27	0.10	0.10	ND	ND	353
WYOU-SW-A-13/15	374	ND	ND	29 J	2 J	14	11	0.28	1.00	0.25	0.09	0.08	ND	ND	432
WYOU-SW-A-15/17	294 J	ND	ND	15 J	ND	11	11	0.38	0.97	0.19	0.09	0.09	ND	ND	333
WYOU-SW-A-23/25	343	ND	ND	19 J	ND	11	10	0.27	0.96	0.25	0.09	0.08	ND	ND	385
WYOU-SW-A-25/27	372	ND	ND	19 J	ND	12	10	0.35	1.03	0.32	0.11	0.11	ND	ND	416
Surface Water Location B Samples															
WYOU-SW-B-3/5	296 J	ND	ND	ND	ND	8	7	0.34	0.97	0.37	0.13	0.14	ND	ND	312
WYOU-SW-B-5/7	364	ND	ND	ND	ND	9	8	0.29	1.00	0.36	0.13	0.13	ND	ND	383
WYOU-SW-B-13/15	350	ND	ND	ND	ND	8	8	0.35	0.95	0.25	0.10	0.09	ND	ND	367
WYOU-SW-B-15/17	284 J	ND	ND	ND	ND	9	8	0.32	0.91	0.27	0.10	0.08	ND	ND	302
WYOU-SW-B-23/25	289 J	ND	ND	ND	ND	8	8	0.33	1.03	0.23	0.10	0.11	ND	ND	307
WYOU-SW-B-25/27	338 J	ND	ND	ND	ND	9	9	0.29	0.97	0.31	0.11	0.11	ND	ND	358
Surface Water Location C Samples															
WYOU-SW-C-3/5	258 J	ND	ND	14 J	ND	11	8	0.25	0.88	0.2	0.09	0.09	ND	ND	293
WYOU-SW-C-5/7	271 J	ND	ND	14 J	ND	11	10	0.36	1.04	0.3	0.10	0.09	ND	ND	308

TABLE 3-2

Solid Phase Micro-Extraction Analytical Testing Results for Polycyclic Aromatic Hydrocarbons[1]

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

	Naphthalene	Fluorene	Acenaphthene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Chrysene	Benzo[a] anthracene	Benzo[b] fluoranthene	Benzo[k]f luoranthene	Benzo[a]pyrene	Dibenzo[ah] anthracene	Benzo[ghi]peryl ene + Indeno[1,2,3-cd]pyrene	Total PAHs [2]
Surface Water Quality Criteria in ng/L	**4.9×10^6 MTCA**	**3.46×10^6 MTCA**	**6.4×10^5 MTCA**	**Not Established**	**2.64×10^7 MTCA**	**9×10^4 MTCA**	**2.59×10^6 MTCA**	**18 CWA**	**18 CWA**	**18 CWA**	**18 CWA**	**18 CWA**	**18 CWA**	**18 CWA**	**Not Established**
WYOU-SW-C-13/15	313 J	ND	ND	14 J	ND	12	10	0.39	1.40	0.3	0.11	0.11	ND	ND	351
WYOU-SW-C-15/17	262 J	ND	ND	10 J	ND	13	10	0.38	1.34	0.4	0.11	0.12	ND	ND	298
WYOU-SW-C-23/25	320 J	ND	ND	15 J	ND	11	10	0.25	1.21	0.3	0.09	0.09	ND	ND	358
WYOU-SW-C-25/27	356	ND	ND	11 J	ND	13	11	0.23	1.36	0.3	0.09	0.08	ND	ND	393
Surface Water Location D Samples															
WYOU-SW-D-3/5	377	ND	ND	ND	ND	4	3	0.22	0.41	0.12	0.05 J	0.05 J	ND	ND	385
WYOU-SW-D-5/7	266 J	ND	ND	11 J	ND	5	5	0.24	0.44	0.13	0.05 J	0.05 J	ND	ND	288
WYOU-SW-D-13/15	341	ND	ND	10 J	ND	6	4	0.19 J	0.57	0.12	0.05 J	ND	ND	ND	362
WYOU-SW-D-15/17	285 J	ND	ND	11 J	ND	6	6	0.23	0.59	0.12	0.1 J	0.1 J	ND	ND	309
WYOU-SW-D-23/25	505	ND	ND	7 J	ND	5	5	0.19 J	0.51	0.15	0.06 J	0.05 J	ND	ND	522
WYOU-SW-D-25/27	398	ND	ND	10 J	ND	5	5	0.15 J	0.50	0.14	0.1 J	0.05 J	ND	ND	419

Notes:

[1] Concentration in nanograms/liter

[2] Total PAHs are summation of detected concentrations listed. Non-detects = 0.

Analyses conducted by University of Texas at Austin using EPA Method 8310 protocols.

Shaded entries indicate result above water quality screening criteria.

CWA Clean Water Act Section 304 Human Health Criteria for Organism Consumption

J Estimated detection > Method Detection Limit (MDL) and < Practical Quantitation Limit (PQL)

MTCA Washington State Model Toxics Control Act (Chapter 173-340-WAC) Method B, non-carcinogen

ND Not detected above MDL

TABLE 4-1
Applicable Relevant and Appropriate Requirements
Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

ARAR	Description	Application for Wyckoff	ARAR Category	Alternatives to Which ARAR May Apply
FEDERAL				
Clean Water Act: Section 304(a)(1)	Surface water quality criteria for the protection of aquatic life and human health	Discharge of groundwater to Eagle Harbor through passive drains system.	Chemical Specific	N/A
Clean Water Act: Section 401	Protection of water quality from discharge of pollutants into waters of the United States	Dredging and capping sediments may cause dispersion of contaminated sediments causing contamination to move through the water column during cleanup activities.	Action Specific	2, 3, 4, 5
Clean Water Act: Section 402	Requirements for point source discharges to water of the U.S.	Discharge of stormwater collected from the surface of the proposed cap. Also discharge of Upper Aquifer groundwater through the proposed passive drainage system	Action Specific	N/A
Clean Water Act: Section 404(b)(1)	Protection of aquatic ecosystems by dredging or filling waters of the U.S.	Construction of a new perimeter bulkhead wall (depending on alignment) and remedial construction on the beaches	Action Specific	2, 3, 4, 5
Endangered Species Act	Protection of endangered or threatened species and critical habitat	Remedy may affect endangered species such as salmon and bull trout.	Action Specific	2, 3, 4, 5
Magnuson-Stevens Fisheries Conservation and Management Act	Protection of essential fish habitat	Remedy may affect essential fish habitat for rock fish or other species in Eagle Harbor.	Action Specific	2, 3, 4, 5
Clean Air Act	Protection of air quality	Dust from general construction activities, discharges to air from thermal desorption or other remedial actions	Chemical Specific	N/A
Native American Graves Protection and Repatriation Act	Procedures for handling human remains or sacred objects if discovered	Construction that impacts subsurface soils, particularly in previously undisturbed areas	Location Specific	N/A
Resource Conservation and Recovery Act Land Disposal Restrictions	Disposal of hazardous waste generated during cleanup activities	Disposal of creosote contaminated debris, NAPL recovered from groundwater, spent treatment media (such as carbon filters)	Action Specific	Potentially 2, 3, 4, 5 if sediment is determined to be listed waste

TABLE 4-1
Applicable Relevant and Appropriate Requirements
Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

ARAR	Description	Application for Wyckoff	ARAR Category	Alternatives to Which ARAR May Apply
Resource Conservation and Recovery Act Requirements for Incinerators	Requirements for operation of incinerators to protect air quality	Thermal oxidation of contaminated soil vapor. Also, Medium temperature thermal desorption of contaminated soils	Action specific	N/A
STATE				
Hazardous Waste Management Act Dangerous Waste Regulations	Generation, management and offsite disposal of hazardous waste	Hazardous wastes will likely be generated during remedy implementation that may be designated as a characteristic or listed hazardous waste.	Action Specific	Potentially 2, 3, 4, 5 if sediment is determined to be listed waste
Solid Waste Management Reduction and Recycling Act Solid Waste Handling Standards	Requirements for the management and disposal of solid waste	Requirements for upland management of remediation waste designated as a solid waste (e.g., excavated soil, dredged sediments).	Action Specific	2, 3, 4, 5
Model Toxics Control Act (MTCA)	Cleanup standards for soil, groundwater, surface water, and air	If MTCA cleanup standards are more stringent than the federal standards or risk-based concentrations, the promulgated MTCA standards will be used.	Chemical Specific	2, 3, 4, 5
MTCA Sediment Management Standards (SMS)	Cleanup standards for freshwater sediments	If SMS cleanup standards are more stringent than the federal standards or risk-based concentrations, the promulgated SMS standards will be used.	Chemical Specific	2, 3, 4, 5
Washington State Water Pollution Control Act Water Quality Standards for Surface Waters of the State of Washington	Surface water quality criteria for the protection of aquatic life and human health	If state WQC standards are more stringent than the federal standards or risk-based concentrations, the promulgated state WQC will be used.	Chemical Specific	N/A 5

TABLE 4-1
Applicable Relevant and Appropriate Requirements
Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

ARAR	Description	Application for Wyckoff	ARAR Category	Alternatives to Which ARAR May Apply
Washington State Water Pollution Control Act National Pollutant Discharge Elimination System	Standards for discharge of pollutants into waters of the United states	The remedial action will include the discharge of treated water and stormwater to surface water.	Chemical Specific	N/A
Washington Underground Injection Control Program	Establishes criteria and standards for an underground injection control program for class V injection wells	Remedial activities that involve underground injection such as steam injection for thermal enhanced extraction; injection of oxidants for ISCO treatment; injection of Portland cement and bentonite for ISS	Action Specific	N/A
Washington State Shoreline Management Act	Establishes wetland and shoreline protection measures for work in the shoreline zone.	Remedial activities on the intertidal beaches	Action Specific	2, 3, 4, 5
Washington Clean Air Act	Regulations for Air Pollution Sources, also Puget Sound Clean Air Agency Regulations	Remedial Actions that result in the emission of hazardous air pollutants, including decontamination, demolition and excavation, and thermal desorption	Chemical Specific	N/A

TABLE 4-2

Potential Preliminary Remediation Goals for OU-1 Intertidal Sediment and Shellfish Tissue

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

RAO	**RAO #1 and RAO #2**	**RAO #3**		**RAO #4**	
Media	**Sediment**	**Sediment**		**Horse Clam Tissue**	**Sediment**
COC	**MTCA Method B for Unrestricted Use [a] (mg/kg)**	**SQS SCO for 0.5% < TOC < 3.5% [b] (mg/kg)**	**AET [c] (mg/kg dry weight)**	**1 x 10^{-5} Excess Lifetime Cancer Risk for Tribal Shellfish Consumption (mg/kg)**	**Puget Sound Background [d] (mg/kg)**
NAPL	No visible	Not applicable		Not applicable	
LPAH	Not specified	370	5.2	Not specified	0.017
Naphthalene	1,600 (nc)	99	2.1		0.002
Acenaphthylene	Not specified	66	1.3		0.005 [e]
Acenaphthene	4,800 (nc)	16	0.50		0.005 [e]
Fluorene	3,200 (nc)	23	0.54		0.005 [e]
Phenanthrene	Not specified	100	1.5		0.005
Anthracene	24,000 (nc)	220	0.96		0.002
2-Methylnaphthalene	320 (nc)	38	0.67		0.002
HPAH	Not specified	960	12		0.057
BAP TEQ	Not specified	Not specified			Not Specified
Fluoranthene	3,200 (nc)	160	1.7	Not specified	0.008
Pyrene	2,400 (nc)	1,000	2.6	Not Specified	0.007
Benz(a)anthracene	1.37 (c)	110	1.3	0.0001	0.004
Chrysene	137 (c)	110	1.4	0.0098	0.004
Benzo(b)fluoranthene	1.37 (c)	Not specified		0.0001	0.010
Benzo(k)fluoranthene	13.7 (c)	Not specified		0.001	0.005
Total Benzofluoranthenes	Not specified	230	3.2	Not specified	NC
Benzo(a)pyrene	0.137 (c)	99	1.6	0.00001	0.006
Indeno(1,2,3 c,d) Pyrene	1.37 (c)	34	0.60	0.0001	0.004
Dibenzo (a,h) Anthracene	0.137 (c)	12	0.23	0.00001	0.002
Benzo (g,h,i) Perylene	Not specified	31	0.67	Not specified	0.003
Pentachlorophenol	2.50 (c)	360	0.36	Not specified	
Dioxin (2,3,7,8-TCDD)	0.0000128 (nc)	Not specified		Not specified	0.000004

TABLE 4-2

Potential Preliminary Remediation Goals for OU-1 Intertidal Sediment and Shellfish Tissue

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

RAO	RAO #1 and RAO #2	RAO #3		RAO #4	
Media	Sediment	Sediment		Horse Clam Tissue	Sediment
COC	MTCA Method B for Unrestricted Use [a] (mg/kg)	SQS SCO for 0.5% < TOC < 3.5% [b] (mg/kg)	AET [c] (mg/kg dry weight)	1×10^{-5} Excess Lifetime Cancer Risk for Tribal Shellfish Consumption (mg/kg)	Puget Sound Background [d] (mg/kg)

Notes:

[a] Source: CLARC Master Spreadsheet September 2015. Lowest concentration of non-cancer (nc) or cancer (c) listed. Value shown corresponds to excess lifetime cancer risk of 1×10^{-6} and has not been adjusted downward to meet the requirements of 1×10^{-5} for multiple carcinogens per WAC 173-340-708 (5).

[b] Source: Table 8-1. SMS Marine Sediment and Marine Sediment AETs, SCUM II – Washington State Department of Ecology, March 2015.

[c] Applicable to samples with less than 0.5 percent TOC based on guidance from Draft Sediment Cleanup Users' Manual II (Ecology 2013), and LAET values from Dredged Material Management Program Guideline Chemistry Values (USACE 2011). Dry weight normalized AETs are recommended when TOC is outside the recommended range of 3.5% for organic carbon normalization.

[d] Background concentration calculated from *OSV Bold Summer 2008 Survey Data Report* (USACE, June 25, 2009).

[e] Due to 100 percent non-detect frequency the background concentration is based on the maximum reported detection limit.

SMS: Sediment Management Standard. SCO: Sediment Cleanup Objectives. AET: apparent effects threshold. mg/kg: milligrams per kilogram. BAP TEQ: benzo(a)pyrene toxicity equivalents.

LPAHs include: naphthalene, acenaphthalene, acenaphthene, fluorene, phenanthrene, and anthracene (WAC 173-204-320)

HPAHs include: fluoranthene, pyrene, benz(a)anthracene, chrysene, total benzofluoranthenes, benzo(a)pyrene, indeno(1,2,3,-c,d)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene (WAC 173-204-320)

TABLE 5-1
Guidelines for Technology Screening Ranking
Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Ranking Guidelines for Technology Screening Evaluation in Table 2
Effectiveness
1. Not expected to be effective.
2. Expected to be only partially effective, or the effectiveness is unproven or unknown.
3. A proven or innovative technology that has been successfully applied at some sites with similar conditions.
4. Effectiveness is more certain or is relatively well established based on documented experience at other sites.
Implementability
1. Would cause a high amount of disruption in the project area and would require significant specialized equipment, technical knowledge, and/or administrative permits.
2. Would cause a modest amount of disruption in the project area and would require some specialized equipment, technical knowledge, and/or administrative permits.
3. Would cause a modest amount of disruption in the project area but would not require significant specialized equipment, technical knowledge, or administrative permits.
4. Could be readily implemented at the site with minimal equipment and limited disruption to the project area.
Relative Cost
1. High
2. Moderate
3. Low
4. No Action Baseline – no cost in comparison to other alternatives

TABLE 5-2
Remedial Technologies Screening Evaluation
Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

General Response Actions	Technology Type	Process Option	Description of Process Option	Relative Ranking[1]			Retained for Further Evaluation?	Screening Comments
				Effectiveness	Implementability	Cost		
No action	No action	N/A	No remedial actions would be implemented; no action assumes the Site would be unchanged.	1	NA	4	Yes	No action would not be effective at mitigating NAPL impacts. No action is retained for comparative baseline evaluation as relative to other alternatives in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan.
Access controls	Government controls	Notification of waterway use	Provide notice to mariners to prevent damage to caps, in-situ treatment, enhanced natural recovery, or other remedy components.	1	4	3	Yes	A notification of waterway use is a readily implementable institutional control but may have limited effectiveness in preventing damage to remedy components. The project area site is located near Washington State Department of Transportation ferry lanes. Ferries will continue to operate and generate vessel-driven waves that must be considered for the remedy.
		Commercial fishing bans	Restrictions that ban commercial fishing for specific species or sizes of fish or shellfish. These bans are established by state departments of health or other governmental entities.	2	2	3	Yes	An advisory currently prohibits commercial shellfish harvesting in Eagle Harbor and vicinity by the Bremerton-Kitsap County Health District. Advisories or complete bans are useful to protect exposure pathways prior to assessing the impact of remedies during post-construction monitoring. Advisories require enforcement, however, to be effective. A complete ban is not envisioned as being needed.
		Regulated navigation area (RNA)	Limitations or prohibitions on anchoring or other vessel operations to prevent damage to caps, in-situ treatment, enhanced natural recovery, or other remedy components.	2	4	3	Yes	RNAs are potentially more effective than notifications of waterway use for minimizing potential damage to remedy components. Areas that have been previously capped are currently subject to the restrictions listed in 33 CFR Chapter 1: 165.1309. The restrictions state "All vessels and persons are prohibited from anchoring, dredging, laying cable, dragging, seining, bottom fishing conducting salvage operations, or any other activity which could potentially disturb the seabed in the designated area. Vessels may otherwise transit or navigate this area without reservation."
	Proprietary controls	Land use and/or access restrictions	Restrictions, such as deed restrictions, easements, and covenants. These types of controls can be used to limit the types of structures allowed on a site (e.g., dug foundation or slab foundation) and restrict intrusive activities (e.g., installation of subsurface piping, utilities, or conduits). Access restrictions may also require site security measures.	3	1	3	No	Land use or access restriction institutional controls can be effective in conjunction with other remedial measures to mitigate exposure to NAPL and related contaminants. This IC could be readily combined with other remedial technologies to enhance the effectiveness of a remedy. EPA has an existing agreement with the City, and this agreement would override any potential additional deed restrictions. The implementation of additional land use or access restrictions is not anticipated and this IC is not retained for further evaluation.
	Enforcement and Permit Tools	Permits, consent decrees	Legal tools, such as administrative orders, permits, and consent decrees, that limit certain Site activities or require the performance of specific activities (e.g., to monitor and report on an institutional controls' effectiveness). They may be issued unilaterally or negotiated.	5	5	2	Yes	Retained in the context of CERCLA administrative tools, including potential amendments to the Record of Decision and Explanation of Significant Differences. This IC is otherwise not applicable to Wyckoff OU-1 as part of a Fund-Lead Site.
	Informational devices	Education and public outreach	Education and public outreach would provide information to the public regarding the Site and any potential risks that exist. These could be in the form of public open houses, fact sheets, sign postings, or other means.	2	4	3	Yes	Education and public outreach alone will not be effective in achieving remedial action objectives. However, they can be useful for mitigating human exposures to contaminants when combined with other remedial technologies. Notification and warning signs would continue to be posted at the site; therefore, it is retained for further evaluation.
		Deed notices	Notices provide information in public land records to alert persons regarding property conditions, including the type of contamination present and associated risks and activities that could result in exposures to contaminants left on the Site.	2	4	3	Yes	Deed notices are non-enforceable documents that can provide site informational background that may benefit interested parties. Deed notices may help to discourage inappropriate land use and provide a means of alerting the public about site conditions. This IC provides a higher benefit when used in conjunction with other ICs and with additional remedy components.
		Seafood consumption advisories	State departments of health or other governmental entities provide information to the public on acceptable fish consumption rates and fish preparation techniques.	2	5	3	Yes	Current advisories for limiting seafood consumption and closure of harvesting areas provide nominal protection of human health, but these are difficult to enforce. It is also difficult to assess the overall effectiveness of advisories. Seafood advisories are retained for further evaluation in conjunction with other technologies, although the duration of such advisories requires further evaluation.

TABLE 5-2
Remedial Technologies Screening Evaluation
Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

General Response Actions	Technology Type	Process Option	Description of Process Option	Relative Ranking[1]			Retained for Further Evaluation?	Screening Comments
				Effectiveness	Implementability	Cost		
		Site registry	Placing and maintaining Site information on a state registry (Washington State Department of Ecology's Hazardous Sites List and Site Register) would provide information regarding restrictions and hazards associated with the Site.	2	4	3	Yes	Maintaining current information for the entire Wyckoff site on the Washington State Department of Ecology's Hazardous Sites List and Site Registry is retained as an informational device.
Containment	Engineered capping	Permeable cap	Physical isolation and containment of NAPL, and biological barrier using sand cover.	3	3	2	Yes	Depending on thickness and configuration, a sand cap could be effective as a physical barrier for NAPL. A sand cap could also be used in conjunction with other cap components (e.g. composite/reactive capping materials, and surface armoring). Above-grade placement of capping materials would alter the coastal environment and sediment transport processes, as well as the intertidal habitat. A sand cap is retained for further evaluation. If selected as an alternative component, additional sediment transport modeling and impacts assessment may be required for post-FFS evaluation of alternatives where this technology is implemented.
		Low permeability cap (e.g., HDPE liner or geotextile fabric, low permeability engineered soil)	Physical and/or chemical isolation of contaminants by placement of heavy-duty composite mats or engineered soils designed for use over sediments to control contaminant migration. These types of materials may also provide limited protection against damage by erosion, scouring, heavy equipment, or other forces.	3	2	1	No	There are several challenges associated with low permeability passive caps. One is that, over time, NAPL that is initially contained beneath the low permeability layer, may tend to flow laterally toward the cap boundaries. This is of particular concern when the existing impacted sediments are relatively permeable. A second challenge is that bubbles from ebullition, if present, can migrate upward through the sediment and collect beneath the low permeability layer, making the layer less stable and potentially displacing the cap. Within the FFS Project Area, the upper portion of the sediment profile is dominated by marine sand and gravel with coarser zones of gravel and cobbles. Consequently, the sediment is relatively permeable and mobile NAPL may readily migrate. NAPL encountering a low permeability layer or impervious material in an engineered cap could travel laterally and could be expressed at the cap boundaries. In addition, evidence of ebullition may be difficult to observe in this scenario, given the dynamic exchange of seawater during the tidal cycle (Viana et al. 2007a, 2007b; Reible 2004). For these reasons, low-permeability capping technologies were are not best suited for the OU-1 FFS and were not retained.
		Cap armoring	Erosion protection, physical isolation, and potential biological barrier using gravel or other structural protection as necessary (e.g., rip rap) to maintain cap stability.	4	3	2	No	Cap armoring may be used to protect other cap components (e.g., sand cap, composite/reactive cap) from erosion due to tidal forces, wave action, or propeller wash. The armoring could also serve as a biological barrier, as needed. Based on the results of the Year 17 Report (USACE, 2012), which showed no evidence of erosion on the North Shoal or East Beach between 1999 and 2011, armoring is not retained for further evaluation.
		Reactive or sorbent cap	Placement of capping layers containing activated carbon, oleophilic clay, or other sequestration/degradation agents to reduce and/or redirect contaminant flux through capping materials.	3	2	2	Yes	The effectiveness of caps using activated carbon for remediating NAPL is generally limited. Oleophilic clay caps are generally more suitable to immobilize and prevent NAPL migration to the water column. Activated carbon caps are typically more effective for dissolved phase hydrophobic contaminants due to higher sorption coefficients compared to oleophilic clay. Caps can be engineered to achieve specific ranges of permeabilities using different configurations of commercial products such as AquaGate, reactive core mats, and other materials. Coastal, intertidal and subtidal multilayer caps over NAPL impacted formations have been installed in a number of NAPL contaminated sites (Salem, MA; Bangor ME; Dorchester, MA). The composition of the active layer and its thickness are generally site-specific. Some of these caps have been in place for nearly a decade and have demonstrated suitable performance.

TABLE 5-2
Remedial Technologies Screening Evaluation
Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

General Response Actions	Technology Type	Process Option	Description of Process Option	Relative Ranking[1] Effectiveness	Implementability	Cost	Retained for Further Evaluation?	Screening Comments
Containment	Vertical barriers	Sheet pile	Consists of an array of inter-locking steel sheet piles driven vertically around the perimeter of the NAPL contaminated zones to prevent lateral NAPL migration.	4	4	2	Yes	This technology is often used as a land based containment technology as demonstrated by its application for OU2/OU4. Interlocking sheet pile isolates mobile NAPL zones to prevent lateral migration and beach area sheening. Effectiveness is dependent on the joint sealant as barrier leaks generally occur at the joints. Barrier materials include steel, epoxy-coated steel, fiberglass, and other synthetic materials. Potential corrosion from seawater is a consideration.
		Slurry wall	One-Pass or standard trenching methods are used to construct a bentonite or bentonite –sand mix vertical wall around the NAPL contaminated zone(s). Once the bentonite swells, the permeability is reduced creating a barrier to lateral NAPL migration.	2	2	3	No	Performance of bentonite is saltwater environment is uncertain. Additionally, due to saturated conditions, the One-Pass method would have to be used to allow bentonite placement. A slurry wall would also generate large amounts of material, some of it potentially contaminated, that would require handling and disposal thus increasing cost.
Removal	In-water Dredging	Mechanical dredging	Use clamshell or other closed "environmental" buckets to remove contaminated sediment using a barge or upland staging platform.	4	2	2	Yes	Mechanical dredging may be effective in the intertidal area, but water-side access in shallow areas will be limited by tidal conditions. The dredged material needs to be transported for treatment and/or disposal facilities. Dewatering and potential stabilization or other treatment of the dredged materials would be needed prior to shipping offsite for disposal or other reuse. Mechanical dredging would likely mobilize suspended sediments and NAPL, requiring control and likely enclosed containment to prevent contaminant release to the water column and adjacent areas. Dredge material drainage water and water extracted from containment enclosures could pumped for temporary storage, and processed at the existing upland water treatment plant.
		Hydraulic dredging	Use hydraulic dredges with various cutter and suction heads (e.g., cutterhead, horizontal auger, plain suction, pneumatic, or specialty dredges) to remove contaminated sediments from the environment in a low-solids slurry phase.	3	1	1	No	Hydraulic dredging may be difficult to implement at this site due to the sediment size variability, presence of gravel to cobble size materials, and high water volumes generated. Discharge lines and pumps would require careful configuration to delivery slurry from the dredge to the upland management and processing area. The slurry would have a water to solids ratio of approximately 90 percent. It may be possible to treat some of the water at the existing onsite water treatment plant. For this to be possible the dredge effluent would have to be placed in an impoundment structure, geotubes, or other containment requirement significant upland area and management. Hydraulic dredging applicability is limited due to upland space constraints and limited capacity for onsite water treatment.
	Dry excavation	Mechanical excavation at low tide	Excavation includes removing sediment using conventional earthmoving equipment (e.g., excavator, backhoe). The excavation area must first be dewatered and this process option assumes work would be conducted at low tide to promote gravity drainage of the shallow beach bank storage water.	4	3	3	Yes	Depending on depth of removal, dry excavation of sediments containing NAPL could be effective in the upper intertidal zones which are essentially free-draining at low tide. However, without additional dewatering, mechanical excavation will be constrained by the limited time that these areas are exposed at low tide. This process option assumes that excavation would proceed in individual cells of manageable size to dig and backfill or cap during a given low tide cycle. The size and depth of the open excavations may be constrained by back-sloping or additional sidewall stabilization measures needed. This process option could be effective at upper intertidal locations, and potentially combined with other remedial process options.
		Mechanical excavation using pumping to dewater	Same as mechanical excavation at low tide, except that excavation areas would be dewatered via pumping. Installation of temporary barriers, such as shallow steel plate sections would likely be necessary to maintain sidewall stability during excavation and backfilling.	4	3	2	Yes	This dewatering method and temporary sidewall stabilization may be effective at mid-level intertidal elevations where residual tidal bank storage water could effectively be removed by gravity drainage and pumping at low tide. This process option assumes that excavation would proceed in individual cells sized so that excavation and backfill or cap placement could both occur during a given low tide cycle. In this process option, pumping would be used to extend the working period within practical limits and/or provide for better working conditions within a shorter timeframe. It is recognized that mechanical excavation using pumping to dewater individual excavation cells may be ineffective for some removal scenarios because it is depth-limited due to the site hydrogeology. Dredge material drainage water, and water extracted from shallow excavations could be pumped for temporary storage, and processed at the existing upland water treatment plant. .

TABLE 5-2
Remedial Technologies Screening Evaluation
Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

General Response Actions	Technology Type	Process Option	Description of Process Option	Relative Ranking[1]			Retained for Further Evaluation?	Screening Comments
				Effectiveness	Implementability	Cost		
		Mechanical excavation using sheet-piling and/or coffer dams to isolate and dewater or dredge	Excavation includes removing sediment via dredging or using earthmoving equipment (e.g., excavator, backhoe). Isolation and dewatering would be accomplished through installation of temporary barriers such as sheet piling or coffer dams.	4	3	1	Yes	Dry dredging or mechanical excavation using temporary barriers to dewater portions of the site is effective and implementable; however, it is likely a relatively high cost option. Sheet pilings/coffer dams could also be used to isolate wet dredging/excavation without further dewatering. Dredge material drainage water, and water extracted from enclosures could be pumped for temporary storage, and processed at the existing upland water treatment plant.
Disposal	Onsite RCRA Landfill	Standard transportation methods Clean offsite backfill material required	Waste materials are excavated and placed in an onsite landfill constructed with liner, leachate collection, and impermeable cap per regulatory standards.	4	1	1	No	Not consistent with future land use (park).
	Offsite RCRA Subtitle C (TSD)	Transport and dispose of waste at offsite RCRA TSD Pretreatment to meet LDRs Clean offsite backfill material required	Waste materials are excavated and transported offsite to a permitted disposal facility. Offsite disposal may require treatment of some or all waste material if subject to LDR.	4	3	2	Yes	Offsite treatment and disposal at a RCRA TDS facility is a viable option but will be costly due to site's remote location. Alternative that minimize the quantity of material that needs to be transported offsite will need to be developed to make this technology cost-effective.
	Offsite Subtitle D	Transport and dispose of waste at offsite Subtitle D subject to waste acceptance criteria Clean backfill material required	Waste materials are excavated and transported offsite to a permitted disposal facility. Waste subject to receiving facility's acceptance criteria.	4	3	3	Yes	Offsite disposal at a Subtitle D (nonhazardous) landfill is a viable option.
	In-water disposal	Barge transport to designated location with clean cover	Waste material placed on barge and transported to a designated open water dredged sediment disposal cell. Material placed in cell using environmental buckets and then covered with a layer of clean material.	4	2	3	No	Due to the presence of NAPL in the sediment, open water disposal is not a viable option.
	Onsite beneficial reuse	Material transported and reused onsite	Waste material transported via truck or conveyor to upland cell for drying and stabilization to allow for reuse as grading fill for the OU2/OU4 final cap.	2	2	2	Yes	Waste material could be readily transported to a designated location in the OU2/OU4 upland for drying and stabilization to allow for reuse as grading fill beneath the final soil cap planned for OU2/OU4.
Ex-Situ Treatment	Biological treatment	Landfarming	Landfarming involves mixing sediment contaminated with organic chemicals with nutrients, water, and amendments and placing the mixture in an engineered treatment unit.	1	1	2	No	Landfarming would not be effective at treating free-phase NAPL, would require a significant space and an unreasonably long time. Landfarming is not retained for further evaluation.
	Physical and/or chemical treatment	Stabilization/ solidification (ex-situ)	Cementitious, fly ash, or other pozzolanic or stabilization agents are mixed with contaminated sediments to immobilize contaminants by fixing the contaminants through physical or chemical reactions.	4	2	2	Yes	Stabilization/ solidification may be used to treat dredged or excavated sediments to reduce moisture content and NAPL leachability prior to onsite ruse or offsite transport. This process option would not reduce concentrations of contaminants, but could reduce the leachability of some contaminants.

TABLE 5-2

Remedial Technologies Screening Evaluation

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

General Response Actions	Technology Type	Process Option	Description of Process Option	Relative Ranking[1]			Retained for Further Evaluation?	Screening Comments
				Effectiveness	Implementability	Cost		
	Dewatering	Passive or mechanical dewatering	Passive dewatering uses gravity drainage and evaporation to dry sediments. Common passive dewatering methods include stockpile drainage, dewatering beds and geotextile tubes (geotubes). Mechanical systems such as belt presses and filter presses can be used to accelerate the dewatering process. Dewatering additives (e.g., polymers, hydrated lime, and ferric sulfate) can be added to the dredged sediments to aid in the dewatering process.	4	3	2	Yes	Dewatering is ancillary technology used to prepare dredged sediments for treatment and/or transport. This process option is needed to support the dredging and excavation technologies.
	Thermal treatment	Thermal destruction	Thermal destruction technologies (e.g., Cement-Lock, co-generation electrical plant) destroy organic contaminants by heating the waste at very high temperatures (greater than 1,400 degrees Celsius). Inorganic chemicals are concentrated in the ash generated during the incineration process. Beneficial use may result from the thermal process through heat capture from the process or through the incorporation of treated sediments into construction materials (e.g., cement replacement or as a partial replacement for sand in concrete, electricity production).	2	1	1	No	This process option may be used after reduction of the moisture content in sediments. The acceptability of OU-1 sediments for treatment at various facilities would need to be evaluated in considerable detail. The effectiveness of thermal destruction has not been demonstrated for similar sediments in comparative case histories. The cost for thermal treatment is expected to be disadvantageous relative to other technologies with similar or better expected effectiveness. It is further assumed that the sediments in OU-1 do not have enough energy value for practicable recovery as fuel. Because of limited documented case histories for successful application for expected dredge material conditions similar to OU-1 sediments, this technology is not retained for further evaluation.
		Thermal destruction and/or immobilization (ex-situ vitrification)	Ex-situ vitrification (e.g., Minergy Glass Furnace Technology) involves melting dewatered sediment contaminated with organics and/or heavy metals at very high temperatures (greater than 1,400 degrees Celsius) and turning it into a glass aggregate. The vitrified sediment may be used beneficially in road construction projects and in the making of concrete, shingles and ceramic floor tiles.	1	1	1	No	Vitrification of NAPL-contaminated sediments may not be effective and construction of vitrification facilities for this project would be cost prohibitive. This technology and has also not been widely demonstrated on sediments of this type; therefore, this process option is not retained. Concerns identified for the other thermal destruction process options are also applicable to ex-situ vitrification.
		Thermal desorption	Medium temperature thermal desorption (MTDD) technologies heat contaminated media to temperatures of about 500 degrees Celsius or greater and the contaminants are condensed and collected as an offgas, captured on activated carbon, and/or destroyed in an afterburner.	3	3	2	No	This process option is typically applied after reducing the moisture content of the sediments. However, the presence of NAPL and the variable amounts in the sediment will influence the energy consumptions, remedy effectiveness and cost. Performing thermal treatment in the Wyckoff upland area or at an offsite facility is not expected to be cost-effective due to the small volume of material requiring treatment. The acceptability of sediments at an off-site thermal desorption facility is also questionable. Concerns identified for the other thermal treatment process options are also applicable to this process option.
In-Situ Treatment	Biological Treatment	Enhanced biological oxidation and/or reduction	Bioremediation uses natural microbiological processes to degrade or transform organic chemicals. Nutrients and potential electron donors/acceptors are provided while controlling temperature and pH to stimulate existing populations of microorganisms to grow, facilitating processes that degrade or transform chemicals. Limnofix™ is an example bioremediation technology that degrades organic contaminants (e.g., PAH and TPH). Sugarcane bagasse material has also been used as a reactive treatment bed in other remediation applications.	1	1	1	No	Bioremediation has not proven to be effective or implementable in treatment of NAPL-impacted sediment. The setting is also not optimal for bioremediation because delivery of nutrients or other reagents required to enhance the biological activity would be difficult to control in the intertidal environment.
	Thermal	Vitrification	Contaminated media is heated to a molten state with electrical current, destroying the organic constituents, such as NAPL, and immobilizing inorganic parameters.	1	1	1	No	In-situ vitrification is very energy intensive, costly, and the application becomes more costly as the water content of the sediments increases. Special precautions would have to be implemented to capture and treat off-gas.

TABLE 5-2

Remedial Technologies Screening Evaluation

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

General Response Actions	Technology Type	Process Option	Description of Process Option	Relative Ranking[1]			Retained for Further Evaluation?	Screening Comments
				Effectiveness	Implementability	Cost		
	Physical	Solidification and stabilization (S/S)	Immobilizes contaminants by physically binding or enclosing the sediments within a stabilized mass, effectively destroying the permeability of the material and preventing contaminant migration, or chemically treating the contaminants. Portland cement, lime, pozzolans, oleophilic clay, or other additives are mixed with the sediments in-situ to encapsulate the sediments and/or reduce the solubility, mobility, and toxicity of the contaminants.	3	2	1	No	S/S can significantly reduce the permeability of the soil/sediment media into which it is mixed, effectively immobilizing NAPL. However, there are significant concerns for habitat impacts. Use of deep stabilization mixing methods as described by Maher et al. (2005), or potentially other methods such as jet grouting may be achievable, but would require bench and field-scale pilot testing to demonstrate effectiveness and feasibility for stabilizing NAPL-contaminated sediments in the OU-1 intertidal zone, as well as evaluating implementability issues, including bulking (swell) and approaches for managing material swell and controlling impacts to the beach environment.
	Chemical Treatment	Chemical destruction and/or oxidation	Chemical oxidants are injected into the subsurface sediments to oxidize organic contaminants.	1	1	3	No	This process option would require the injection of significant quantities of reagents to reduce NAPL contaminants in the intertidal zone. Implementation would be difficult since the heterogeneity and permeability of the subsurface sediments will control reagent migration through the formation, which would likely limit the remedy effectiveness. Additionally, an increase in NAPL mobility may also occur during implementation. The effectiveness of this process option for the conditions at the site is uncertain. Reagent application is also a potential habitat impact issue.
		In-situ adsorption material placement	This technology is based on mixing activated carbon (e.g., granular) into the biologically active sediment zone (typically the top 6 to 12 inches) to reduce hydrophobic organic chemical concentrations in sediment. Granular activated carbon may be mixed into the sediments using large-scale equipment. SediMite™ is an amended carbon agglomerate material that does not require mechanical mixing. It uses bioturbation to naturally mix the activated carbon into the top sediment layers over an extended time period.	1	1	2	No	Treatment using adsorption technologies could be effective for addressing relatively shallow zones of NAPL constituents and dissolved phase contaminants, but would likely not be effective in treating deeper sediments and NAPL. If considered, this process option would require extensive pilot testing to demonstrate efficacy. Tidal conditions and concerns over potential habitat impacts would also likely preclude using SediMite™ – type granular materials.
	Monitored natural recovery (MNR)	Long-term monitoring of natural processes occurring in OU-1 FFS Project Area sediments	This involves use of ongoing, naturally occurring physical, biological, and chemical processes that contain, destroy, or reduce the bioavailability or toxicity of contaminants in sediment. Involves monitoring over time to confirm that these processes are occurring and a contingency plan, if the site remediation goals are not met within the established time frame.	2	1	2	Yes	MNR was selected as the preferred remedy for the intertidal area in the 1994 ROD and is still appropriate for portions of the area, particularly where known or inferred NAPL concentrations are absent, low and/or have shown to be decreasing over time. Ongoing monitoring indicates improvement of site conditions following upland source containment measures were implemented beginning in the 1990s (USACE 2012). Natural recovery processes are on-going at the site and are expected to continue.
	Enhanced natural recovery (ENR)	Thin-layer cap placement	Enhancement of monitored natural recovery by placing a thin layer of sand and/or other suitable material typically up to 24-inches thickness. ENR material is incorporated with underlying shallow substrate through bioturbation or physical mixing to reduce contaminant levels, promote contaminant degradation, or reduce bioavailability.	3	2	2	Yes	ENR using thin-layer capping, coupled with a reactive layer, in the OU-1 intertidal area should reduce NAPL upwelling while also restoring beach function and habitat. Implementation may be challenging due to short tidal cycles. However, capping has been used successfully in other portions of OU-1.
		Thin-layer cap placement with activated carbon or other amendments to attenuate or sequester NAPL	ENR variant involving placement of a thin layer of suitable material mixed with carbon amendments or other sequestration/degradation agent(s) to further enhance NAPL remediation.	3	2	2	Yes	Thin-layer capping with carbon amendments, oleophilic clay or other sequestration/degradation agents has similar challenges as conventional ENR in the intertidal environment. An amended ENR thin-layer cap may have limited effectiveness for NAPL and would be susceptible to erosion and potential exposure of underlying NAPL. Engineered mats and capping sections of varying thickness are expected to provide greater effectiveness.

[1] Ranking is on scale of 1 (poorest) to 4 (best). Guidelines for ranking are presented in Table 1.

[2] Eagle Harbor RNA: http://www.gpo.gov/fdsys/pkg/FR-1999-12-28/html/99-33581.htm

TABLE 5-3
Retained Technologies and Process Options
Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

General Response Actions	Technology Type	Process Options Evaluated	Retained for Further Consideration
No Action	No Action	NA	Yes
Access Controls	Government Controls	Notification of Waterway Use	Yes
		Commercial Fishing Bans	Yes
		Regulated Navigation Area (RNA)	Yes (Potential No Anchor Zones)
	Enforcement and Permit Tools	Permits, Consent Decrees	Retained in the context of CERCLA administrative tools
	Informational Devices	Education and Public Outreach	Yes
		Deed Notices	Yes
		Seafood Consumption Advisories	Yes
		Site Registry	Yes
Containment	Engineered Capping	Permeable Cap	Yes
		Reactive or Sorbent Cap	Yes
	Vertical Barriers	Sheet pile	Yes
Removal	In-water Dredging	Mechanical Dredging	Yes
	Dry Excavation	Mechanical Excavation at Low Tide	Yes
		Mechanical Excavation Using Pumping to Dewater	Yes
		Mechanical Excavation Using Sheet Piling/Coffer Dam to Isolate and Dewater	Yes
Disposal	Onsite Disposal	Upland Placement and Reuse	Yes
	Offsite Disposal	Permitted Landfill (Subtitle C/Subtitle D)	Yes
	Transportation	Conveyor (onsite)	Yes
		Truck (onsite and offsite)	Yes
Ex-Situ Treatment	Physical/Chemical Treatment	Stabilization and Solidification	Yes
	Dewatering	Passive or Mechanical Dewatering and/or Dewatering Additives	Yes
In-Situ Treatment	Monitored Natural Recovery (MNR)	Long-Term Monitoring of Natural Processes Occurring in OU-1 FFS Project Area Sediments	Yes
	Enhanced Natural Recovery (ENR)	Thin-Layer Capping Placement	Yes
		Thin-Layer Capping Placement With Activated Carbon or Other Amendments to Attenuate/Sequester NAPL	Yes

TABLE 5-4

Comparison of Reactive Core Mat and Granular Adsorptive Bulk Media Process Options

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Characteristic	RCM	Granular Adsorptive Bulk Media	Application to OU-1 FFS
Adsorptive Layer Thickness	Thin profile application, typically inches or less	Installation depth varies based on the amount of sorptive media required for site – typical applications 0.25-1.5 feet	Cap must provide approximate 24-inch top layer of clean gravelly sand substrate habitat material. Cap will therefore require adequate inset depth into beach. While a thin profile reduces overall excavation depth, it is not a substantial factor for this application.
QA/QC	Engineered material – high quality assurance/quality control	Same as RCM	Both materials are manufactured with appropriate QA/QC specifications. Both materials have the capability to be manufactured for specific site needs such as percent reactive media.
Deployment Ease	Deployed in rolls – can relatively quick installation depending on surface conditions and area	Deployed as bulk media – commonly slower compared to RCMs	With the limited daily tidal exposure to work in the dry, expedient deployment is beneficial. However, if the media can be within the work window, both deployment mechanisms are feasible in the intertidal area.
Permeability	$1x10^{-6}$ m/s or 0.3 ft/day	Media permeability can be modified to match that of surrounding sediment	The sorbent cap would be constructed with a permeability comparable to surrounding sediment to maintain existing hydraulic conditions and optimize NAPL removal.
Density	Relatively low density: approximately 0.8 lbs/ft^3	Bulk density similar to natural granular sediments	Higher density materials match existing sediment more closely and promote stability in the intertidal zone.

TABLE 5-5

Comparison of Vertical Barrier Process Options

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Characteristic	Steel or Fiberglass Sheet Piles	Soil Bentonite	Application to OU-1
Optimal Substrate Conditions for Installation	Loose to moderately soils	Moderately compact to compact soils	Marine sediments in the FFS Project Area are approximately 70 percent sand, which would facilitate sheet pile installation. Higher quantities of soil bentonite would be consumed during installation compared to less permeable sediments.
Beach Surface Disturbance	Wall can be installed without pre-trenching and surface restoration	Amendments can be delivered hydraulically using continuous trenching or using augers. NAPL in may be hydraulically mobilized.	Top of sheet pile wall can be set below beach surface to eliminate visual and physical impacts. Bentonite wall results in greater beach disturbance and requires near-surface restoration.
Subsurface Obstruction Concerns	Must be formed around obstructions or obstructions removed	Can use grouting techniques to accommodate obstructions	Although the intertidal mudflat area is expected to be largely free of obstructions, further investigation of potential buried logs and boulders and other objects is needed.
Groundwater Chemical Effects	Sheet pile material must be resistant to corrosive agents and COCs	Soil bentonite hydration must not be impeded by COCs or groundwater constituents	Seawater and NAPL constituents may complicate the use of bentonite which is subject to ionic and chemical fouling preventing complete hydration.
NAPL Mobilization During Installation	Vibration or hydraulic push insertion may minimize disturbance and potential NAPL mobilization relative to impact driving	Amendments can be delivered hydraulically using continuous trenching or using augers. NAPL in may be hydraulically mobilized.	The extent of the NAPL may be beyond the boundary of the proposed vertical barrier. Any barrier constructed has the potential to mobilize NAPL in the short term.

TABLE 6-1
Summary of Key Components of Operable Unit 1 Focused Feasibility Study Alternatives
Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Alternatives and Key Components[1]	Active Remediation Area (Acres)	MNR Area (Acres)	Removal Volume (CY)[2]	Disposal Mass (tons)[3]	Construction Duration (Months)	Total Costs[4]
Alternative 2 – Seep Capping and MNR	0.3	10.5	900	1,500	1	$3,110,000
• Thin, carbon- and clay-amended caps placed over 15 active NAPL seeps						
• Two seeps replaced in each of Years 10, 20, 30, and 40, and one seep replaced in each of Years 50 and 60						
Alternative 3 – Partial Excavation and Capping	1.6	9.2	6,600	11,000	4	$11,769,000
• Thin, carbon- and clay-amended caps placed over areas with suspect mobile NAPL						
• 10 percent of cap area replaced in each of Years 10, 20, 30, 40, and 50						
Alternative 4 – Vertical Containment with Partial Excavation and Capping	1.6	9.2	6,600	11,000	4	$15,041,000
• Vertical steel sheet pile barriers to contain potentially mobile NAPL and prevent lateral migration of sheen						
• Thin, carbon- and clay-amended caps placed shoreward of vertical barrier over areas with suspect mobile NAPL						
• 10 percent of cap area replaced in each of Years 10, 20, 30, 40, and 50						
Alternative 5 – Dredging	1.6	9.2	26,000	43,000	8	$29,374,000
• Sediments removed to 10 feet below grade in areas of suspect mobile NAPL						
• Clay-amended lift placed at base of dredge/excavation prisms, with gravelly sand cap backfill to beach surface						

[1] All Alternatives:

MNR applied in areas of suspected non-mobile NAPL
Monitored for 100 years

[2] Excavation volume excluding bulking

[3] Includes weight of cement required for stabilization

[4] Includes capital plus discounted O&M costs (see Table 6-7)

TABLE 6-2

Key Components of Alternative 2 – Seep Capping and Monitored Natural Recovery

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Base Component and Sequence

General Description of Alternative 2
• Alternative 2 (Figure 6-2 and Figure 6-3) includes:
  o Excavation of enough existing sediment to preserve grade and place an AC- and OC-amended cap.
  o MNR in areas with no NAPL, non-mobile NAPL, and NAPL seeps within eelgrass beds.
• A total of 6 seep caps are assumed: 4 during initial implementation, and 2 new seeps identified in the North Shoal during the design investigation.
• The estimated in-place excavation and capping area spans 0.2 acres (9,600 SF) and contains 900 CY.
• Caps would not extend into the eelgrass areas.
• All excavated materials will be disposed off-site and all capping material will be imported.
• Excavation and capping will be performed in the dry and timed to move up and down the beach face with the tide.
• The overall estimated duration is up to about 1 month over one construction season.
• Dredged/excavated material will be dewatered and stabilized as needed in the upland area and disposed offsite in a Subtitle D landfill.
• Caps will be inspected using visual and topographic methods to assess integrity.
• Long-term O&M assumes 1,200 SF of cap repair will be required in Year 9 for the three North Shoal caps and 1,200 SF of cap repair will be required in Year 9 and another 1,200 SF of cap repair required in Year 30 for the East Beach caps.

Source Control Measures • Continue existing upland source control measures, including preserving sheet pile wall integrity.
Institutional Controls • Restrict use of anchors, moorings, and other physical disruption of the lateral containment areas to prevent damage to layers and/or encourage short-circuiting of NAPL through materials. Maintain existing anchoring restrictions in North Shoal and Phase III cap area; include East Beach in restriction. • Maintain Eagle Harbor ICs for fish and shellfish harvesting/flatfish consumption. As remediation/post-remediation monitoring are implemented, evaluate continued application fishing advisories in the FFS Project Area.
Predesign Sampling and Testing • Perform waste characterization to determine disposal requirements for excavated materials. • Perform characterization needed to support the remedial design including geotechnical analyses. • Perform testing to determine NAPL properties in North Shoal and East Beach cap areas. • Perform surveys to determine rate of seep expression to the surface. Cost estimates assume this would be performed by excavation of a series of shallow holes and observing NAPL inflow during low tide. • Perform high resolution, pre-construction baseline bathymetry survey to determine sediment surface elevation for design purposes. • Perform baseline habitat surveys (including eelgrass and general habitat, forage fish). • Perform bench scale testing of NAPL sequestering amendments to verify and refine cap elements (thickness, permeability performance). • Perform baseline TarGOST® survey to refine NAPL delineation in the North Shoal area. Assume 1,000 LF of delineation probing in 2 phases for a total of 50 locations. Each boring advanced to a depth of about 20 feet.

TABLE 6-2
Key Components of Alternative 2 – Seep Capping and Monitored Natural Recovery
Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Base Component and Sequence
Remedial Design • Complete remedy design and identify appropriate subcontractors and vendors for implementation. Cost estimate assumes design process includes Preliminary Design, Pre-Final, and Final Designs, a Remedial Action Work Plan (RAWP), permitting/permit equivalent, contract bid document preparation and procurement. • Conduct design calculations to ensure that the cap has suitable permeability, similar to naturally occurring beach materials to prevent (to maximum extent possible) the formation of preferential pathways. For purposes of developing a cost estimate, the capping system identified below is assumed for alternative development. • Coordinate with agencies and stakeholders. • Identify staging areas in the upland portion of the site.
Preremediation Site Work • Construct temporary access roads, dewatering pads needed and fencing/security around staging area(s). • Prepare upland staging area (site offices, parking areas, equipment storage area). It is assumed existing sanitation facilities will be sufficient to support OU-1 remedial action. • Establish required survey control points and tide gages. • Confirm pre-construction bathymetry has not changed. The cost estimate assumes that another high resolution survey would be performed. • Identify/construct staging areas for stockpiling import gravelly sand to be used as capping backfill, and dredged/excavated materials that will be dewatered, stabilized and transported for off-site disposal. • Prepare stockpile staging/handling areas estimated to be up to approximately 2-1/2 acres. • Preremediation site work would take approximately 1.5 weeks.
Potential Upgrading of Existing Upland Sheet Pile Wall (Same as other Alternatives) • As needed, upgrades to the upland sheet pile wall will be conducted separately from the OU-1 FFS activities. Costs are not included in the OU-1 FFS for this activity.
Sediment Removal • Sediment will be removed using mechanical dredging/excavation. Enclosed 'environmental buckets' will be used. The 900 CY in place volume increases to approximately 1,100 CY with bulking. • Excavation would be limited to working from the land side in the dry at low tide when the beach is exposed using beach-staged excavators. Construction durations are estimated using this assumption, including daily periods of about 3 hours. • It is assumed crane mats or other similar means may be needed to facilitate movement of equipment on the beach. Approximately 1,750 LF of mats are assumed for the cost estimate. • Assumes that trench boxes may be used to control excavation sidewalls for each capping cell if required. The actual means and methods would be at discretion of selected contractor. • Sediment would be placed into 8 cy dump trucks for purposes of transportation to the dewatering pad in the upland. The assumed time to load (8 minutes) and transport to the upland dewatering pad (5 minutes for North Shoal areas and 10 minutes for East Beach areas – each way) and unload (2 minutes) constrains the rate of removal. For the North Shoal area, the estimated cycle time is 20 minutes; for the East Shore the estimated time is 30 minutes. • The assumed production rate is 72 cy/hour. • The amended cap will be not be constructed over existing Phase III cap. • To construct cap and maintain existing grade, approximately 30 inches of existing sediment will need to be removed.

TABLE 6-2

Key Components of Alternative 2 – Seep Capping and Monitored Natural Recovery

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Base Component and Sequence
• The removed sediment will be dewatered, stabilized, and disposed as nonhazardous material.
Cap Excavation and Upland Excavated Material Dewatering • At the excavations, water will need to be extracted to facilitate sediment removal and capping in the dry. • The FFS used AQTESOL modeling (see Appendix E) to establish a 100 gallon per minute (gpm) dewatering requirement for managing water from the beach excavations implemented in a grid pattern with individual cells measuring 40 feet by 40 feet. This rate provides 3 feet of drawdown at the edge of the excavation. This pumping rate would be applied throughout the daily excavation period estimated to be 3 hours as noted above. For each 40 foot by 40 foot excavation a total temporary upland tank storage volume of 30,000 gallons is assumed. • Up to about 2-1/2 acres are available for upland stockpile management, dewatering, and excavated materials stabilization. • Dewatering will be via gravity drainage to pad collection sumps. No mechanical dewatering is anticipated. • Collected stockpile drainage water will be collected for reprocessing and discharge through the GWTP. • An estimated 7 gallons of impacted water/NAPL will gravity drain per cy of stockpiled dredged/excavated material. • Nominal assumed stockpile dewatering time is approximately 2 days. Sediment will be moved around on the dewatering pads to optimize drying and drying amendment management. • Dewatering water will be directed to a holding tank where solids will be permitted to settle. • Water will be drawn from tank and fed into GWTP based on current GWTP allowance of 100 gpm total capacity. No additional cost for treatment of the water is assumed.

Cap Placement
• Perform initial capping pilot test plot as separate or phased mobilization.
• Cap components include (Figure 6-3):
  o 24-inch layer of gravelly sand similar to the existing beach material to restore habitat/function
  o 4 to 6-inch reactive layer. Final media type/mix and thickness determined during remedial design.
• The total cap area would cover approximately 9,600 SF (0.2 acres).
• It is assumed that one 40 foot by 40 foot area can be capped each day depending on location, elevation, and environmental conditions (175 to 215 cy/day).
• All materials would be placed using mechanical earth-moving equipment.
• All cap materials and equipment would be transported to the upland area and protected from environmental degradation at the end of each work shift.
• It is estimated that capping will require approximately 3 hours/seep.

Short-Term Monitoring (During Construction) • Sheens would be monitored visually. • Work zone and perimeter air monitoring would be performed during active construction. • Habitat, fish, and cultural resources monitoring would be conducted. • Some short term application of odor-suppression foams may be needed to manage the sand/sediment on the drying pad. Estimate assumes a limited allowance for odor suppressing foam.
Confirmation Sampling/Bathymetric Surveys • Confirmation field surveys would be performed after sediment removal and after cap placement to document that required depth of contaminated sediment/soil and that final cap/fill grades are achieved. • Physical surveys would also be performed after placement of each of the cap layers to confirm that cap is placed to design elevation/thickness and covers entire area.

TABLE 6-2

Key Components of Alternative 2 – Seep Capping and Monitored Natural Recovery

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Base Component and Sequence
• The final alignment of each of the remediation areas should be surveyed and included on project drawings to facilitate future inspection, repair, and/or any future beach renovation/replenishment.
Material Treatment and Disposal • Dredged sediment would be stabilized in the upland area by mixing with drying agents as needed to reduce moisture content, and then transported by truck to an offsite Subtitle D disposal. Facility • An estimated 1,500 tons of material would require transport and disposal. • For estimating purposes, it is assumed 5 percent by weight Portland cement would be used to stabilize the material in order to pass the paint filter test and to immobilize NAPL. • For estimating purposes, it is assumed that the sediment would be transported approximately 20 miles by truck to an intermodal rail transfer facility and then approximately 200 miles by rail for disposal.
Performance Monitoring of Remedy (Same for all Alternatives) Monitoring at 5-year increments for a period of up to 30 years and in 10-year increments between 30 and 100 years is assumed. Monitoring objective is to generate sufficient data to assess remedy performance, including compliance with meeting RAOs. Data collection in future years may be amended to address specific physical areas and compounds. Performance monitoring will consist of: • **Physical Stability Monitoring.** High-resolution bathymetric surveys for comparison to baseline; cost estimate assumes performance monitoring survey is less detailed than baseline • **Topographic Surveys.** During Years, 1, 2 and 3 to assess erosion and deposition in the vicinity of each cap. • **Chemical Quality Monitoring of Surface and Subsurface Sediments**. Up to approximately 45 samples. Surface sediment samples to be co-located at clam tissue collection locations to the extent practicable. Sampling performed in Years 3, 6, 9, and 15, every 5 years through Year 30, and every 10 years thereafter for duration of 100 year O&M period. • **Clam Tissue Monitoring**. Up to approximately 15 tissue sampling locations performed in year 6, and Year 9, and every 5 years thereafter for duration of 100 year O&M period. • **Biological Surveys.** Includes eelgrass and general habitat survey, forage fish. • **Laboratory Analyses.** All sediment and tissue samples to be analyzed for PAHs. Assume up to 25 percent of sediment and tissue samples to be analyzed for VOCs. • **Reporting.** Performance monitoring and MNR data will be assessed in depth every 5 years to Year 30, and every 10 years between Year 30 and Year 100. Data will be assessed for trends and RAO compliance, with program modifications identified. • **Input to EPA OU-1 Five-Year Review Reports.**
Long-Term Operations and Maintenance • Annual inspections performed to assess integrity of capped areas and to look for seeps or sheens. • Cap O&M assumes 25 percent of the capped area in the North Shoal and 25 percent of the capped area in the East Beach will be repaired in Year 9, and 25 percent of the capped area in the East Beach repaired in Year 30.

TABLE 6-3

Key Components of Alternative 3 – Partial Excavation and Capping

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Base Component and Sequence

General Description of Alternative
• Alternative 3 (Figure 6-3 and Figure 6-4) includes:
  o Excavation of enough existing sediment to preserve grade and place an AC- and OC-amended cap.
  o MNR in areas with no NAPL, non-mobile NAPL, and NAPL seeps in eelgrass beds.
• The estimated in-place excavation area and volume are approximately 1.6 acres and 6,600 CY.
• Caps would not extend into the eelgrass areas.
• All excavated materials will be disposed offsite and all capping material will be imported.
• Excavation and capping will be performed in the dry and timed to move up/down the beach with the tide.
• The overall estimated duration is up to about 4 months over one construction season.
• Dredged/excavated material will be dewatered and stabilized as needed in the upland area and disposed offsite in a Subtitle D landfill.
• Caps will be inspected using visual and topographic mapping methods to assess integrity.
• Long-term O&M assumes 18,000 SF of cap repair will be required in Year 9 for the North Shoal, and 18,000 SF of cap repair will be required in Year 9 and another 18,000 SF of cap repair required in Year 30 for the East Beach.

Source Control Measures • Continue existing upland source control measures, including preserving sheet pile wall integrity.
Institutional Controls • Restrict use of anchors, moorings, and other physical disruption of the lateral containment areas to prevent damage to layers and/or encourage short-circuiting of NAPL through materials. Maintain existing anchoring restrictions in North Shoal and Phase III cap area; include East Beach in restriction. • Maintain Eagle Harbor ICs for fish and shellfish harvesting and flatfish consumption. As remediation and post-remediation monitoring are implemented, evaluate continued application fishing advisories in the FFS Project Area.
Predesign Sampling and Testing • Perform waste characterization to determine disposal requirements for excavated materials. • Perform characterization needed to support the remedial design including geotechnical analyses. • Perform testing to determine NAPL properties in North Shoal and East Beach areas. • Perform surveys to determine rate of seep expression to the surface. Cost estimates assume this would be performed by excavation of a series of shallow holes and observing NAPL inflow during low tide. • Perform high resolution, pre-construction baseline bathymetry survey to determine sediment surface elevation for design purposes. • Perform baseline habitat surveys (including eelgrass and general habitat, forage fish). • Perform bench scale testing of NAPL sequestering amendments to verify and refine cap elements (thickness, permeability performance). • Perform baseline TarGOST® survey to refine NAPL delineation in North Shoal area. Assume 1,000 LF of delineation probing in 2 phases for a total of 50 locations. Each boring advanced to a depth of about 20 feet.

TABLE 6-3

Key Components of Alternative 3 – Partial Excavation and Capping

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Base Component and Sequence
Remedial Design • Complete remedy design and identify appropriate subcontractors and vendors for implementation. Cost estimate assumes design process includes Preliminary Design, Pre-Final, and Final Designs, a Remedial Action Work Plan (RAWP), permitting/permit equivalent, contract bid document preparation and procurement. • Conduct design calculations to ensure that the cap has suitable permeability, similar to naturally occurring beach materials to prevent (to maximum extent possible) the formation of preferential pathways. For purposes of developing a cost estimate, the capping system identified below is assumed for alternative development. • Coordinate with agencies and stakeholders. • Identify staging areas in the upland portion of the site.
Preremediation Site Work • Construct temporary access roads, dewatering pads needed and fencing/security around staging area(s). • Prepare upland staging area (site offices, parking areas, equipment storage area). It is assumed existing sanitation facilities will be sufficient to support OU-1 remedial action. • Establish required survey control points and tide gages. • Confirm pre-construction bathymetry has not changed. The cost estimate assumes that another high resolution survey would be performed. • Identify/construct staging areas for stockpiling import gravelly sand to be used as capping backfill, and dredged/excavated materials that will be dewatered, stabilized and transported for off-site disposal. • Prepare stockpile staging/handling areas estimated to be up to approximately 2-1/2 acres. • Preremediation site work would take approximately 3 weeks.
Potential Upgrading of Existing Upland Sheet Pile Wall • As needed, upgrades to the upland sheet pile wall will be conducted separately from the OU-1 FFS activities. Costs are not included in the OU-1 FFS for this activity.
Sediment Removal • Sediment would be removed using mechanical dredging/excavation. Enclosed 'environmental buckets' will be used. The 6,600 CY in place excavation volume increases to approximately 8,300 CY with bulking. • Excavation would be limited to working from the land side in the dry at low tide when the beach is exposed using beach-staged excavators. Construction durations are estimated using this assumption, including daily periods of about 3 hours. • It is assumed crane mats or other similar means may be needed to facilitate movement of equipment on the beach. Approximately 1,750 LF of mats are assumed for the cost estimate. • Assumes that trench boxes may be used to control excavation sidewalls for each capping cell if required. The actual means and methods would be at discretion of selected contractor. • Sediment would be placed into 8 cy dump trucks for purposes of transportation to the dewatering pad in the upland. The assumed time to load (8 minutes) and transport to the upland dewatering pad (5 minutes for North Shoal areas and 10 minutes for East Beach areas – each way) and unload (2 minutes) constrains the rate of removal. For the North Shoal area, the estimated cycle time is 20 minutes; for the East Shore the estimated time is 30 minutes. • The assumed production rate is 72 cy/hour. • The amended cap will be not be constructed over existing Phase III cap.

TABLE 6-3

Key Components of Alternative 3 – Partial Excavation and Capping

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Base Component and Sequence
• To construct cap and maintain existing grade, approximately 30 inches of existing sediment will need to be removed. • The removed sediment will be dewatered, stabilized, and disposed as nonhazardous material.
Cap Excavation and Upland Excavated Material Dewatering • At the excavations, water will need to be extracted to facilitate sediment removal and capping in the dry. • The FFS used AQTESOL modeling (see Appendix E) to establish a 100 gallon per minute (gpm) dewatering requirement for managing water from the beach excavations implemented in a grid pattern with individual cells measuring 40 feet by 40 feet. This rate provides 3 feet of drawdown at the edge of the excavation. This pumping rate would be applied throughout the daily excavation period estimated to be 3 hours as noted above. For each 40 foot by 40 foot excavation a total temporary upland tank storage volume of 30,000 gallons is assumed. • Up to about 2-1/2 acres are available for upland stockpile management, dewatering, and stabilization of excavated materials. • Dewatering will be via gravity drainage to pad collection sumps. No mechanical dewatering is anticipated. • Collected stockpile drainage water will be collected for reprocessing and discharge through the GWTP. • It is estimated that 7 gallons of impacted water and NAPL will gravity drain per cy of stockpiled dredged/excavated material. • Nominal assumed stockpile dewatering time is approximately 2 days. Sediment will be moved around on the dewatering pads to optimize drying and drying amendment management. • Dewatering water will be directed to a holding tank where solids will be permitted to settle. • Water will be drawn from the tank and fed into the GWTP based on the current GWTP allowance of 100 gpm total capacity. No additional cost for treatment of the water is assumed.

Cap Placement
• Perform initial capping pilot test plot as separate or phased mobilization.
• Cap components include (Figure 6-3):
  o 24-inch layer of gravelly sand similar to the existing beach material to restore habitat/function
  o 4 to 6-inch reactive layer. Final media type/mix and thickness determined during remedial design.
• The total cap area would cover approximately 71,150 SF (1.6 acres).
• It is assumed that one 40 foot by 40 foot area can be capped each day depending on location, elevation, and environmental conditions (175 to 215 cy/day).
• All materials would be placed using mechanical earth-moving equipment.
• All cap materials and equipment would be transported to the upland area and protected from environmental degradation at the end of each work shift.

Short-Term Monitoring (During Construction) • Sheens would be monitored visually. • Work zone and perimeter air monitoring would be performed during active construction. • Habitat, fish, and cultural resources monitoring would be conducted. • Some short term application of odor-suppression foams may be needed to manage the sand/sediment on the drying pad. Estimate assumes limited allowance for odor suppressing foam.

TABLE 6-3

Key Components of Alternative 3 – Partial Excavation and Capping

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Base Component and Sequence
Confirmation Sampling/Bathymetric Surveys • Confirmation field surveys would be performed after sediment removal and after cap placement to document that required depth of contaminated sediment/soil and that final cap/fill grades are achieved. • Physical surveys would also be performed after placement of each of the cap layers to confirm that cap is placed to design elevation/thickness and covers entire area. • The final remediation areas should be surveyed and included on project record drawings to document their locations.
Material Treatment and Disposal • Dredged sediment would be stabilized in the upland area by mixing with drying agents as needed to reduce moisture content, and then transported by truck to an offsite Subtitle D disposal facility. • An estimated 11,000 tons of material would require transport and disposal. • For estimating purposes, it is assumed 5 percent by weight Portland cement would be used to stabilize the material in order to pass the paint filter test and to immobilize NAPL. • For estimating purposes, it is assumed that the sediment would be transported approximately 20 miles by truck to an intermodal rail transfer facility and then approximately 200 miles by rail for disposal.
Performance Monitoring of Remedy (Same for all Alternatives) Monitoring at 5-year increments for a period of up to 30 years and in 10-year increments between 30 and 100 years is assumed. Monitoring objective is to generate sufficient data to assess remedy performance, including compliance with meeting RAOs. Data collection in future years may be amended to address specific physical areas and compounds. Performance monitoring will consist of: • **Physical Stability Monitoring.** High-resolution bathymetric surveys for comparison to baseline; cost estimate assumes performance monitoring survey is less detailed than baseline. • **Topographic Surveys.** During Years, 1, 2 and 3 to assess erosion and deposition in the vicinity of each cap. • **Chemical Quality Monitoring of Surface and Subsurface Sediments**. Up to approximately 45 samples. Surface sediment samples to be co-located at clam tissue collection locations to the extent practicable. Sampling performed in Years 3, 6, 9, and 15, every 5 years through Year 30, and every 10 years thereafter for duration of 100 year O&M period. • **Clam Tissue Monitoring**. Up to approximately 15 tissue sampling locations performed in year 6, and Year 9, and every 5 years thereafter for duration of 100 year O&M period. • **Biological Surveys.** Includes eelgrass and general habitat survey, forage fish. • **Laboratory Analyses.** All sediment and tissue samples to be analyzed for PAHs. Assume up to 25 percent of sediment and tissue samples to be analyzed for VOCs. • **Reporting.** Performance monitoring and MNR data will be assessed in depth every 5 years to Year 30, and every 10 years between Year 30 and Year 100. Data will be assessed for trends and RAO compliance, with program modifications identified. • **Input to EPA OU-1 Five-Year Review Reports.**
Long-Term Operations and Maintenance • Annual inspections performed to assess integrity of capped areas and to look for seeps or sheens. • Cap O&M assumes 25 percent of the capped area in the North Shoal and 25 percent of the capped area in the East Beach will be repaired in Year 9, and 25 percent of the capped area in the East Beach repaired in Year 30.

TABLE 6-4
Key Components of Alternative 4 – Vertical Containment with Partial Excavation and Capping
Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Base Component and Sequence

General Description of Alternative
• Alternative 4 (Figures 6-3, 6-5 and 6-6) includes:
  o Installation of a vertical sheet pile barrier to prevent lateral migration of potentially mobile NAPL.
  o Excavation of enough existing sediment to preserve grade and place an AC- and OC-amended cap.
  o MNR in areas with no NAPL, non-mobile NAPL, and NAPL seeps in eelgrass beds.
• The estimated in-place excavation area and volume are approximately 1.6 acres and 6,600 CY.
• Caps would not extend into the eelgrass areas.
• All excavated materials will be disposed offsite and all capping material will be imported.
• Excavation and capping will be performed in the dry and timed to move up/down the beach with the tide.
• The overall estimated duration is up to about 4 months over one construction season.
• Dredged/excavated material will be dewatered and stabilized as needed in the upland area and disposed offsite in a Subtitle D landfill.
• Caps and steel sheet pile will be inspected using visual and topographic methods to assess integrity.
• Long-term O&M assumes 18,000 SF of cap repair will be required in Year 9 for the North Shoal, and 18,000 SF of cap repair will be required in Year 9 and another 18,000 SF of cap repair required in Year 30 for the East Beach.

Source Control Measures • Continue existing upland source control measures, including preserving sheet pile wall integrity.
Institutional Controls • Restrict use of anchors, moorings, and other physical disruption of the lateral containment areas to prevent damage to layers and/or encourage short-circuiting of NAPL through materials. Maintain existing anchoring restrictions in North Shoal and Phase III cap area; include East Beach in restriction. • Maintain Eagle Harbor ICs for fish and shellfish harvesting and flatfish consumption. As remediation and post-remediation monitoring are implemented, evaluate continued application fishing advisories in the FFS Project Area.
Predesign Sampling and Testing • Perform waste characterization testing to determine disposal requirements for excavated materials. • Perform characterization needed to support the remedial design including geotechnical analyses. Conduct cone-penetration probes or auger borings along barrier alignment for geotechnical or other physical characterization. Assume 1 boring every 100 LF and CPTs every 50 LF. Additional sediment borings are included for contingency should site conditions vary and warrant additional investigation. • Perform testing to determine NAPL properties in Alternative 4 remediation area. • Perform surveys determine rate of seep expression to the surface. Cost estimates assume this would be performed by excavation of a series of shallow holes and observing NAPL inflow during low tide. • Perform high resolution, pre-construction baseline bathymetry survey to determine sediment surface elevation for design purposes. • Perform baseline habitat surveys (including eelgrass and general habitat, forage fish). • Perform bench scale testing of NAPL sequestering amendments to verify and refine cap elements (thickness, permeability performance). • Perform baseline TarGOST® survey to refine NAPL delineation in North Shoal area. Assume 1,000 LF of delineation probing in 2 phases for a total of 50 locations. Each boring advanced to a depth of about 20 feet.

TABLE 6-4
Key Components of Alternative 4 – Vertical Containment with Partial Excavation and Capping
Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Base Component and Sequence
Remedial Design • Complete remedial design and identify appropriate subcontractors and vendors for implementation. Cost estimate assumes design process includes Preliminary Design, Pre-Final, and Final Designs, a Remedial Action Work Plan (RAWP), permitting/permit equivalent, contract bid document preparation and procurement. • Conduct design calculations to ensure that the cap has suitable permeability, similar to naturally occurring beach materials to prevent (to maximum extent possible) the formation of preferential pathways. For purposes of developing a cost estimate, the capping system identified below is assumed for alternative development. • Confirm barrier materials and installation methods. • Coordinate with agencies and stakeholders. • Identify staging areas in the upland portion of the site.
Preremediation Site Work • Construct temporary access roads, dewatering pads needed and fencing/security around staging area(s). • Prepare upland staging area (site offices, parking areas, equipment storage area). It is assumed existing sanitation facilities will be sufficient to support OU-1 remedial action. • Establish required survey control points and tide gages. • Confirm pre-construction bathymetry has not changed. The cost estimate assumes that another high resolution survey would be performed. • Identify/construct staging areas for stockpiling import gravelly sand to be used as capping backfill, and dredged/excavated materials that will be dewatered, stabilized and transported for off-site disposal. • Prepare stockpile staging/handling areas estimated to be up to approximately 2-1/2 acres. • Preremediation site work would take approximately 3 weeks.
Potential Upgrading of Existing Upland Sheet Pile Wall • As needed, upgrades to the upland sheet pile wall will be conducted separately from the OU-1 FFS activities. Costs are not included in the OU-1 FFS for this activity.
Installation of Vertical Sheet Pile Barriers • A vertical, steel sheet pile barrier will be installed to a depth of approximately 20 feet below grade using hydraulic push methods or a vibratory head attached to an excavator. Impact driving is not anticipated. The tops of the vertical barrier will be installed to approximately 0.5 feet below the beach surface. No sediment removal is anticipated for the sheet pile installation (pre-trenching not expected to be needed). • Planned vertical barrier locations are indicated on Figure 6-5. The vertical barriers are located seaward of areas of potentially mobile NAPL. The final design will be based on the most comprehensive and updated information available regarding the nature and extent of subsurface NAPL. • Total estimated sheet pile needed for this remedy is 50,000 SF which includes a 15 percent allowance for contingency for sheet replacement resulting from deformation/refusal during placement. • The cost estimate assumes the use of steel sheet piles one-half inch to three-quarter inch thick to provide some capacity for sacrificial corrosion over time. • The sheet pile joints would be sealed with low permeability material that is chemically resistant to NAPL and corrosion in the marine environment such as epoxy-coated bentonite or other low-permeability joint compound.

TABLE 6-4

Key Components of Alternative 4 – Vertical Containment with Partial Excavation and Capping

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Base Component and Sequence

Sediment Removal

- Sediment would be removed using mechanical dredging/excavation. Enclosed 'environmental buckets' will be used. The 6,600 CY in place excavation volume increases to approximately 8,300 CY with bulking.
- Excavation would be limited to working from the land side in the dry at low tide when the beach is exposed using beach-staged excavators. Construction durations are estimated using this assumption, including daily periods of about 3 hours.
- It is assumed crane mats or other similar means may be needed to facilitate movement of equipment on the beach. Approximately 1,750 LF of mats are assumed for the cost estimate.
- Assumes that trench boxes may be used to control excavation sidewalls for each capping cell if required. The actual means and methods would be at discretion of selected contractor.
- Sediment would be placed into 8 cy dump trucks for purposes of transportation to the dewatering pad in the upland. The assumed time to load (8 minutes) and transport to the upland dewatering pad (5 minutes for North Shoal areas and 10 minutes for East Beach areas – each way) and unload (2 minutes) constrains the rate of removal. For the North Shoal area, the estimated cycle time is 20 minutes; for the East Shore the estimated time is 30 minutes.
- The assumed production rate is 72 cy/hour.
- The amended cap will be constructed within the barriers but not over existing Phase III cap.
- To construct cap and maintain existing grade, approximately 30 inches of existing sediment will need to be removed.
- The removed sediment will be dewatered, stabilized, and disposed as nonhazardous material.

Cap Excavation and Upland Excavated Material Dewatering

- At the excavations, water will need to be extracted to facilitate sediment removal and capping in the dry.
- The FFS used AQTESOL modeling (FFS Appendix E) to establish a 100 gallon per minute (gpm) dewatering requirement for managing water from the beach excavations implemented in a grid pattern with individual cells measuring 40 feet by 40 feet. This rate provides 3 feet of drawdown at the edge of the excavation. This pumping rate would be applied throughout the daily excavation period estimated to be 3 hours as noted above. For each 40 foot by 40 foot excavation a total temporary upland tank storage volume of 30,000 gallons is assumed.
- Up to about 2-1/2 acres available for upland stockpile management, dewatering, and stabilization of excavated materials.
- Dewatering will be via gravity drainage to pad collection sumps. No mechanical dewatering is anticipated.
- Collected stockpile drainage water will be collected for reprocessing and discharge through the GWTP.
- It is estimated that 7 gallons of impacted water and NAPL will gravity drain per cy of stockpiled dredged/excavated material.
- Nominal assumed stockpile dewatering time is approximately 2 days. Sediment will be moved around on the dewatering pads to optimize drying and drying amendment management.
- Dewatering water will be directed to a holding tank where solids will be permitted to settle.
- Water will be drawn from the tank and fed into the GWTP based on the current GWTP allowance of 100 gpm total capacity. No additional cost for treatment of the water is assumed.

TABLE 6-4

Key Components of Alternative 4 – Vertical Containment with Partial Excavation and Capping

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Base Component and Sequence

Cap Placement
• Perform initial capping pilot test plot as separate or phased mobilization.
• Cap components include (Figure 6-3):
  o 24-inch layer of gravelly sand similar to the existing beach material to restore habitat/function
  o 4 to 6-inch thick reactive layer. Final media type/mix and thickness determined during remedial design.
• The total cap area would cover approximately 71,150 SF (1.6 acres).
• It is assumed that one 40 foot by 40 foot area can be capped each day depending on location, elevation, and environmental conditions (175 to 215 cy/day).
• All materials would be placed using mechanical earth-moving equipment.
• All cap materials and equipment would be transported to the upland area and protected from environmental degradation at the end of each work shift.

Short-Term Monitoring (During Construction) • Sheens would be monitored visually. • Work zone and perimeter air monitoring would be performed during active construction. • Habitat, fish, and cultural resources monitoring would be conducted. • Some short term application of odor-suppression foams may be needed to manage the sand/sediment on the drying pad. Estimate assumes limited allowance for odor suppressing foam.
Confirmation Sampling/Bathymetric Surveys • Confirmation field surveys would be performed after sediment removal and after cap placement to document that required depth of contaminated sediment/soil and that final cap/fill grades are achieved. • Physical surveys would also be performed after placement of each of the cap layers to confirm that cap is placed to design elevation/thickness and covers entire area. • The final remediation areas should be surveyed and included on project record drawings to document their locations.
Material Treatment and Disposal • Dredged sediment would be stabilized in the upland area by mixing with drying agents as needed to reduce moisture content, and then transported by truck to an offsite Subtitle D disposal facility. • An estimated 11,000 tons of material would require transport and disposal. • Drying and stabilizing amendment consisting of 5 percent Portland cement may be needed to meet paint filter test and stabilize material with free product. • Dredged/excavated sediment would be transported approximately 20 miles by truck to an intermodal rail transfer facility and then approximately 200 miles by rail for disposal.
Performance Monitoring of Remedy (Same for all Alternatives) Monitoring at 5-year increments for a period of up to 30 years and in 10-year increments between 30 and 100 years is assumed. Monitoring objective is to generate sufficient data to assess remedy performance, including compliance with meeting RAOs. Data collection in future years may be amended to address specific physical areas and compounds. Performance monitoring will consist of: • **Physical Stability Monitoring.** High-resolution bathymetric surveys for comparison to baseline; cost estimate assumes performance monitoring survey is less detailed than baseline • **Topographic Surveys.** During Years, 1, 2 and 3 to assess erosion and deposition in the vicinity of each cap.

TABLE 6-4

Key Components of Alternative 4 – Vertical Containment with Partial Excavation and Capping

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Base Component and Sequence
• **Chemical Quality Monitoring of Surface and Subsurface Sediments**. Up to approximately 45 samples. Surface sediment samples to be co-located at clam tissue collection locations to the extent practicable. Sampling performed in Years 3, 6, 9, and 15, every 5 years through Year 30, and every 10 years thereafter for duration of 100 year O&M period. • **Clam Tissue Monitoring**. Up to approximately 15 tissue sampling locations performed in year 6, and Year 9, and every 5 years thereafter for duration of 100 year O&M period. • **Biological Surveys.** Includes eelgrass and general habitat survey, forage fish. • **Laboratory Analyses.** All sediment and tissue samples to be analyzed for PAHs. Assume up to 25 percent of sediment and tissue samples to be analyzed for VOCs. • **Reporting.** Performance monitoring and MNR data will be assessed in depth every 5 years to Year 30, and every 10 years between Year 30 and Year 100. Data will be assessed for trends and RAO compliance, with program modifications identified. • **Input to EPA OU-1 Five-Year Review Reports.**
Long-Term Operations and Maintenance • Annual inspections performed to assess integrity of capped areas and maintenance of the beach surface in the vicinity of the steel sheet pile, and to look for seeps or sheens. • Annual inspections will include collection and visual evaluation of shallow cores of the upper gravelly sand layer of the cap to determine if NAPL breakthrough has occurred. • Cap O&M assumes 25 percent of the capped area in the North Shoal and 25 percent of the capped area in the East Beach will be repaired in Year 9, and 25 percent of the capped area in the East Beach repaired in Year 30. • The uppermost portions of the steel sheet pile will be inspected visually via shallow holes dug in beach to assess their integrity. Geophysical and remote sensing methods may also be used also.

TABLE 6-5

Key Components of Alternative 5 - Dredging

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Base Component and Sequence

General Description of Alternative
• Alternative 5 (Figure 6-9 and Figure 6-10) includes:
  o Removal of marine sand and gravel sediment to 10 feet below grade from areas of the North Shoal and East Beach with potentially mobile NAPL.
  o MNR in areas with no NAPL, non-mobile NAPL, and NAPL seeps in eelgrass beds.
• The estimated in-place dredging/excavation and capping volume is approximately 26,000 cy over 1.6 acres.
• Dredging and excavation would not extend into the eelgrass areas.
• All excavated materials will be disposed offsite and all capping material will be imported.
• Temporary, sealed sheet pile enclosures will be installed to facilitate wet excavation or dredging. These enclosures are conceptualized on Figure 6-10. Sheeting will be installed using water-based equipment.
• It is envisioned that Alternative 5 can be implemented sequentially between enclosure cells. The operations sequence depends on the rate of dredging/excavation and subsequent material transfer and handling in the upland.
• The overall estimated duration is up to about 8 months over one or two construction seasons.
• Dredged/excavated material will be dewatered and stabilized as needed in the upland area and disposed offsite in a Subtitle D landfill.
• Long-term O&M assumes annual inspections to assess the physical integrity of beach surface in removal areas and verify the anticipated absence of seeps.

Source Control Measures • Continue existing upland source control measures, including preserving sheet pile wall integrity.
Institutional Controls • Maintain existing anchoring restrictions in North Shoal and Phase III cap area; include East Beach in restriction. • Maintain existing Eagle Harbor ICs for fish and shellfish harvesting closure and flat fish consumption. As remediation and post-remediation monitoring are implemented, evaluate continued application fishing advisories in the FFS Project Area.
Predesign Sampling and Testing • Perform waste characterization testing to determine disposal requirements for excavated materials. Material to be excavated includes NAPL-impacted sediment and some areas of potentially uncontaminated overburden. During design, different disposal/reuse scenarios could be considered for these materials. Based on available data, approximately half of the material to be removed may be ‘uncontaminated.’ • Perform characterization needed to support the remedial design including geotechnical analyses. Due to volume of material and limited upland staging area, dewatering bench tests will need to be conducted to confirm rates of dewatering, and rate of dredging/excavation. Conduct cone-penetrometer (CPT) probes or auger borings for geotechnical, dredgeability, or other physical characterization in the vicinity of planned temporary sheet pile containment for excavation cells. Assume 1 boring per 100 LF and CPTs every 50 LF. • Perform testing to determine NAPL properties in Alternative 5 remediation area. • Perform high resolution, pre-construction baseline bathymetry survey to determine sediment surface elevation for design purposes. • Perform baseline habitat surveys (including eelgrass and general habitat, forage fish). • Perform bench scale testing of NAPL sequestering amendments to verify and refine amendment materials in capping backfill (thickness, performance).

TABLE 6-5

Key Components of Alternative 5 - Dredging

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Base Component and Sequence

- Perform baseline TarGOST® survey to refine NAPL delineation in North Shoal area. Assume 1,000 LF of delineation probing in 2 phases for a total of 50 locations. Each boring advanced to a depth of about 20 feet.

Remedial Design

- Complete remedy design and identify appropriate subcontractors and vendors for implementation. Cost estimate assumes design process includes Preliminary Design, Pre-Final, and Final Designs, a Remedial Action Work Plan (RAWP), permitting/permit equivalent, contract bid document preparation and procurement. Full scale design will include: 1) sheet pile design; 2) dredge design; 3) environmental monitoring; 4) dredge material management including transloading facility inspection/upgrade; 4) dredge spoil dewatering; and 5) off-site disposal.
- Confirm sheet pile materials and installation methods.
- Coordinate with agencies and stakeholders.
- Identify staging areas in the upland portion of the site.

Preremediation Site Work

- Construct temporary access roads, dewatering pads needed and fencing/security around staging area(s).
- Prepare upland staging area (site offices, parking areas, equipment storage area). It is assumed existing sanitation facilities will be sufficient to support OU-1 remedial action.
- Establish required survey control points and tide gages.
- Confirm pre-construction bathymetry has not changed. The cost estimate assumes that another high resolution survey would be performed.
- Identify/construct staging areas for stockpiling import gravelly sand to be used as capping backfill, and dredged/excavated materials that will be dewatered, stabilized and transported for off-site disposal.
- Prepare stockpile staging/handling areas estimated to be approximately 2-1/2 acres.
- Preremediation site work would take approximately 4 weeks.

Potential Upgrading of Existing Upland Sheet Pile Wall

- As needed, upgrades to the upland sheet pile wall will be conducted separately from the OU-1 FFS activities. Costs are not included in the OU-1 FFS for this activity.

Installation and Removal of Temporary Sheet Pile Cells

- This FFS assumes temporary sheet pile enclosures will be installed to facilitate sediment excavation or dredging. These enclosures are conceptualized on Figure 6-9 and Figure 6-10.
- Impacted sediment will be removed in the wet by enclosing the removal areas with sheeting installed using water-based crane and vibratory hammer equipment.
- Steel sheet sections will have minimum thickness of one-half to three-quarters inches, design to determine.
- The sheeting must be installed deep enough to support a 10 foot excavation from existing grade, and stand through the water column of about 15 feet depth. With a nominal subsurface sheet embedment of at 20 to 25 feet below existing grade, approximate 45-foot minimum sheet lengths will be needed to safely extend above the water column and provide freeboard. This will result in sheet pile wall exposure heights up to about 25 feet including dredge/excavation prism height and height through the water column.
- Sheet piling is temporary and will be reused to enclose successive excavation areas. Deformation/breakage is assumed to be 15 percent based on the marine sands and gravels present.
- The final design should be based on the most comprehensive and updated information regarding the location of NAPL in the subsurface.

TABLE 6-5
Key Components of Alternative 5 - Dredging
Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Base Component and Sequence
• The Contractor may further optimize the containment approach and dredge cell size to economize the footage of steel sheet piles, or use of alternative techniques where determined to be suitable.

Sediment Removal/Backfill

- Sediment would be removed using mechanical dredging/excavation.
- Enclosed 'environmental buckets' are assumed but may not be needed inside the enclosures. The 26,000 CY in place excavation volume increases to approximately 32,500 CY with bulking.
- North Shoal
  - Work will be conducted using water-based mechanical dredges operating inside the enclosures. Four enclosures up to about 150 feet by 150 feet in dimension will be constructed.
  - The estimated North Shoal removal rate is approximately 300 cy/day.
  - The sheet pile equipment set (Set A) will initiate enclosure installation, with the dredging/capping equipment set (Set B) to follow.
  - Equipment sets will leapfrog from cell to cell to complete dredging.
  - Dredged materials will be rehandled over the enclosure wall and transferred 1) across the upland sheet pile wall to haul vehicles in the upland, or 2) haul vehicles on the beach at low tide.
  - Haul vehicles will transfer dredged materials to the upland dewatering pads.
- East Beach
  - Work will be conducted using a long arm excavator staged in the upland and set back from the upland sheet pile wall.
  - Two enclosures up to approximately 200 feet long (parallel to shoreline) and 100 feet wide will be constructed.
  - Sheet pile equipment (Set A) will initiate enclosure installation from the water side, with upland excavation equipment (Set C) mechanically removing sediment from the enclosure. Upland equipment staging may require additional structural support such as a load-bearing platform.
  - Upland Set C equipment will transfer excavated material from the sheet pile enclosure to containers, haul trucks, or directly onto dewatering pads.
  - The estimated East Beach removal rate is approximately 200 cy/day.
- To balance hydraulic forces and enclosure loading, a nominal assumption is that a standing head of eight feet of water will be maintained within the enclosures. Additional pumping for water extraction and addition with assistance from a water storage vessel may be needed, but is not further considered for the FFS.
- Capping:
  - Gravelly sand import cap fill, over 2-inch thick layer of sand with oleophilic clay (OC) amendment, over 2-inch sand layer.
  - Lowermost sand layer placed to settle residuals.
  - Lowermost sand layer and OC sand amendment layer placed using tremie methods.
  - Bench scale testing will needed to confirm the appropriate blending rate of adsorbent media to sand. For the FFS, an estimate of 5 parts sand to 2 parts adsorbent is assumed. The FFS cost estimate conservatively assumes all material excavated will be disposed off-site and all capping material must be purchased and transported to the site.
- The capping material will provide suitable habitat restoration.
- Water within each enclosure will be pumped to the GWTP following capping and prior to removing sheet piles.

TABLE 6-5
Key Components of Alternative 5 - Dredging
Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Base Component and Sequence
Upland Dredged/Excavated Material Dewatering
• Up to about 2-12 acres available for upland stockpile management, dewatering, and stabilization of dredged/excavated materials. • Dewatering will be via gravity drainage to pad collection sumps. No mechanical dewatering is anticipated. • Collected stockpile drainage water will be collected for reprocessing and discharge through the GWTP. • It is estimated that 7 gallons of impacted water and NAPL will gravity drain per cy of stockpiled dredged/excavated material. • Nominal assumed stockpile dewatering time is approximately 2 days. Sediment will be moved around on the dewatering pads to optimize drying and drying amendment management. • Dewatering water will be directed to a holding tank where solids will be permitted to settle. • Water will be drawn from the tank and fed into the GWTP based on the current GWTP allowance of 100 gpm total capacity. No additional cost for treatment of the water is assumed.
Short-Term Monitoring (During Construction)
• Sheens would be monitored visually. • Work zone and perimeter air monitoring would be performed during active construction. • Water quality monitoring outside sheet pile enclosures would be monitored. • Sheet pile enclosures and seams/seals would be monitored for integrity. • Habitat, fish, and cultural resources monitoring would be conducted. • Some short term application of odor-suppression foams may be needed to manage the sand/sediment on the drying pad. Estimate assumes limited allowance for odor suppressing foam.
Confirmation Sampling/Bathymetric Surveys
• Confirmation field surveys would be performed after sediment removal and after cap placement to document that required depth of contaminated sediment/soil and that final cap/fill grades are achieved. • Physical surveys would also be performed after placement of each of the cap layers to confirm that cap is placed to design elevation/thickness and covers entire area. • The final remediation areas should be surveyed and included on project record drawings to document their locations.
Material Treatment and Disposal
• Dredged/excavated sediment would be stabilized in the upland area by mixing with drying agents as needed to reduce moisture content, and then transported by truck to an off-site Subtitle D disposal facility. • An estimated 43,000 tons of material would require transport and disposal. • Drying and stabilizing amendment consisting of 5 percent Portland cement may be needed to meet paint filter test and stabilize material with free product. • Dredged/excavated sediment would be transported approximately 20 miles by truck to an intermodal rail transfer facility and then approximately 200 miles by rail for disposal.
Performance Monitoring of Remedy (Same for all Alternatives)
Monitoring at 5-year increments for a period of up to 30 years and in 10-year increments between 30 and 100 years is assumed. Monitoring objective is to generate sufficient data to assess remedy performance, including compliance with meeting RAOs. Data collection in future years may be amended to address specific physical areas and compounds. Performance monitoring will consist of:

TABLE 6-5
Key Components of Alternative 5 - Dredging
Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Base Component and Sequence
• **Physical Stability Monitoring.** High-resolution bathymetric surveys for comparison to baseline; cost estimate assumes performance monitoring survey is less detailed than baseline. • **Topographic Surveys.** During Years, 1, 2 and 3 to assess erosion and deposition of backfill areas. • **Chemical Quality Monitoring of Surface and Subsurface Sediments**. Up to approximately 45 samples. Surface sediment samples to be co-located at clam tissue collection locations to the extent practicable. Sampling performed in Years 3, 6, 9, and 15, every 5 years through Year 30, and every 10 years thereafter for duration of 100 year O&M period. • **Clam Tissue Monitoring**. Up to approximately 15 tissue sampling locations performed in year 6, and Year 9, and every 5 years thereafter for duration of 100 year O&M period. • **Biological Surveys.** Includes eelgrass and general habitat survey, forage fish. • **Laboratory Analyses.** All sediment and tissue samples to be analyzed for PAHs. Assume up to 25 percent of sediment and tissue samples to be analyzed for VOCs. • **Reporting.** Performance monitoring and MNR data will be assessed in depth every 5 years to Year 30, and every 10 years between Year 30 and Year 100. Data will be assessed for trends and RAO compliance, with program modifications identified. • **Input to EPA OU-1 Five-Year Review Reports.**
Long Term Operations and Maintenance • Annual inspections performed to assess integrity of beach surface in the vicinity of the performed remediation, and to look for seeps or sheens. • No physical maintenance or cap replacement is assumed for Alternative 5.

TABLE 6-6
Detailed Evaluation of Operable Unit 1 Focused Feasibility Study Alternatives
Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Criteria	Alternative 1: No Action	Alternative 2: Seep Capping and MNR	Alternative 3: Partial Excavation and Capping	Alternative 4: Vertical Containment with Partial Excavation and Capping	Alternative 5: Dredging
Threshold Criteria					
Overall protection of human health and the environment	No RAOs would not be achieved. This alternative would not provide additional protection to human health and the environment beyond the ongoing natural recovery processes occurring at the site. Natural recovery processes would continue to occur, but the RAOs would not be achieved within an acceptable time frame. There would also be no monitoring under this alternative to assess progress. The sources of seeps would not be controlled and seeps would continue to appear until the mobile NAPL was exhausted.	Yes The caps, where placed, would provide a physical, chemical, and biological barrier, effectively mitigating exposure pathways and these areas would meet the RAOs upon completion of construction. The remainder of the site would meet the RAOs through MNR. Alternative would address seep(s) in eelgrass areas through MNR.	Yes Implementation of this alternative would meet RAOs upon completion where cap was placed. The cap would provide a physical, chemical, and biological barrier, effectively mitigating exposure pathways. The remainder of the site would meet the RAOs through MNR. Alternative would address seeps in eelgrass areas through MNR.	Yes Implementation of this alternative would meet RAOs upon completion where cap was placed. The cap would provide a physical, chemical, and biological barrier, effectively mitigating exposure pathways. The installation of additional sheet pile would provide a physical barrier and block NAPL transport of NAPL to areas further from shore; and would be expected to cut off the NAPL source to the sheen seep on the North Shoal. Controlling the NAPL migration to the beach is expected to increase the rate of recovery through natural processes, which would be expected to further reduce the NAPL constituent concentrations in the sediment downgradient of the (new) wall. The remainder of the site would meet the RAOs through MNR. Alternative would address seep(s) in eelgrass areas through MNR; vertical barrier would likely cut off NAPL source to this seep.	Yes Backfilling with clean material would result in the RAOs being met upon completion within the excavation cells, since the backfill would provide a physical, chemical, and biological barrier, effectively mitigating exposure pathways. Partial removal will eliminate some of the source material, but the practicable removal depth is approximately 10 feet due to engineering constraints. Some NAPL will remain below this depth and historic NAPL-wetted pathways associated with these areas represent a potential transport pathway. Areas outside the excavation footprint would rely on MNR to continue to reduce contaminant concentrations in the sediments and pore water. Alternative would address seep(s) in eelgrass areas through MNR; much of the NAPL source to this seep will likely be removed.
Compliance with ARARs	No	Yes Alternative would be designed to comply with the substantive requirements of the action and location specific ARARs. Water upwelling through capped areas would comply with chemical-specific ARARs. Water upwelling though MNR areas would comply with chemical-specific ARARs at conclusion of the remedial action.	Yes Similar to Alternative 2.	Yes Similar to Alternatives 2 and 3.	Yes Similar to Alternatives 2, 3, and 4.
Balancing Criteria					
Long-term effectiveness and permanence	Alternative 1 would provide a low level of long-term effectiveness and permanence since no action would be taken.	Alternative 2 would provide a moderate level of long-term effectiveness and permanence based on the discussion below. The time frame to achieve the RAOs for areas of the site managed using MNR is likely the longest compared to other alternatives, since this alternative remediates the smallest area and will only remove minimal source material. Unlikely to achieve RAOs in 10-year timeframe.	Alternative 3 would provide a moderate level of long-term effectiveness and permanence based on the discussion below. The time frame required for MNR to achieve the RAOs for areas of the site not actively remediated is less than Alternative 2, but likely greater than Alternatives 4 and 5	Alternative 4 would provide a moderate to high level of long-term effectiveness and permanence based on the discussion below. The time frame required for MNR to achieve the RAOs for areas of the site not actively remediated is less than Alternatives 2 and 3, but likely greater than Alternative 5.	Alternative 5 would provide a high level of long-term effectiveness and permanence based on the discussion below. The time frame required for MNR to achieve the RAOs for areas of the site not actively remediated is likely the shortest of the alternatives evaluated.
- Magnitude of residual risk remaining from untreated waste or treatment residuals	Not applicable	Most of the contamination in OU1 would remain onsite under Alternative 2. There would be potential human and ecological exposure in areas managed using MNR, until the RAOs had been reached in those areas.	Some contamination will remain on site under Alternative 3, but the extent of the capping would limit the degree of human health and ecological exposure.	Some contamination will remain on site under Alternative 4, but the extent of the capping would limit the degree of human health and ecological exposure.	Under Alternative 5, some contamination will remain on site, but much less than other alternatives (it is estimated that this alternative would remove approximately 80% of the mobile NAPL in OU1).

TABLE 6-6
Detailed Evaluation of Operable Unit 1 Focused Feasibility Study Alternatives
Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Criteria	Alternative 1: No Action	Alternative 2: Seep Capping and MNR	Alternative 3: Partial Excavation and Capping	Alternative 4: Vertical Containment with Partial Excavation and Capping	Alternative 5: Dredging
remaining at the conclusion of the remedial activities		Since potential risks would remain, 5-year reviews will be required.	There would be potential human and ecological exposure in areas managed using MNR, until the RAOs had been reached in those areas. 5-year reviews will be required.	There would be potential human and ecological exposure in areas managed using MNR, until the RAOs had been reached in those areas. The vertical barrier would contain the NAPL and facilitate MNR in the areas outside the active remediation footprint. 5-year reviews will be required.	There would be potential human and ecological exposure in areas managed using MNR, until the RAOs had been reached in those areas; however, the extent of the source removal would be expected to expedite MNR in the remaining areas. Since potential risks would remain, 5-year reviews will be required.
- Adequacy and reliability of controls	Not applicable	Removal using excavation or dredging is an established technology that would readily meet performance objectives for that component of the alternative (see Table 6-2). Capping is an established technology and can be designed to meet the performance specifications of the alternative. The O&M plan developed during the remedial design would determine the monitoring and maintenance frequencies required to assure and maintain cap integrity based on site-specific factors. Cap repairs would be performed as needed. Component failures (i.e., sediment cap failure) could potentially result in sheens on the water surface and limited exposure to ecological or human receptors; however, catastrophic failure of the cap is unlikely if appropriate long-term O&M plans are implemented. Landfilling is an established means of disposal. Material stabilized prior to landfilling Long-term O&M requirements are listed in Table 6-2.	Similar to Alternative 2; long-term O&M requirements are listed in Table 6-3.	Similar to Alternatives 2 and 3 for the removal, capping, and disposal and MNR data collection; long-term O&M requirements are listed in Table 6-4. Sheet pile wall installation, as well as sealing the walls, are established technologies are effective in isolating NAPL. Established data collection techniques can be used to assess performance of the wall.	Similar to Alternatives 2, 3, and 4 for the removal, disposal, and MNR; long-term O&M requirements are listed in Table 6-5. Carbon amendment for contaminant sequestration is an established technology and the amendments can be designed to meet the performance specifications of the alternative.
Reduction of toxicity, mobility, or volume through treatment	Low - Alternative does not include a treatment component and does not meet the statutory preference for treatment as a principal element of a remedy.	Low - The capping component is considered a treatment that would reduce the mobility of NAPL constituents. Toxicity and volume would not be markedly affected. Sorption of NAPL or NAPL constituents to the treatment layers of the cap is considered irreversible, but if the media were to become saturated, the effect would be nullified. MNR is a longer-term process decreasing toxicity, mobility, and volume. Landfilled materials are stabilized.	Moderate - The capping component is considered treatment that would reduce the mobility of NAPL constituents. Similar to Alternative 2, although some volume of NAPL would be removed as a result of excavation done for cap placement.	Moderate to high- The vertical barrier alone does not constitute a treatment, but the capping component of this alternative, if implemented, is considered a treatment to limit mobility. Similar to Alternatives 2 and 3, although some volume of NAPL would be removed as a result of excavation done for cap placement.	Low to moderate - Treatment is not a primary component of this remedy - removal does not reduce TMV through treatment. Placement of amendment in bottom of excavation cells is considered treatment to mitigate some of the sheening associated with the NAPL immediately below placement, but would not substantively reduce the TMV. Sorption of NAPL or NAPL constituents to the treatment layers of the cap is considered irreversible, but if the media were to become saturated, the effect would be nullified. MNR is a longer-term process decreasing toxicity, mobility, and volume. Landfilled materials are stabilized.

TABLE 6-6
Detailed Evaluation of Operable Unit 1 Focused Feasibility Study Alternatives
Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Criteria	Alternative 1: No Action	Alternative 2: Seep Capping and MNR	Alternative 3: Partial Excavation and Capping	Alternative 4: Vertical Containment with Partial Excavation and Capping	Alternative 5: Dredging
Short-term effectiveness	Low – no actions are taken under this alternative.	The short-term effectiveness of Alternative 2 is considered high due to the construction duration and the potential risks and environmental impacts described below.	The short-term effectiveness of Alternative 3 is considered moderate due to the construction duration and the potential risks and environmental impacts described below	The short-term effectiveness of Alternative 4 is considered moderate due to the construction duration and the potential risks and environmental impacts described below	The short-term effectiveness of Alternative 3 is considered low due to the construction duration potential short-term risks to the community and site workers.
- Risks to community, workers, and the associated controls	Since no remedial actions would be taken, there would be no construction-related risks to the community or workers.	Potential risks to the community would include increased levels of traffic, dust, noise, and odors during the removal and handling of contaminated sediment and soils. Engineering controls and best management practices can mitigate most potential risks: Access to the active work and support zones would be prohibited. Notification of work schedule would be provided to surrounding community. Dust and noise levels would be monitored. Odors are expected during sediment removal and may not be able to be fully controlled. Odor suppression foams could be used in the sediment stockpiling areas, if needed. Potential risks to workers would include physical hazards associated with general construction, potential exposure to and direct contact with dredged sediment and NAPL, noise, odors, dust, and vapors. These would be mitigated through: Engineering controls and best management practices. Compliance with appropriate health and safety plans and site management plans. Use of appropriate personal protective equipment.	Similar to Alternative 2, but with a longer expected duration.	Similar to Alternatives 2 and 3, with the addition of greater amount of noise during sheet pile installation. It is possible that work periods could be restricted for the especially noisy operations. Future each erosion may expose the top of the sheet pile posing an aesthetic and safety hazard to beach users. Based on observations of timber pile exposure on the North Shoal, the potential for this to occur is expected to be moderate to high.	Similar to Alternative 4, with longer construction duration.
- Environmental Impacts of Remedy and Controls	Since no remedial actions would be taken, there would be no construction-related environmental impacts.	Alternative would have smallest intrusive footprint on the beach/habitat (approximately 0.6 acres); habitat would be restored in work areas upon completion. All targeted seep locations are outside of the eelgrass area and there are no expected impacts to eelgrass. Construction would be performed in the dry, during low tide, obviating concerns related to increased turbidity and chemical releases to the water column due to suspended sediment. Short-term environmental effects during implementation may include potential NAPL releases to the beach surface and odors. Control	Approximately 2.5 acres of the beach, would be disrupted. The habitat would be restored when complete. The remedial footprint does not extend into the eelgrass area, but is adjacent to it. Minimal effects to eelgrass are anticipated. Construction would be sequenced so that active excavation and cap placement would be performed in the dry, avoiding concerns related to increased turbidity and chemical releases to the water column due to suspended sediment. Short-term environmental effects during implementation may include potential NAPL releases to the beach surface and odors. Control measures to	Approximately 1.7 acres of the beach would be disrupted. The habitat would be restored when complete. The remedial footprint does not extend into the eelgrass area, but is adjacent to it. Minimal effects to eelgrass are anticipated. Installation of sheet pile could be locally disruptive. To the extent possible, construction would be sequenced so that active sheet pile installation, excavation, and cap placement would be performed in the dry, minimizing concerns related to increased turbidity and chemical releases to the water column due to suspended sediment. Short-term environmental effects during implementation may include potential NAPL	Approximately 2.3 acres of the beach would be disrupted for nearly 13 months. The habitat would be restored upon completion of work. Short-term environmental effects during implementation may include potential NAPL releases to surface water, turbidity increases, and releases of some sediment-associated contamination within the enclosed excavation or dredge cells. Water would be treated before disposal or discharge. It is expected that dredge cells would contain suspended sediments (turbidity and sediment associated contaminants) and potential NAPL releases that could result from the dredging process. Water within the dredge cells would need to be managed through pumping, storage, and treatment,

TABLE 6-6
Detailed Evaluation of Operable Unit 1 Focused Feasibility Study Alternatives
Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Criteria	Alternative 1: No Action	Alternative 2: Seep Capping and MNR	Alternative 3: Partial Excavation and Capping	Alternative 4: Vertical Containment with Partial Excavation and Capping	Alternative 5: Dredging
		measures to mitigate NAPL releases would include absorbent booms. The duration of any potential releases to the beach surface would be very short and would only occur during the excavation and capping at of the seeps.	mitigate NAPL releases would include absorbent booms. The duration of any potential releases to the beach surface would be very short and would only occur during the excavation and cap placement.	releases to the beach surface and odors. Control measures to mitigate NAPL releases would include absorbent booms. Potential releases to the beach surface could occur during installation of sheet piling, excavation, and cap placement.	or treatment in place by adding sorbent materials during backfilling to remove NAPL and settle suspended solids. The remedial footprint does not extend into the eelgrass area, but is adjacent to it. Minimal effects to eelgrass are anticipated. The duration of these releases would be very short and would only occur during construction; however, implementation of the water management controls represents a significant engineering challenge.
- Duration of short-term risks	Since no remedial actions would be taken, there would be no short-term risks related to construction.	Construction would last approximately 2 months.	Construction would last approximately 6 months.	Construction would last approximately 6 months.	Construction would last approximately 13 months.
Implementability	Not applicable – no actions are taken under this alternative.	The overall implementability of Alternative 2 is high	The overall implementability of Alternative 3 is moderate to high	The overall implementability of Alternative 4 is moderate	The overall implementability of Alternative 5 is low to moderate
- Technical feasibility	Not applicable - no actions are taken under this alternative.	Alternative is technically implementable and sediment removal and capping are established, field-proven technologies The short- and long-term monitoring requirements can be performed using standard practices and technologies. Bench testing would be required to determine most suitable cap design. Tide cycles will control available work windows and work will need to be phased and planned accordingly; however, small, targeted removal and capping cells are expected to be able to be done at a rate of one per day. Restarting the upland GWTS for the short construction period that is anticipated for this alternative may not be cost effective. Water would be pumped to the upland to temporary storage tanks and then shipped offsite for disposal. The available staging area is limited and may pose logistical challenges for the water storage.	Similar to Alternative 2, but on a larger scale within the FFS project area. Construction sequencing will rely heavily on the tidal cycles and the work will need to be carefully planned to maximize production. The challenges associated with implementing the dewatering and water treatment elements of the remedy will be more complex relative to Alternative 2. The transportation of dredged materials from the beach area to the upland could potentially be the limiting step related to daily production rates. The upland GWTS would be reactivated for this alternative and has a limited capacity and water from excavation cells and dredged sediment would need to be temporarily stored in Baker tanks and then bled into the system – depending on the amount of water infiltrating excavation; this could potentially be a rate limiting step.	Alternative is technically implementable and sheet piling and capping are established, field-proven technologies The short- and long-term monitoring requirements can be performed using standard practices and technologies. As noted for Alternatives 2 and 3, construction sequencing needs to consider the tide cycles. Alternative 4 would have an additional degree of complexity associated with the sequencing and installation of the new sheet pile containment wall. The challenges associated with implementing the dewatering and water treatment elements of the remedy would be comparable to Alternative 3. The transportation of dredged materials from the beach area to the upland could potentially be the limiting step related to daily production rates.	Alternative would require the installation of excavation or dredge cells (as described in Section 6) – which would add a significant level of logistical complexity compared to other alternatives, particularly with respect to the management of dredged material. The material would need to be transported from the beach area to the upland using several interim steps. The existing sheet pile wall around OU2 may require additional bracing during the removal to prevent the wall from becoming compromised. This would pose a significant engineering and implementation challenge for this alternative. The lack of available staging and stockpiling area in the upland would also limit the production rates and technical feasibility of this alternative. Management of water within the dredging cells could be challenging and could be a considerable constraint for this alternative. Sheens resulting from the removal of the NAPL may be difficult to control. The short- and long-term monitoring requirements can be performed using standard practices and technologies.
- Administrative feasibility	Alternative would not be administratively feasible because it would not meet RAOs.	Alternative is administratively feasible and will require coordination between the Federal and state regulatory agencies, Tribes, and other stakeholders, as well as with upland remedial actions. Availability of staging and stockpiling areas in the upland could hinder implementation.	Same as Alternative 2.	Same as Alternative 2.	Same as Alternative 2, except that availability of staging and stockpiling areas in the upland will constrain implementation.

TABLE 6-6
Detailed Evaluation of Operable Unit 1 Focused Feasibility Study Alternatives
Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Criteria	Alternative 1: No Action	Alternative 2: Seep Capping and MNR	Alternative 3: Partial Excavation and Capping	Alternative 4: Vertical Containment with Partial Excavation and Capping	Alternative 5: Dredging
		Institutional controls will need to be maintained to assure remedy protectiveness.			
- Availability of services and materials	Not applicable - no actions are taken under this alternative.	Equipment and subcontractors for the sediment removal and cap placement are commercially available. The volume of amendments and capping materials is anticipated to be relatively small and is expected to be available. The amount of material anticipated for off-site disposal is expected to be small (approximately 1,500 tons) and landfill capacity is expected to be available.	Equipment and subcontractors for the sediment removal and cap placement are commercially available. The procurement of specialty capping amendments may require advance coordination and potential use of multiple vendors with comparable products. The amount of material anticipated for off-site disposal is expected to be moderate (approximately 11,000 tons). Landfill capacity is expected to be available; however, the limited availability of upland stockpiling and dewatering areas would necessitate very careful management of waste materials.	Equipment and subcontractors for the sheet pile installation, sediment removal and cap placement are commercially available. The procurement of specialty capping amendments, if the cap is installed, may require advance coordination and potential use of multiple vendors with comparable products. The amount of material anticipated for off-site disposal is expected to be moderate (approximately 11,000 tons). Landfill capacity is expected to be available; however, the limited availability of upland stockpiling and dewatering areas would necessitate very careful management of waste materials.	Equipment and subcontractors for the sheet pile installation, sediment removal and cap placement are commercially available. Amount of sediment for disposal is the largest of the alternatives, approximately 43,000 tons. It is anticipated landfill capacity is available; however, a key limitation will be lack of upland staging area available for sediment dewatering and material staging.
Total Capital Plus O&M Cost [a] (see Table 6-7)	$0	$3,110,000	$11,769,000	$15,219,000	$29,374,000

Notes:
[a] Present value O&M cost based on 7 percent discount rate

TABLE 6-7

Operable Unit 1 Focused Feasibility Study Alternatives Cost Summary

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

	At 7 Percent Discount Rate			At 1.4 Percent Discount Rate			
Alternatives	**Capital Costs**	**Operations and Maintenance Costs[1]**	**Total Capital Plus Operations and Maintenance Costs**	**Capital Costs**	**Operations and Maintenance Costs[1]**	**Total Capital Plus Operations and Maintenance Costs**	**Non-Discounted Operations and Maintenance Costs**
Alternative 1—No Action	$0	$0	$0	$0	$0	$0	$0
Alternative 2—Seep Capping and MNR	$2,612,000	$498,000	$3,110,000	$2,612,000	$1,328,000	$3,940,000	$4,771,000
Alternative 3—Partial Excavation and Capping	$8,920,000	$2,849,000	$11,769,000	$8,920,000	$6,014,000	$14,934,000	$16,890,000
Alternative 4—Vertical Containment with Partial Excavation and Capping	$12,837,000	$2,382,000	$15,219,000	$12,837,000	$5,118,000	$17,955,000	$19,781,000
Alternative 5—Dredging	$28,957,000	$417,000	$29,374,000	$28,957,000	$1,179,000	$30,136,000	$30,942,000

Notes:

See Appendix F for additional cost details.

[1] 7 Percent discount rate applied over 100-year life-cycle term.

TABLE 6-8

Comparative Evaluation of Operable Unit 1 Focused Feasibility Study Alternatives

Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Alternatives	Threshold Criteria		Balancing Criteria				
	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility, or Volume	Short-Term Effectiveness	Implementability	Total Cost[1]
Alternative 1: No Action	No	No	★☆☆	★☆☆	★★★	★★★	$0
Alternative 2: Seep Capping and MNR	Yes	Yes	★☆☆	★☆☆	★★★	★★★	$3,110,000
Alternative 3: Partial Excavation and Capping	Yes	Yes	★★☆	★★☆	★★☆	★★☆	$11,769,000
Alternative 4: Vertical Containment with Partial Excavation and Capping	Yes	Yes	★★☆	★★☆	★★☆	★★☆	$15,219,000
Alternative 5: Dredging	Yes	Yes	★★★	★★★	★★☆	★★☆	$29,374,000

[1]Capital plus O&M costs based on 100 year period of performance with 7.00 percent discount factor for present worth. See Table 6-7 and Appendix F for additional cost detail.

Legend:

Threshold Criteria:

No Does not satisfy criterion (or not applicable for No Action Alternative 1 balancing criteria)

Yes Satisfies criterion

Balancing Criteria:

★★★ = Alternative expected to perform very well against the CERCLA balancing criterion with minimal disadvantages or uncertainties

★★☆ = Alternative expected to perform moderately well against the CERCLA balancing criterion but with some disadvantages or uncertainties

★☆☆ = Alternative expected to perform less well against the CERCLA balancing criterion with more disadvantages or uncertainty

TABLE 6-9

Sustainability Evaluation of Operable Unit 1 Focused Feasibility Study Alternatives

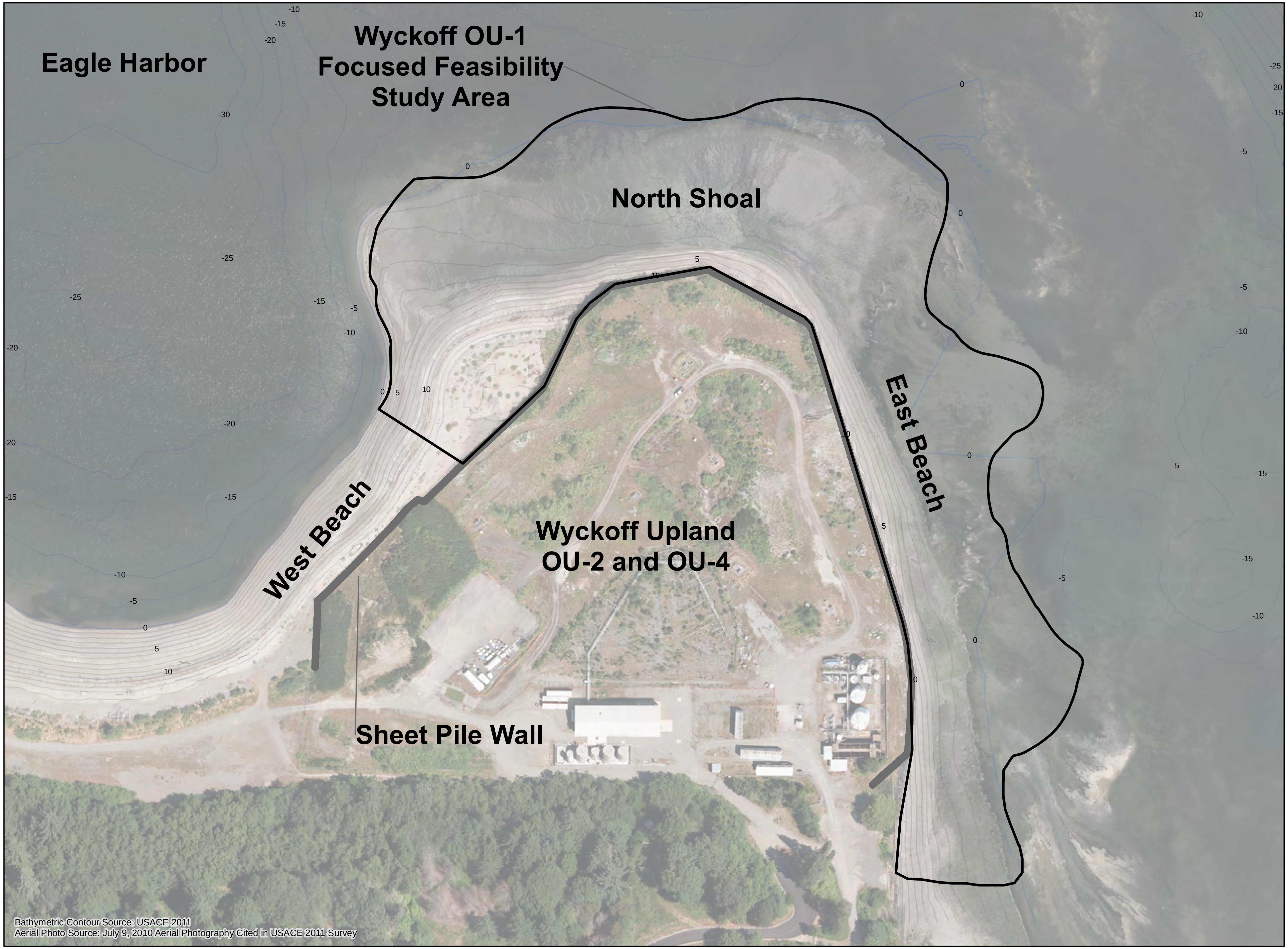
Focused Feasibility Study Wyckoff/Eagle Harbor Superfund Site Operable Unit 1

Sustainability Impacts	Alternative 2: Seep Capping and MNR	Alternative 3: Partial Excavation and Capping	Alternative 4: Vertical Containment with Partial Excavation and Capping	Alternative 5: Dredging
Energy Consumed/Fossil Fuel Depletion • Use of renewable energy	Lowest comparative energy consumption because the least amount of sediment removed and alternative requires the lowest quantity of material (i.e., capping components) to be transported to or from the site. Since the material quantities are lower, the associated on-site material handling needs will also be less.	Moderate level of energy consumption relative to Alternatives 2 and 5, which are markedly lower and higher, respectively. Alternative 3 requires more material be transported to and from the site than Alternative 2, but much less than Alternative 5.	Comparable to Alternative 3. Although the quantities of excavated sediment and cap materials are slightly lower, this is offset by the need to transport the sheet pile to the site.	Alternative 5 would require the greatest amount of energy/fuel consumption as a result of the amount of sediment removed and transported, the amount of backfill and associated amendment needed, and the sheet piles required for the conceptual design. The onsite material handling requirements would also be much greater than any of the other alternatives.
Green House Gas (GHG) and Other Air Emissions	GHG emissions would be the lowest of the four alternatives considered due to the lowest volume of material requiring handling and transport to and from the site; the comparatively low volume of water requiring treatment; and the short duration of implementation.	GHG emissions would largely be related to the materials transportation requirements and the on-site earth work requirements. GHG emissions for Alternative 3 would be greater than Alternative 2 and less than Alternative 5.	Moderate – comparable to Alternative 3.	High – GHG emissions largely related to material transport and earthwork.
Transportation Impacts • Proximity • Efficiency • Hauling	FS assumes that the disposal facility is the same distance away for all four alternatives. However, Alternative 2 requires the least amount of material to be taken offsite, as well as the least amount of construction materials to be brought to the site, therefore, the overall transportation impacts are low relative to the other alternatives.	The transportation impacts are moderate relative to Alternatives 2 and 5.	Moderate – comparable to Alternative 3.	High – Alternative 5 would require transport of the most amount of sediment or construction materials.
Waste Reduction, Reuse, and Recycling • Waste or Residuals Generated from Treatment • Solid/ Hazardous Waste Reduction • Use or reuse of materials that would be otherwise considered a waste product	*NA – alternative does not include a treatment option that would significantly reduce waste or residuals.*	*NA – alternative does not include a treatment option that would significantly reduce waste or residuals.*	*NA – alternative does not include a treatment option that would significantly reduce waste or residuals.*	*NA – alternative does not include a treatment option that would significantly reduce waste or residuals.*
Water Requirements and Impacts on Water Resources	*Based on conceptual designs any water infiltrating the excavations or sheet pile work zones would be pumped and treated at the upland groundwater treatment plant, treated, and discharged. No net impact to the resource is expected. The amount of water treated and discharged is expected to be low for Alternative 2, moderate for Alternatives 3 and 4, and comparatively high for Alternative 5.*			
Overall sustainability impacts	**Low**	**Moderate**	**Moderate**	High

No shading /italicized	Insignificant relative to other impacts
(green shading)	Lower negative impacts
(yellow shading)	Moderate negative impacts
(red shading)	Higher negative impacts

Figures

Figure 2-1
Wyckoff FFS OU-1
Project Area and Vicinity Map
Wyckoff OU-1 Focused Feasibility Study



Wyckoff OU-1 Focused Feasibility Study Project Area

0 Surface Elevation Contours in Feet (MLLW)

1-foot contour intervals were generated using USACE interpolation methods

2011 survey data provided by USACE

N

0 60 120 240 Feet

Figure 2-2
Wyckoff OU-1 FFS Project Area
Wyckoff OU-1 Focused Feasibility Study

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Wyckof OU-1 Focused Feasibility Study Project Area

Approximate Boundary Between East Harbor and West Harbor Operable Units
1994 Phase I Cap Boundary
2000 Phase II Cap Boundary
2001 Phase III Cap Boundary
2007 Exposure Barrier System

N
0 130 260 520 Feet

Figure 2-3
Previous OU-1 Remedial Actions
Wyckoff OU-1 Focused Feasibility Study

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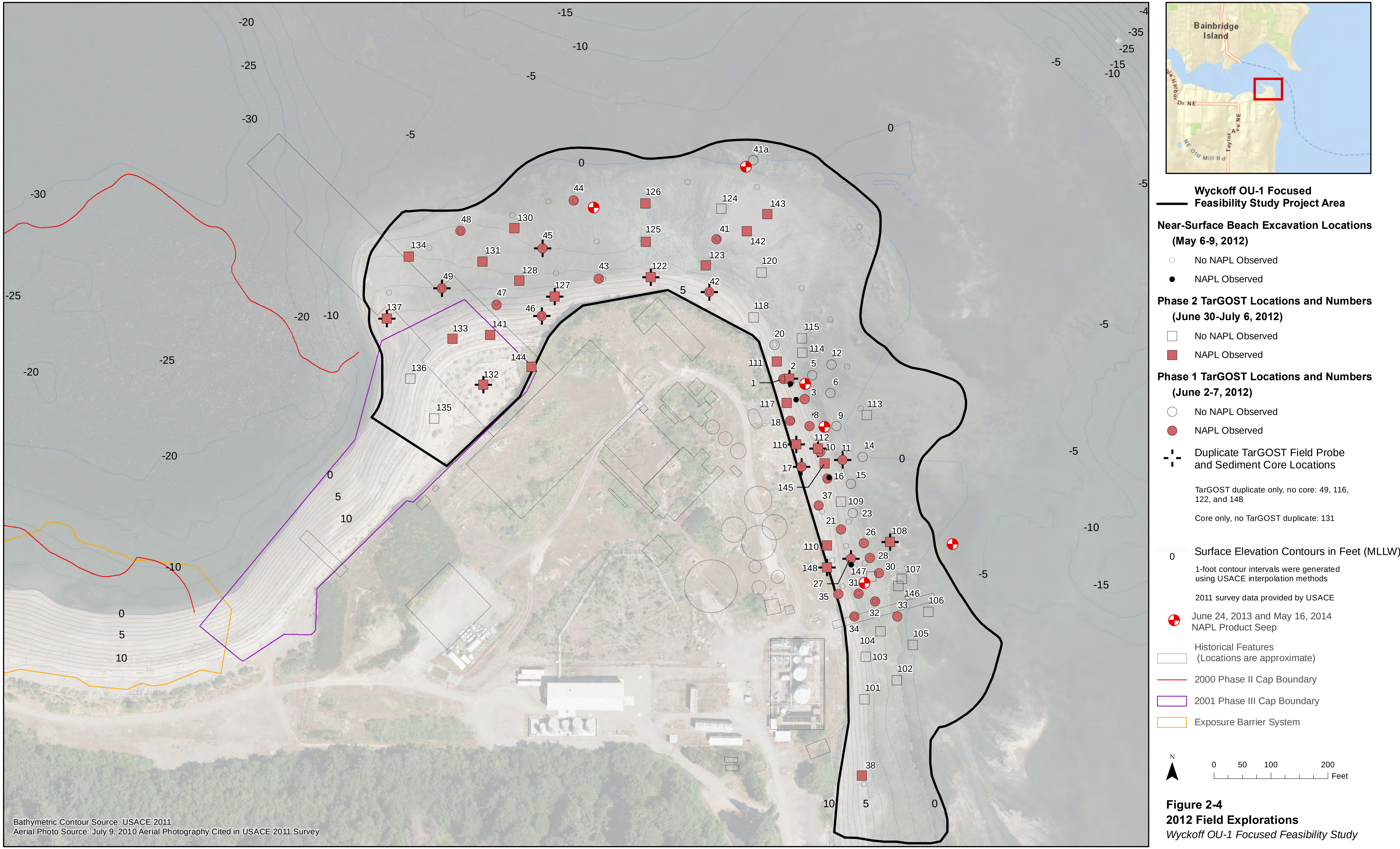


Figure 2-4
2012 Field Explorations
Wyckoff OU-1 Focused Feasibility Study

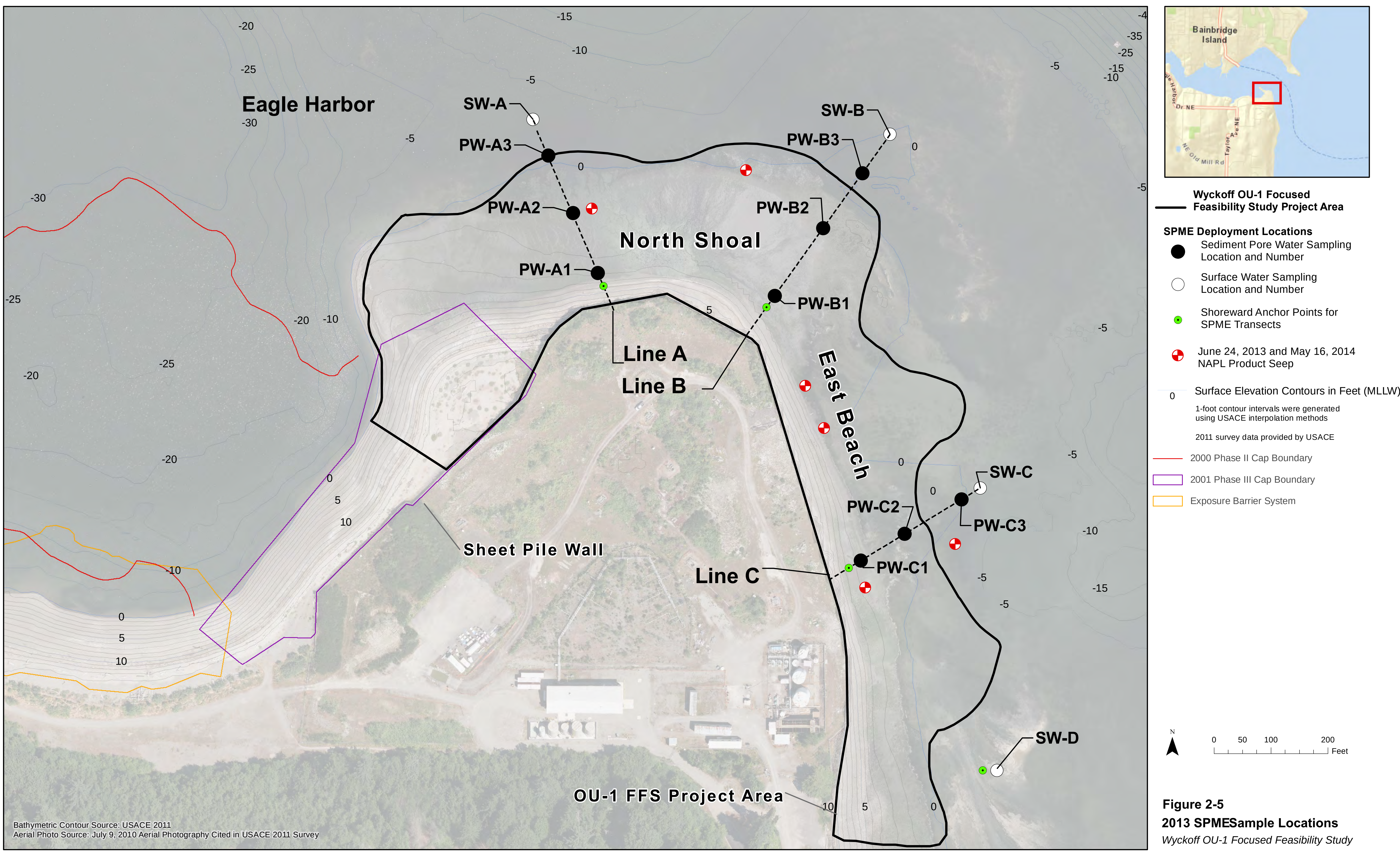


Figure 2-5
2013 SPMESample Locations
Wyckoff OU-1 Focused Feasibility Study

Figure 3-1
Eelgrass Distribution in North Shoal and East Beach Areas
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 1000 hrs on 12/13/2012 - Basecase

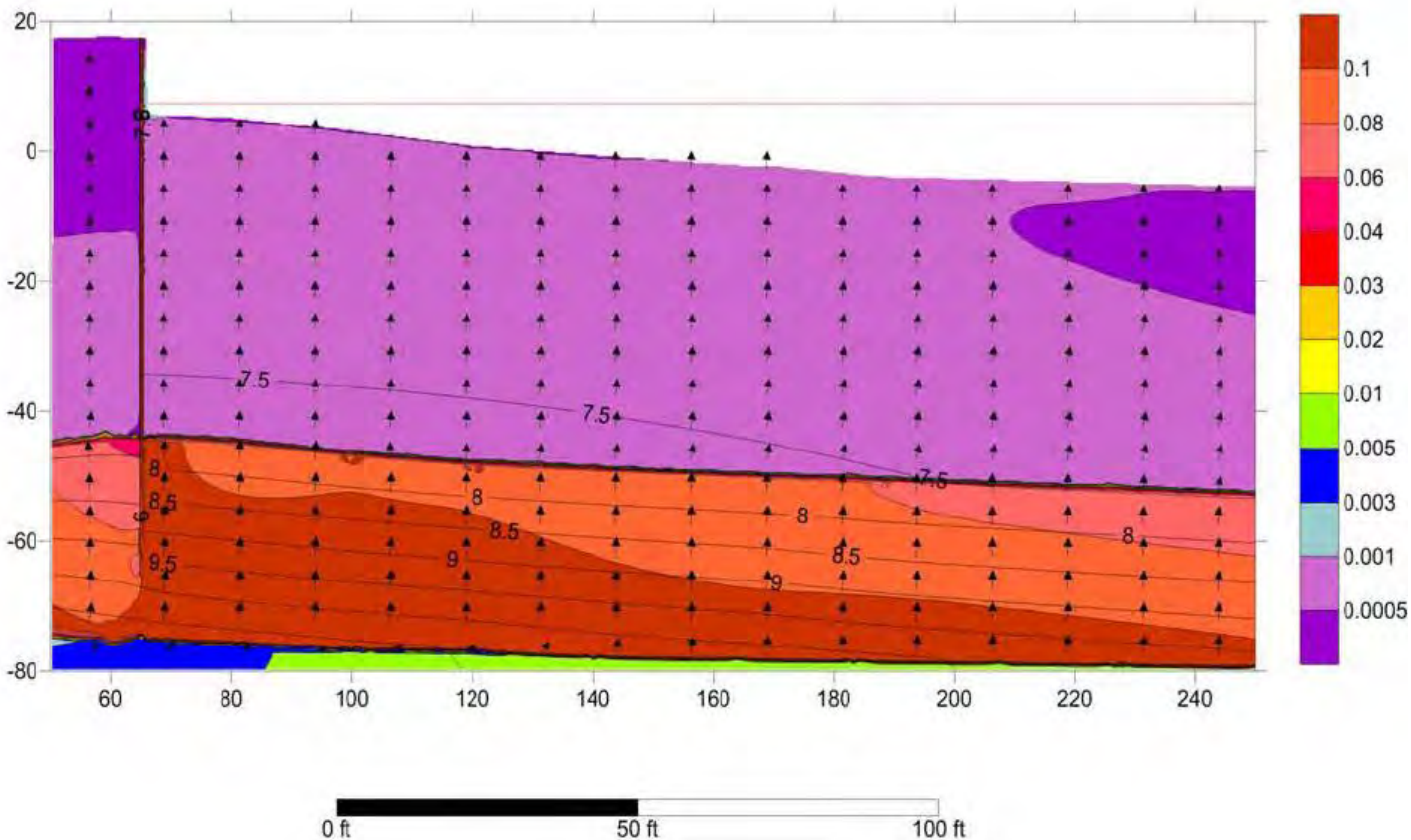


Figure 3-2
Vertical Hydraulic Gradient Basecase
Simulation at 1000 Hours
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 2100 hrs on 12/13/2012 - Basecase

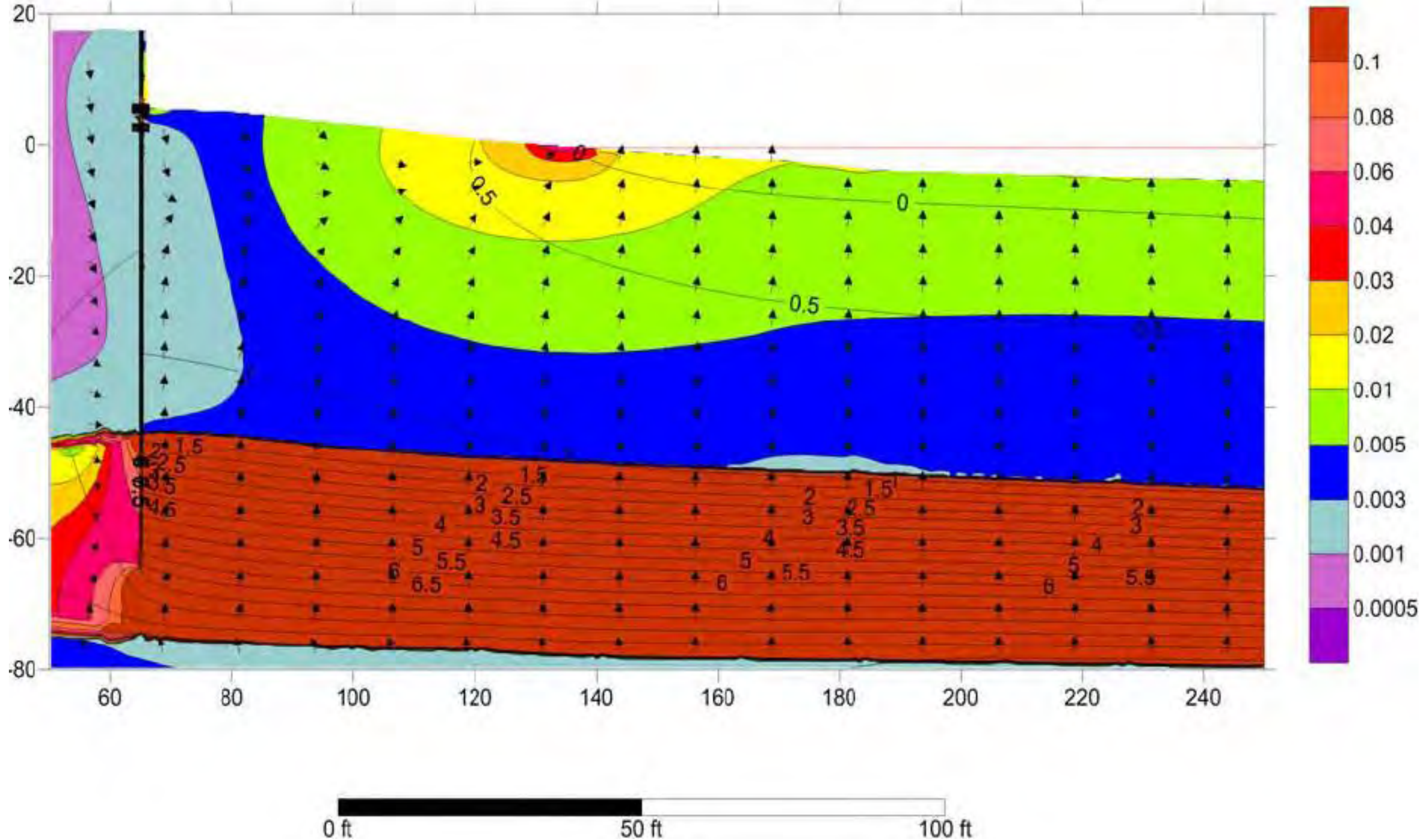
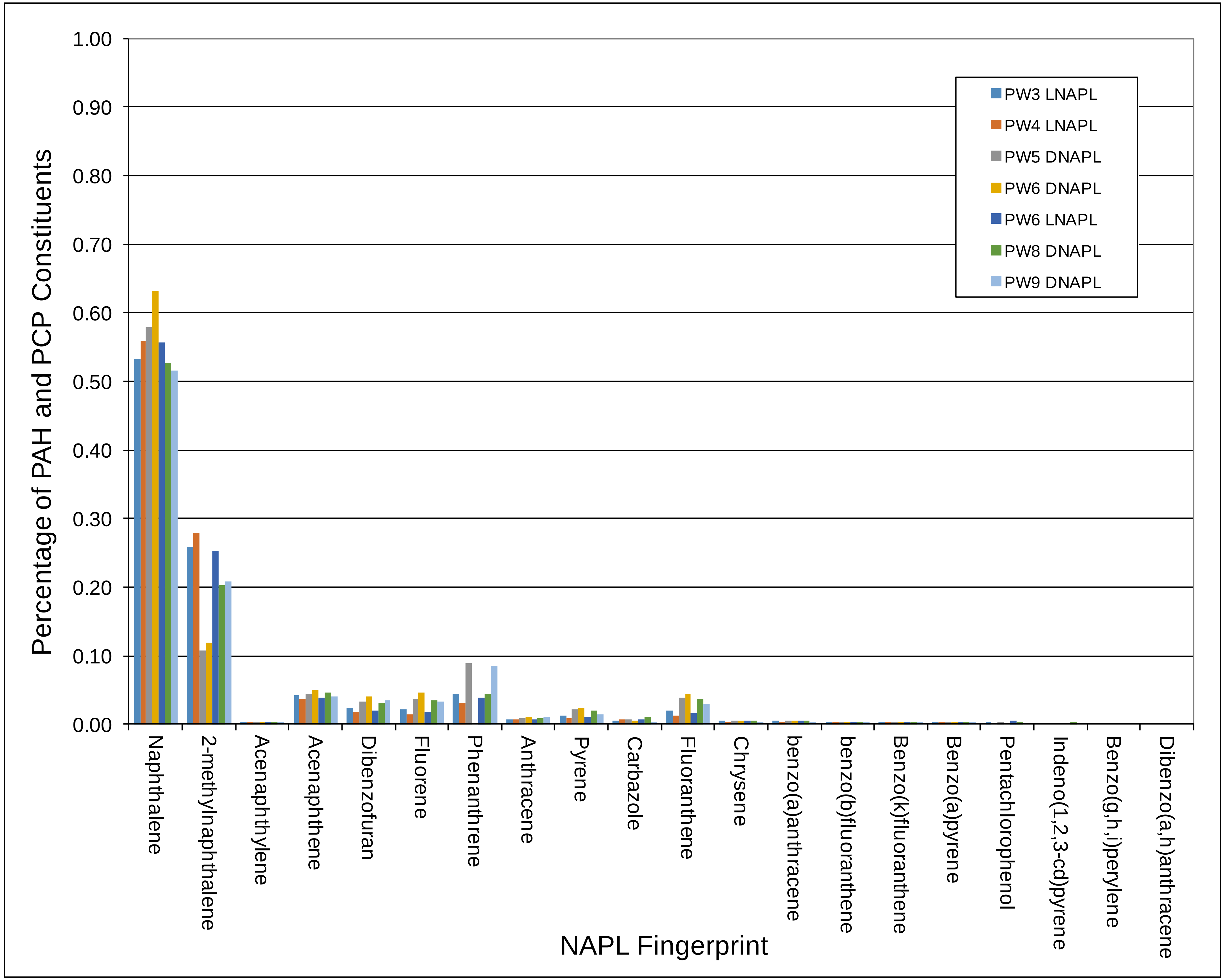


Figure 3-3
Vertical Hydraulic Gradient Basecase Simulation at 2100 Hours
Wyckoff OU-1 Focused Feasibility Study



Fingerprint Based on NAPL Product Sources from Upland Wells

Figure 3-4
Graphical Fingerprint of PAH and PCP Constituents in Upland NAPL Samples
Wyckoff OU-1 Focused Feasibility Study

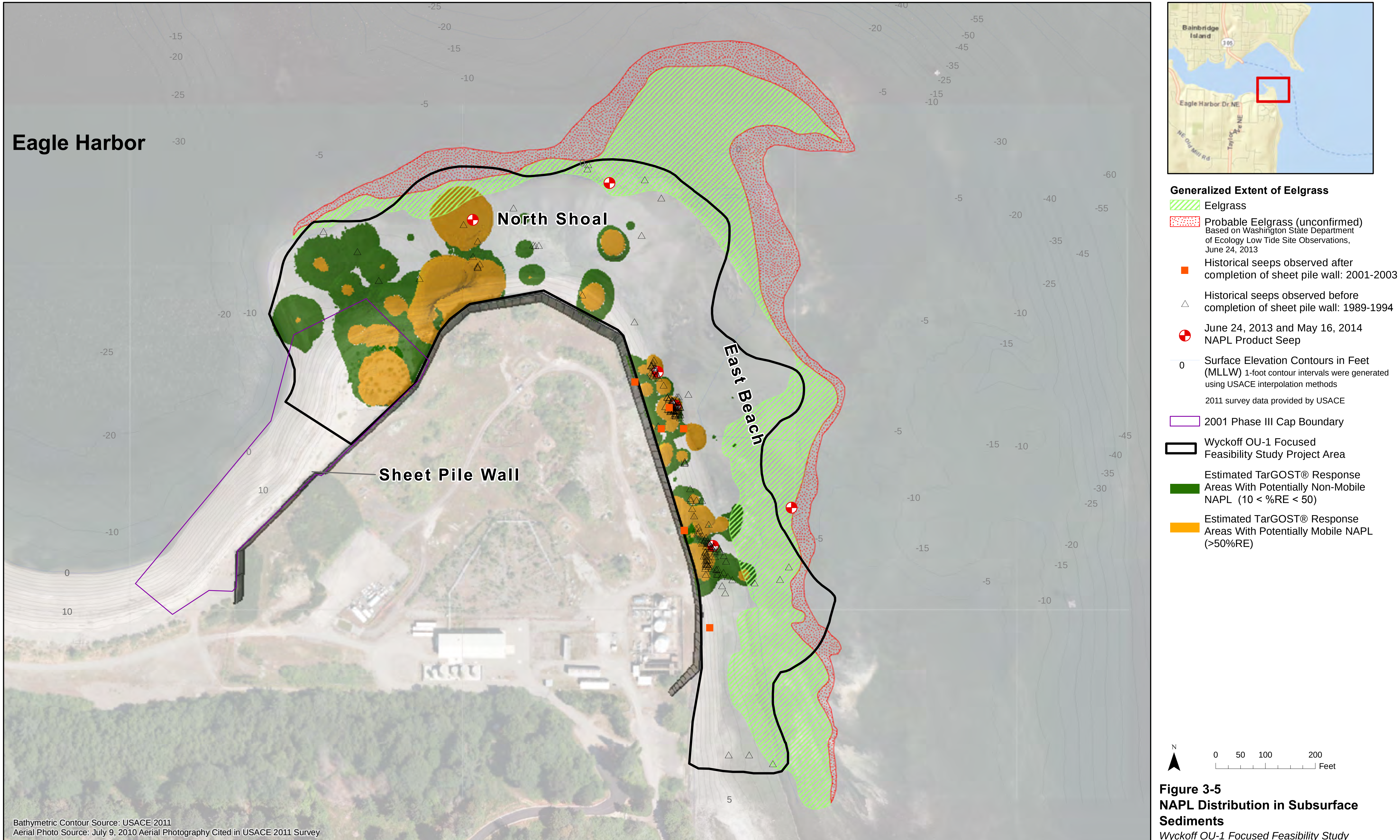


Figure 3-5
NAPL Distribution in Subsurface Sediments
Wyckoff OU-1 Focused Feasibility Study

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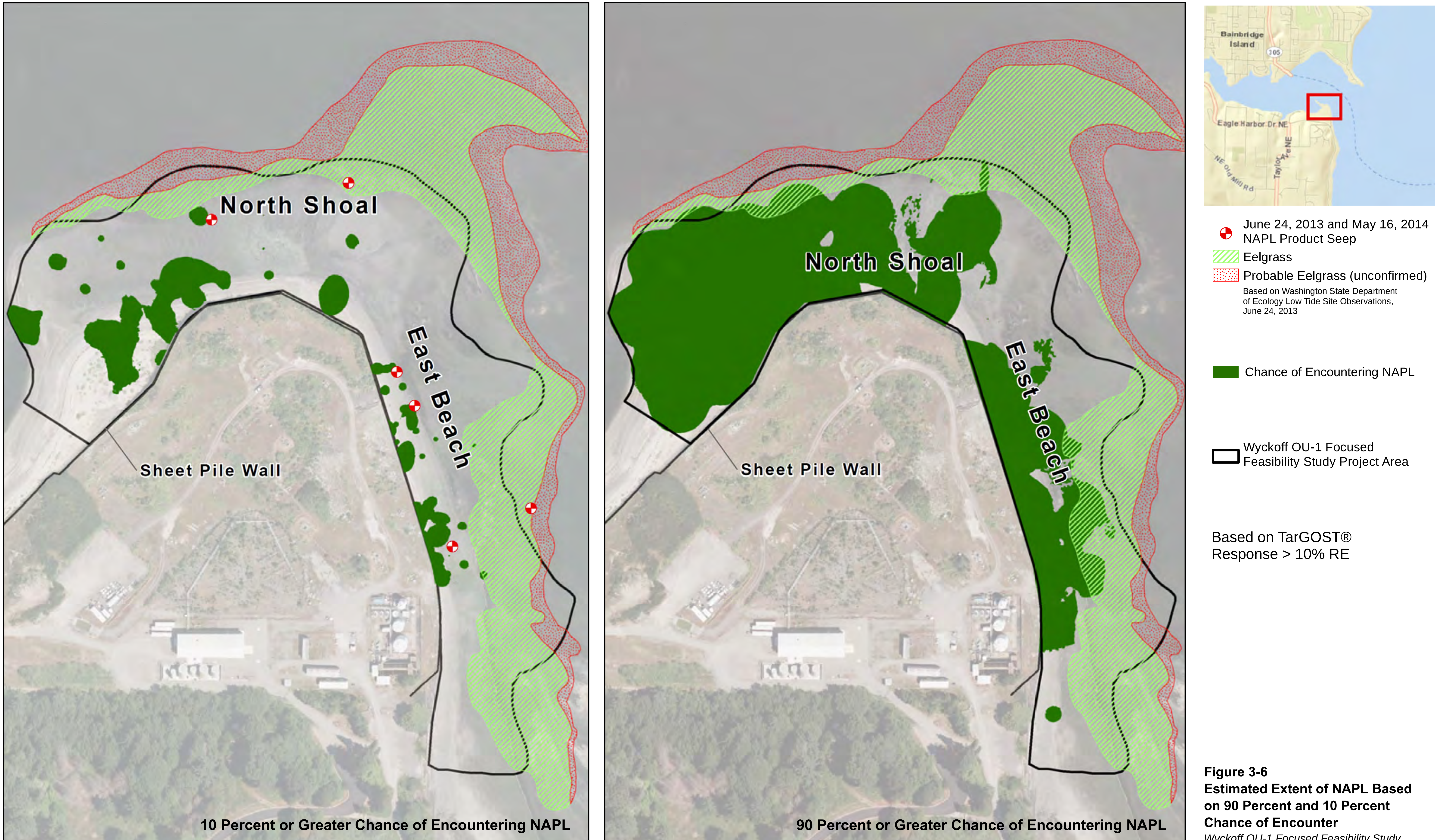


Figure 3-6
Estimated Extent of NAPL Based on 90 Percent and 10 Percent Chance of Encounter
Wyckoff OU-1 Focused Feasibility Study

Figure 3-7
Estimated Extent of NAPL Based on 50 Percent or Greater Chance of Encounter
Wyckoff OU-1 Focused Feasibility Study

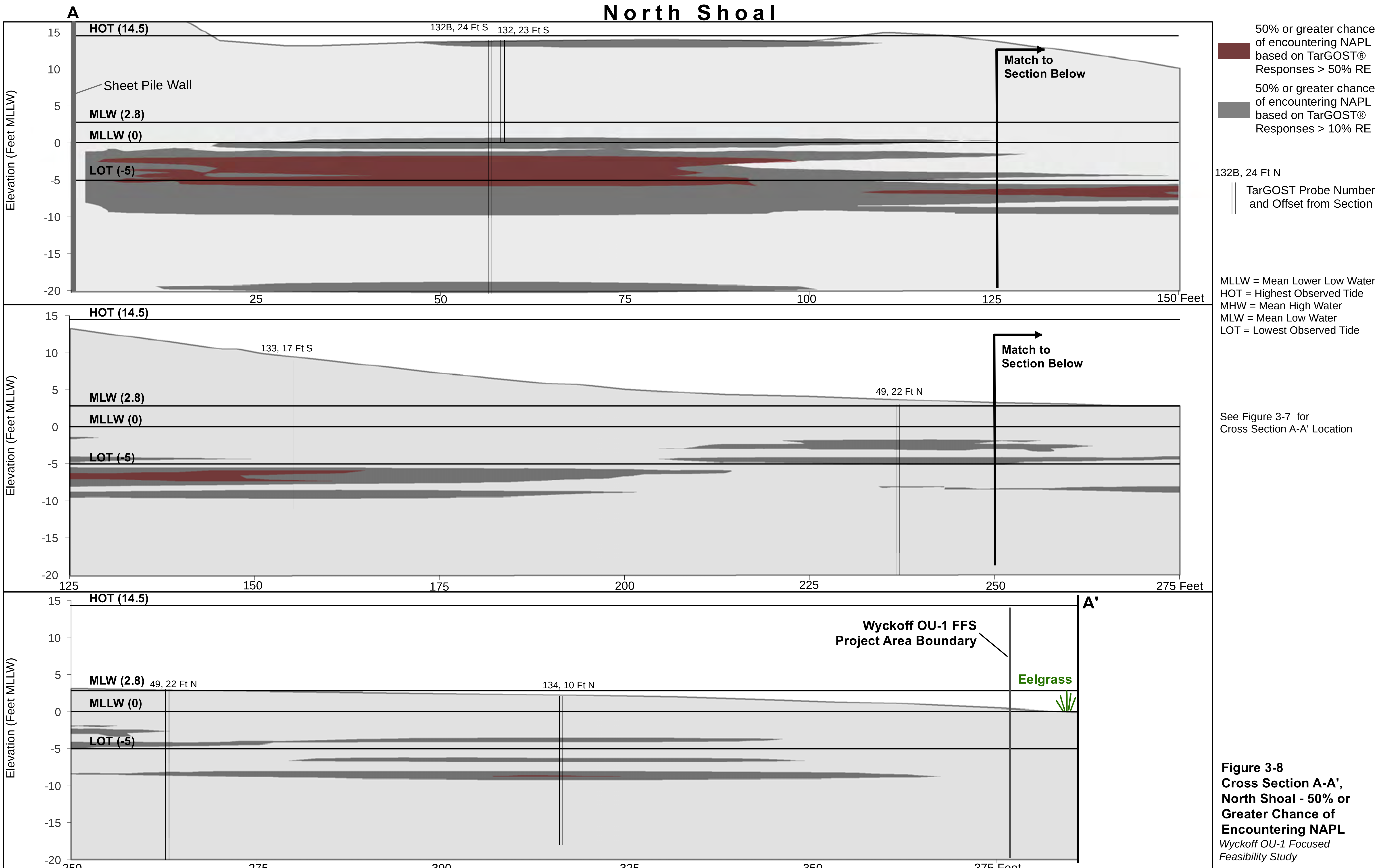
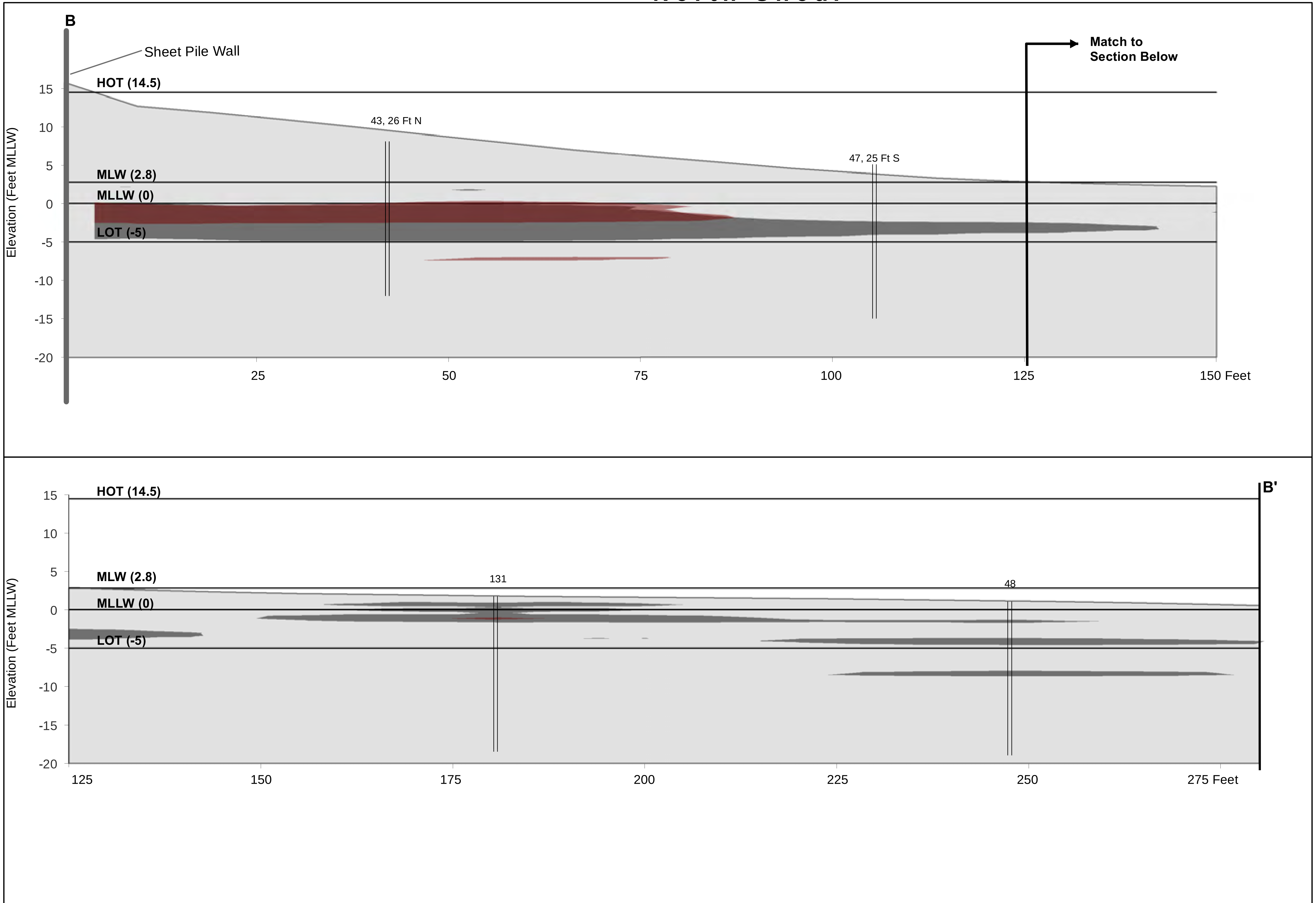


Figure 3-8
Cross Section A-A', North Shoal - 50% or Greater Chance of Encountering NAPL
Wyckoff OU-1 Focused Feasibility Study

North Shoal



50% or greater chance of encountering NAPL based on TarGOST® Responses > 50% RE

50% or greater chance of encountering NAPL based on TarGOST® Responses > 10% RE

49, 29 Ft N
TarGOST Probe Number and Offset from Section

MLLW = Mean Lower Low Water
HOT = Highest Observed Tide
MHW = Mean High Water
MLW = Mean Low Water
LOT = Lowest Observed Tide

See Figure 3-7 for Cross Section B-B' Location

Figure 3-9
Cross Section B-B', North Shoal- 50% or Greater Chance of Encountering NAPL

Wyckoff OU-1 Focused Feasibility Study

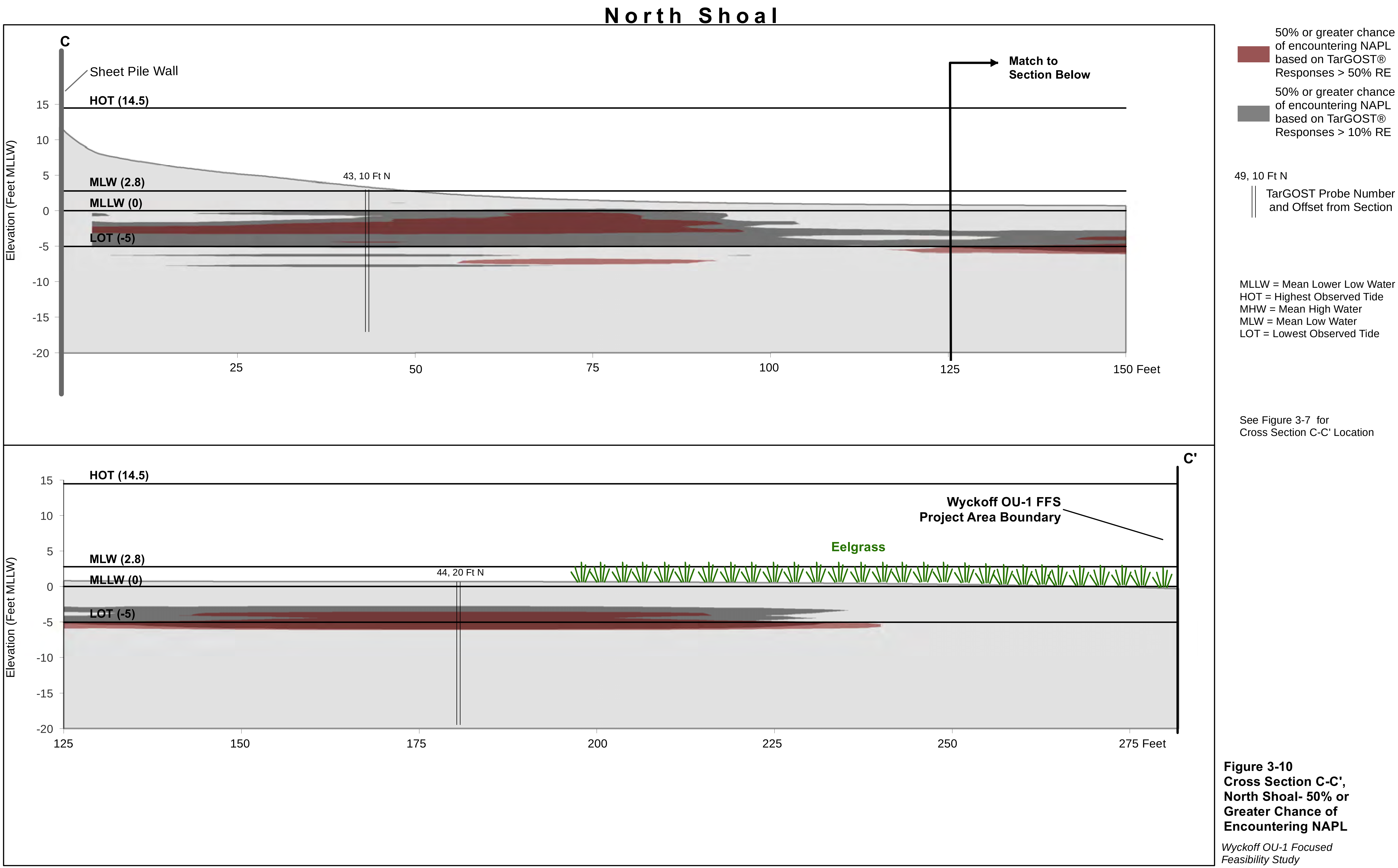
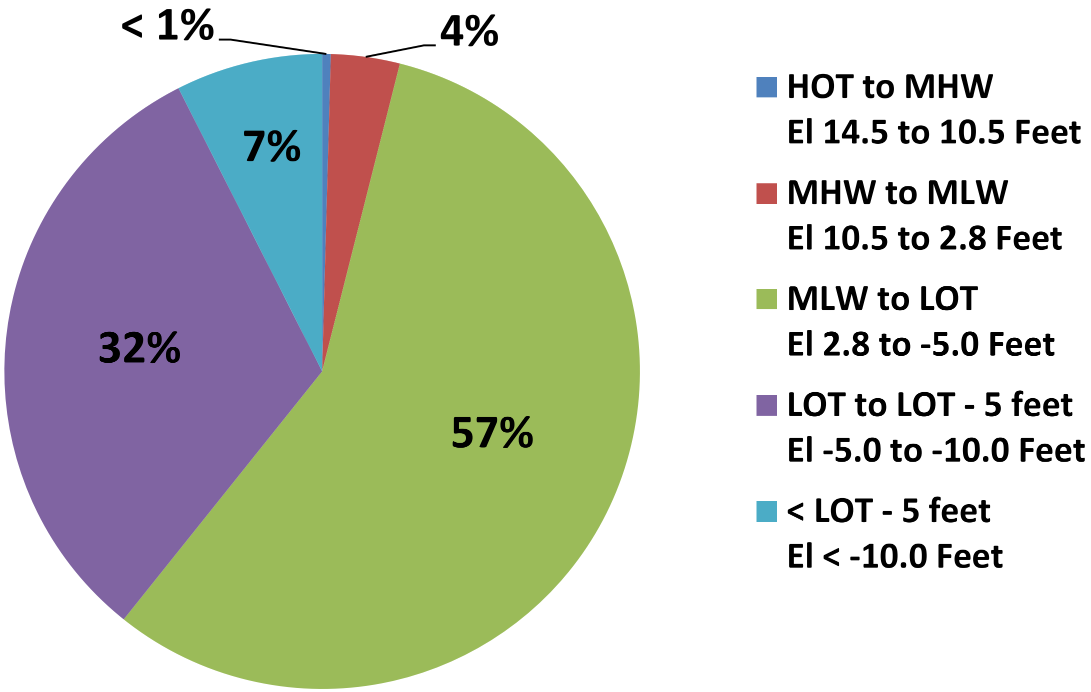


Figure 3-10
Cross Section C-C', North Shoal- 50% or Greater Chance of Encountering NAPL

Wyckoff OU-1 Focused Feasibility Study



Notes:
HOT – Highest Observed Tide
MHW – Mean High Water
MLW – Mean Low Water
LOT – Lowest Observed Tide

Figure 3-11
NAPL Probability Distribution Volumes Relative to Tide Elevation – 50 Percent NAPL Probability Distribution
Wyckoff OU-1 Focused Feasibility Study

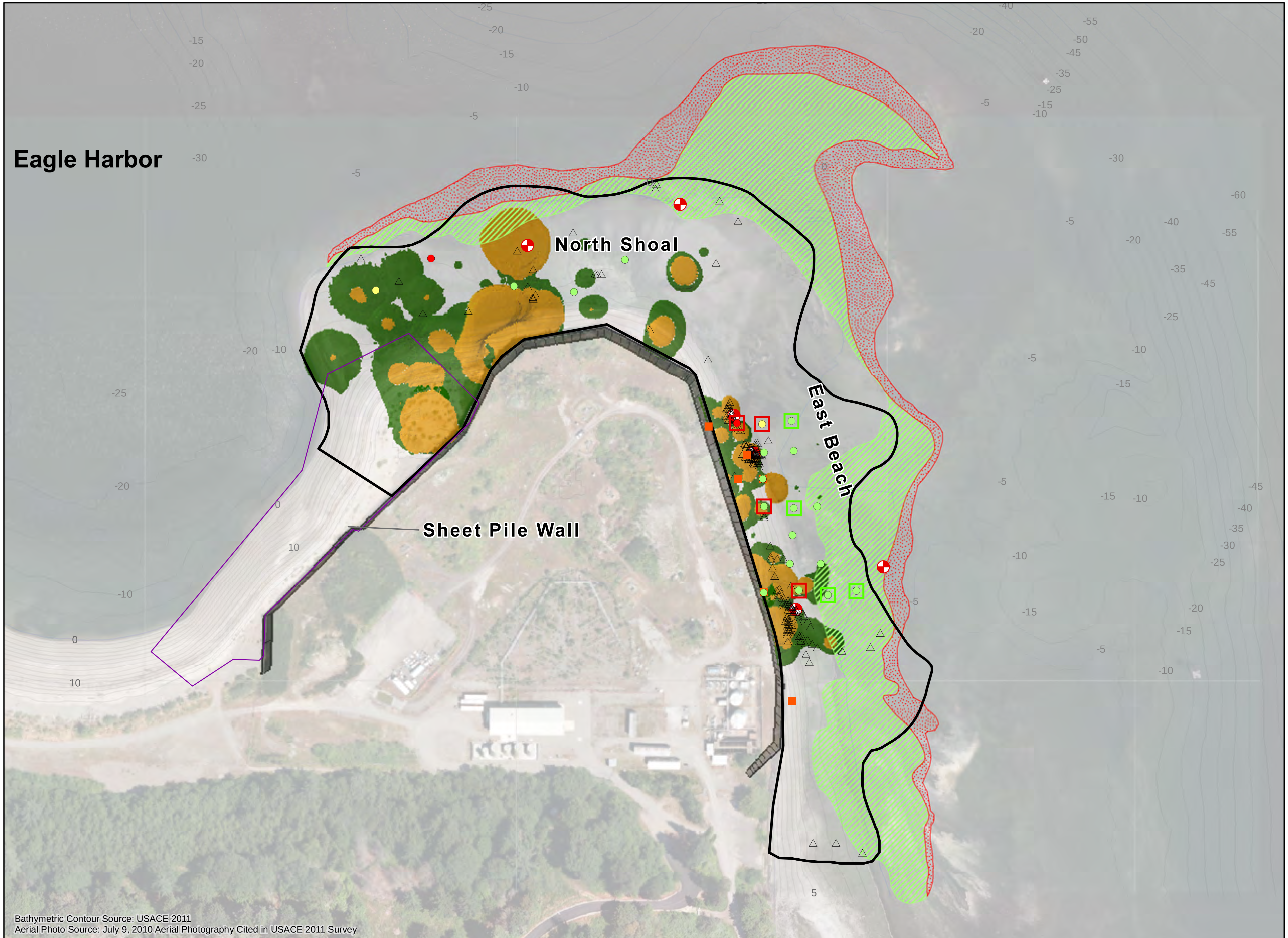


Figure 3-12
2011 Sediment Sampling Locations and EelgrassBeds
Wyckoff OU-1 Focused Feasibility Study

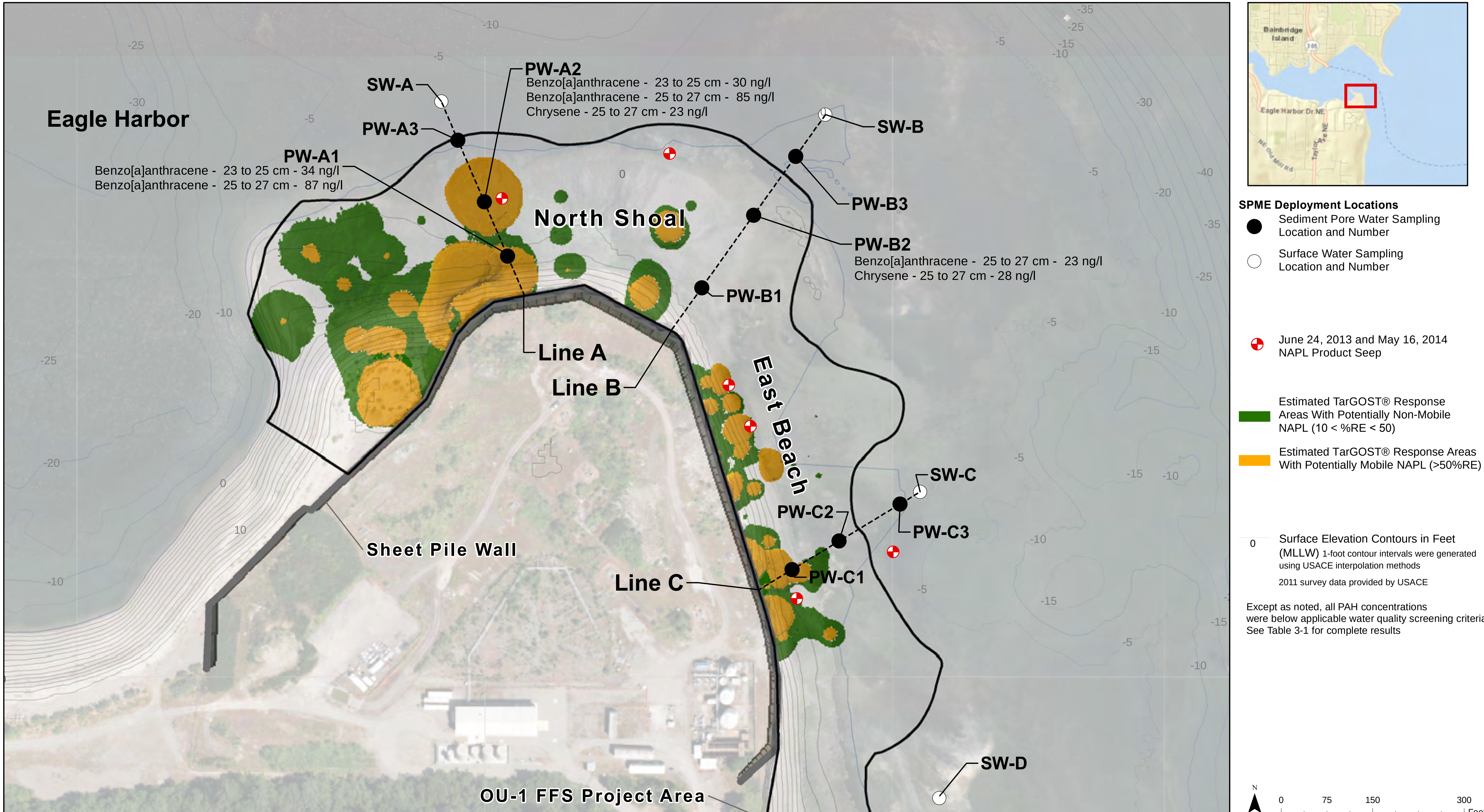


Figure 3-13
PAH Concentration Summary for 2013 SPME Pore Water and Surface Water Samples
Wyckoff OU-1 Focused Feasibility Study

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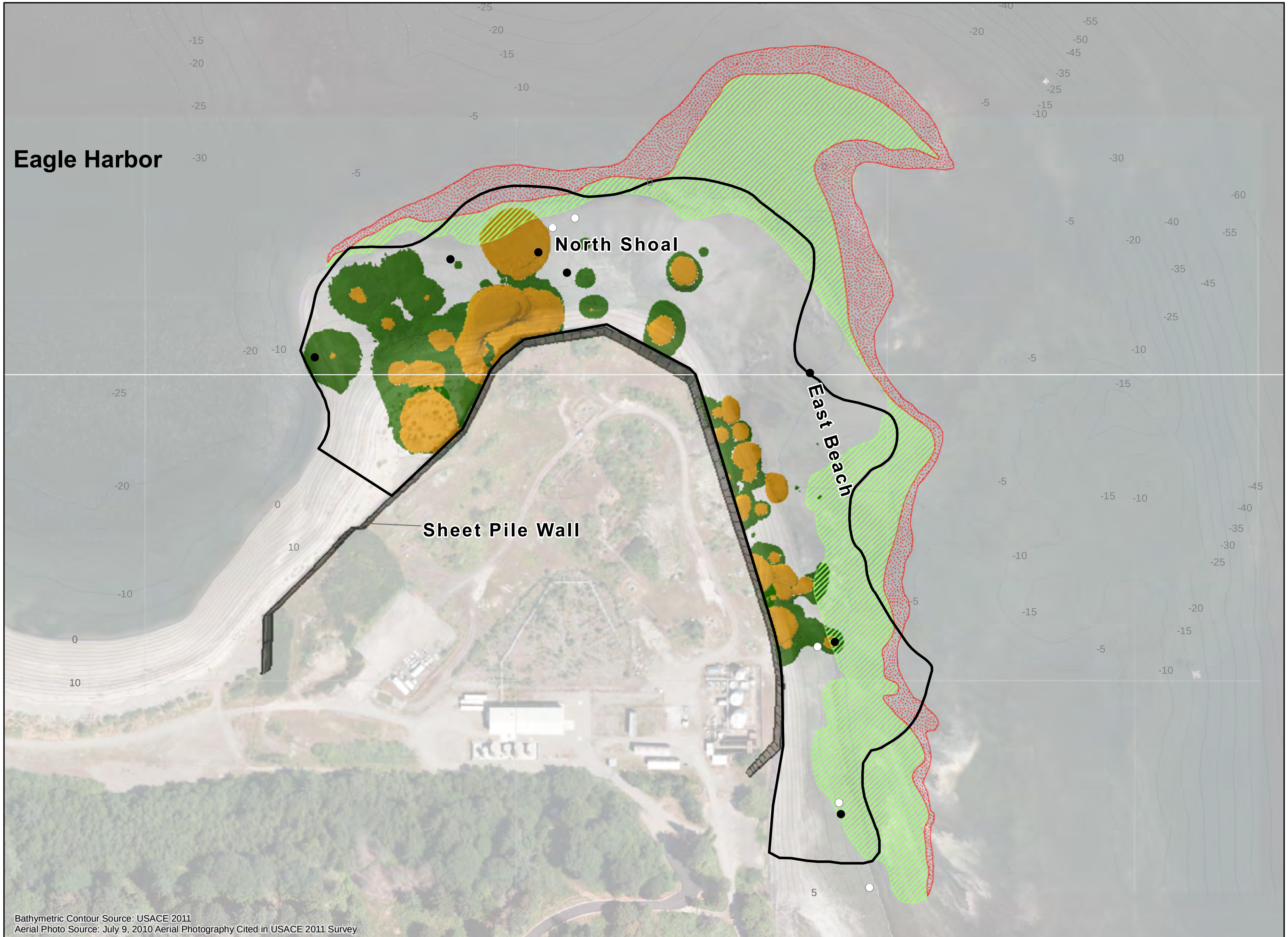

Clam Sampling Locations

- 2003 (Integral, 2004)
- 2011 (USACE, 2012)

Generalized Extent of Eelgrass

- Eelgrass
- Probable Eelgrass (unconfirmed) Based on Washington State Department of Ecology Low Tide Site Observations, June 24, 2013

0 Surface Elevation Contours in Feet (MLLW) 1-foot contour intervals were generated using USACE interpolation methods

2011 survey data provided by USACE

- Wyckoff OU-1 Focused Feasibility Study Project Area
- Estimated TarGOST® Response Areas With Potentially Non-Mobile NAPL (10 < %RE < 50)
- Estimated TarGOST® Response Areas With Potentially Mobile NAPL (>50%RE)

N

0 50 100 200 Feet

Figure 3-14
Clam Collection Locations for Tissue Sampling
Wyckoff OU-1 Focused Feasibility Study

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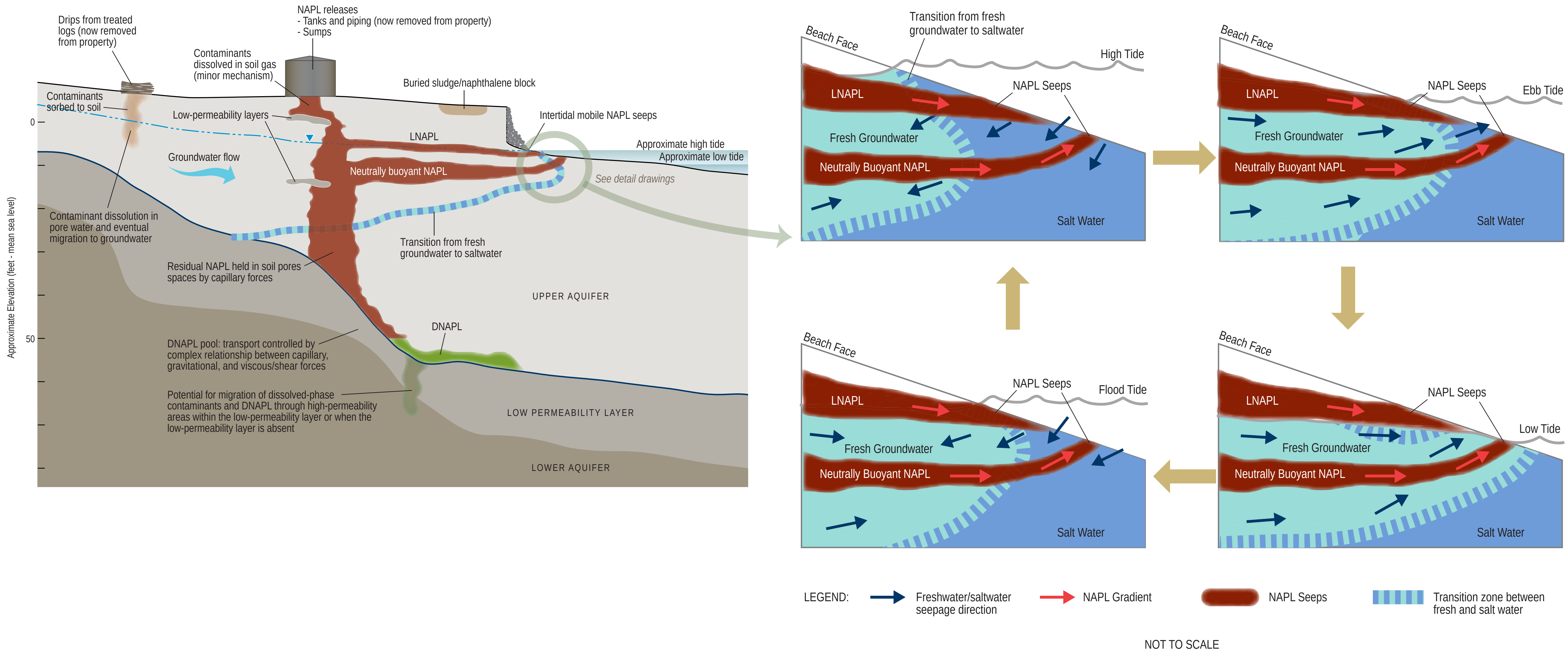

Figure 3-15
Conceptual Site Model Representing Pre-Sheet Pile Wall Conditions
Wyckoff OU-1 Focused Feasibility Study

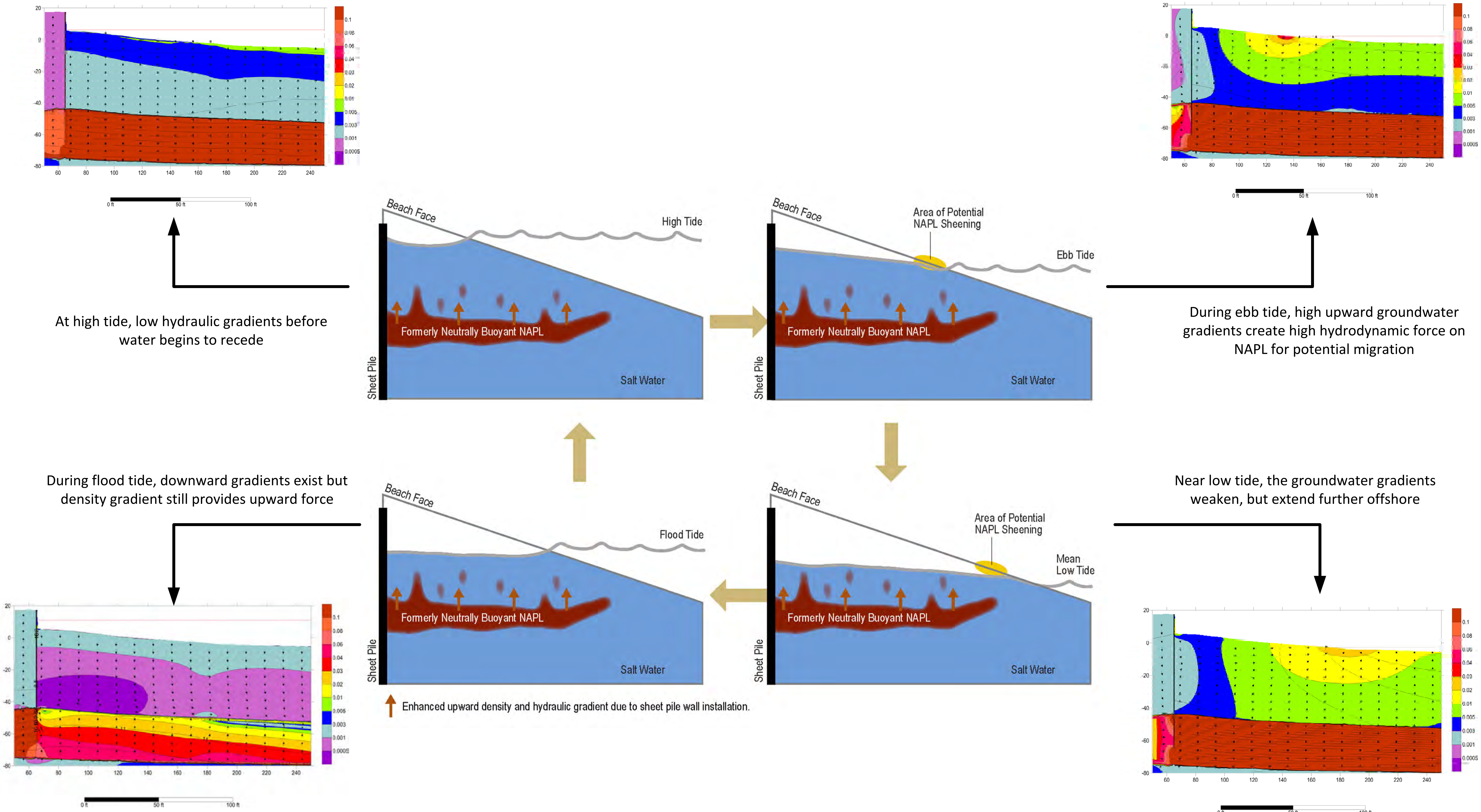

Figure 3-16
NAPL Conceptual Site Model Post Wall Construction
Wyckoff OU-1 Focused Feasibility Study

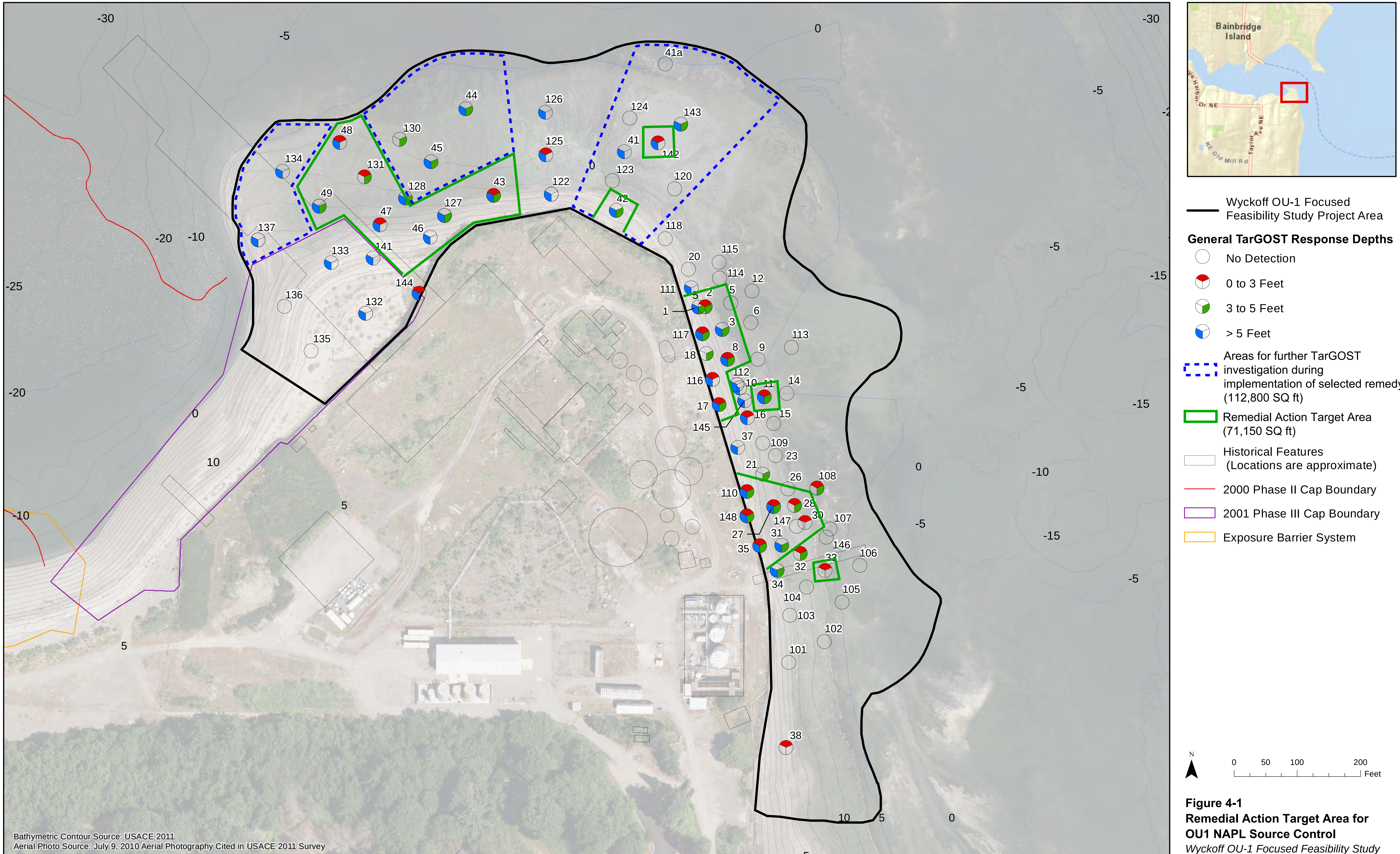

Figure 4-1
Remedial Action Target Area for OU1 NAPL Source Control
Wyckoff OU-1 Focused Feasibility Study

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Figure 6-1
Upland Facility Features and Potential Staging Areas
Wyckoff OU-1 Focused Feasibility Study

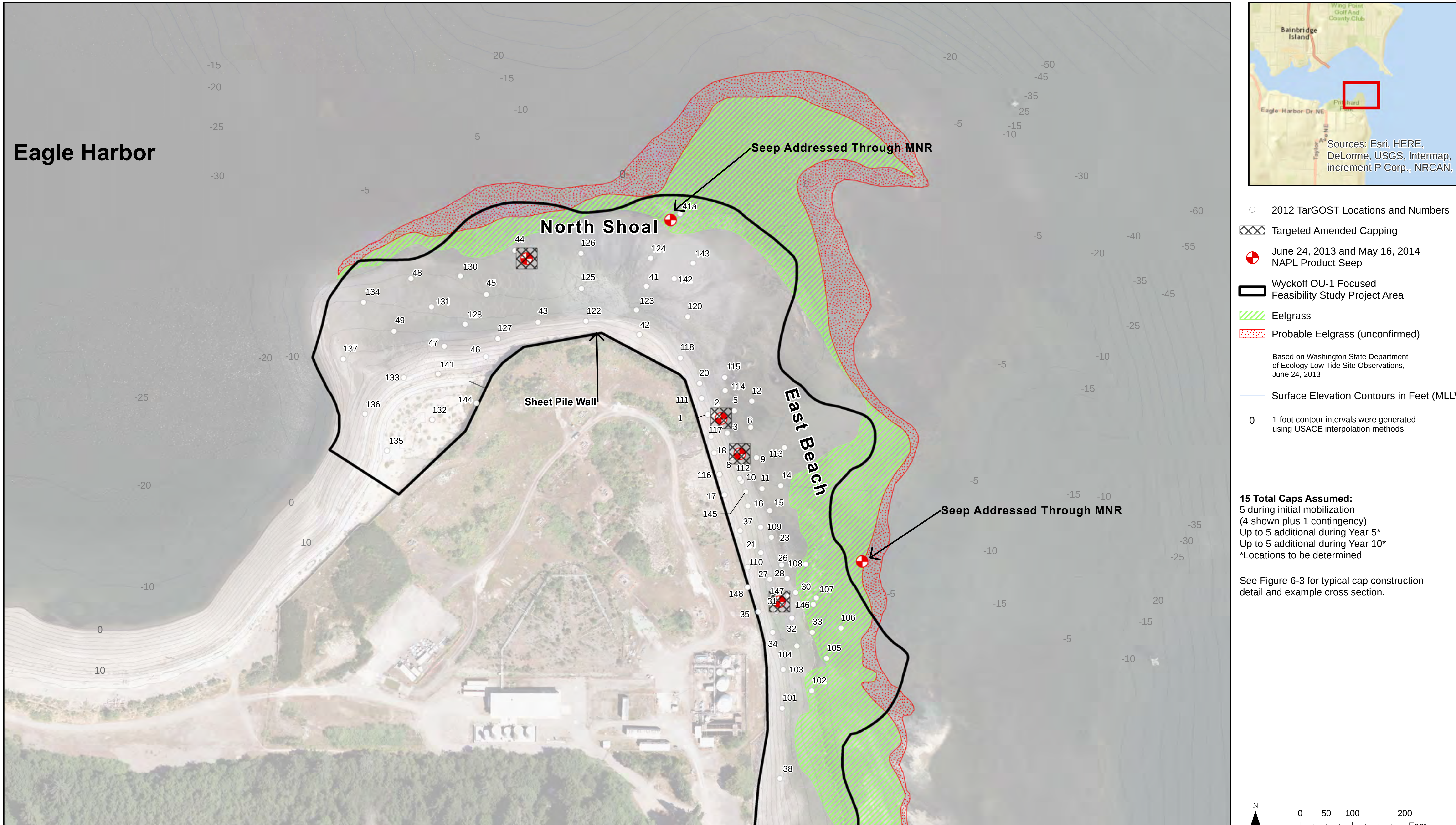

Figure 6-2
Seep Capping and Monitored Natural Recovery
Wyckoff OU-1 Focused Feasibility Study

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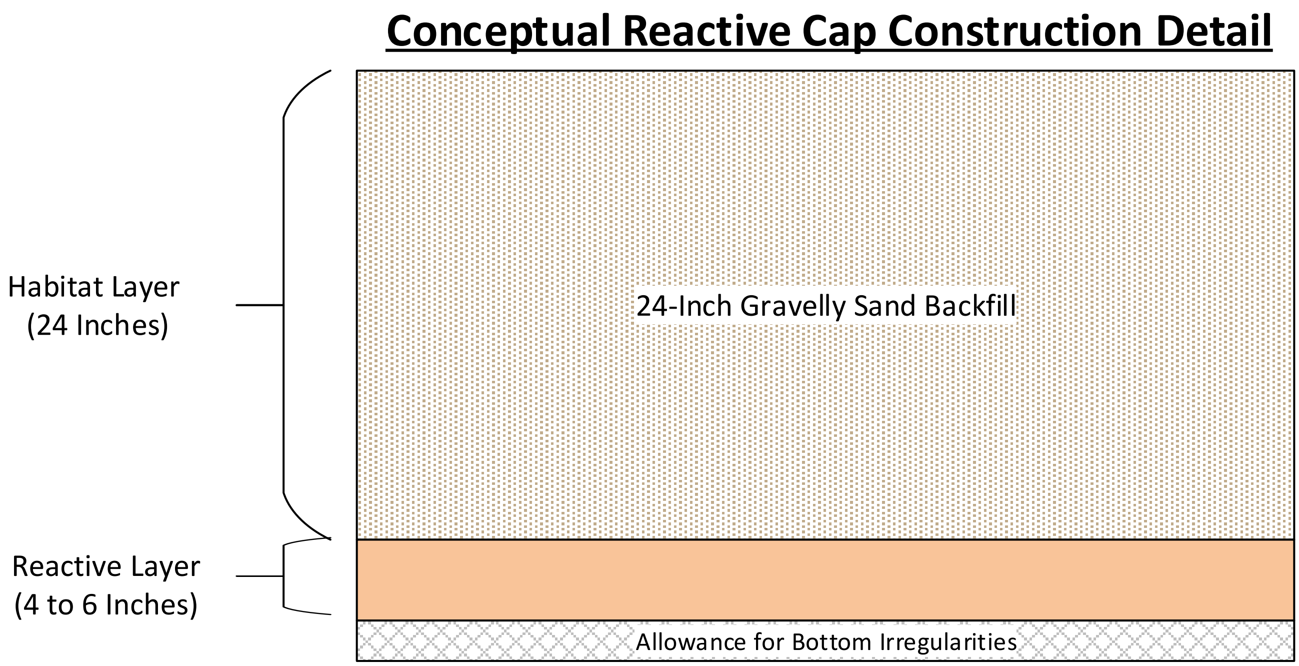

Figure 6-3
Conceptual Cap Cross Section – Alternatives 2, 3, and 4
Wyckoff OU-1 Focused Feasibility Study

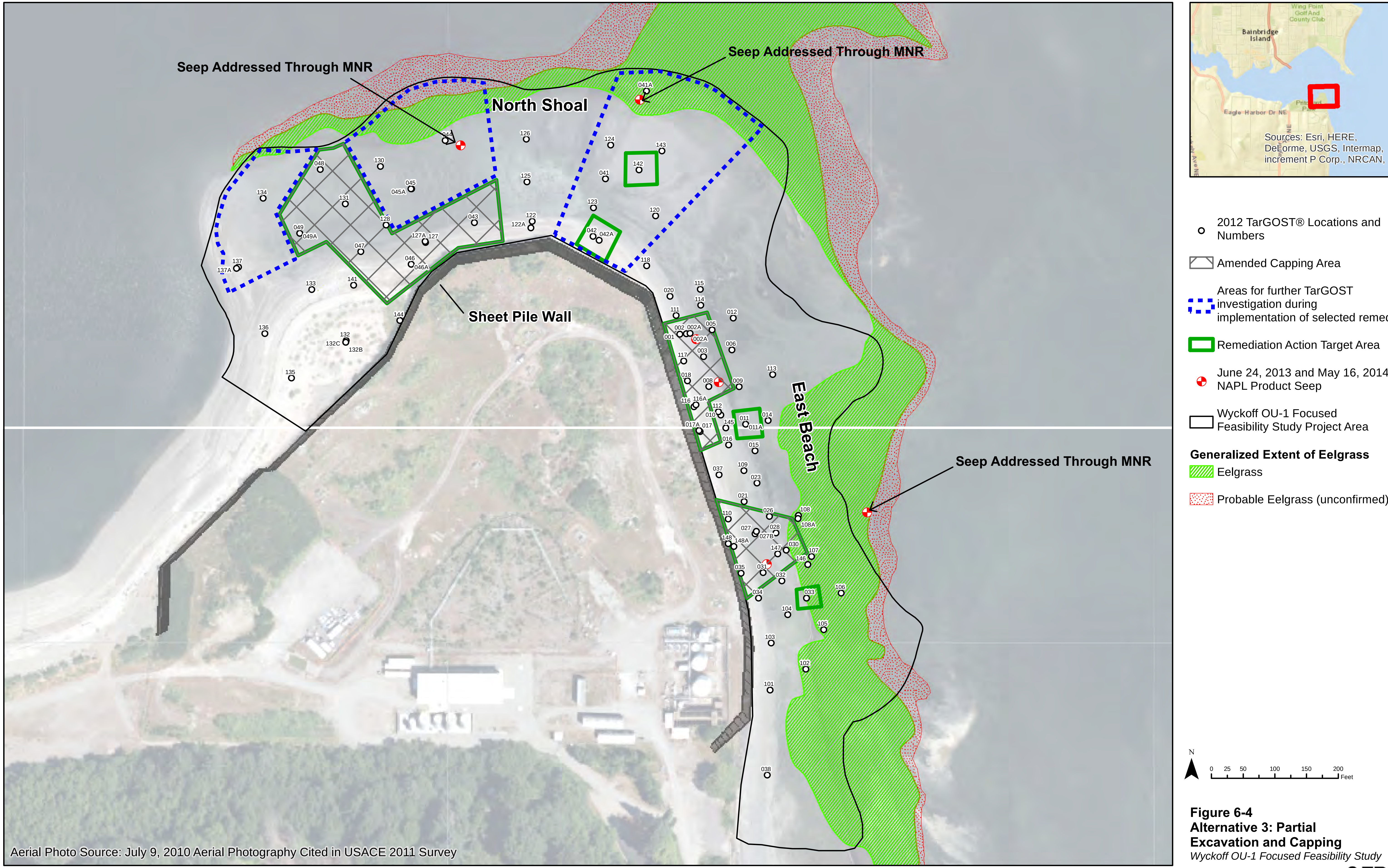

Figure 6-4
Alternative 3: Partial Excavation and Capping
Wyckoff OU-1 Focused Feasibility Study

C:\USERS\GGEE\DOCUMENTS\GIS\WYCKOFF\MAPFILES\2015\OFFSHORE\FIGURE6-4.MXD GGEE 12/23/2015 4:17:21 PM

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Figure 6-5
Alternative 4: Vertical Containment with Partial Excavation and Capping
Wyckoff OU-1 Focused Feasibility Study

C:\USERS\GGEE\DOCUMENTS\GIS\WYCKOFF\MAPFILES\2016\OFFSHORE\PROPOSED PLAN\REVISED_032216\FIGURE6-5.MXD GGEE 4/4/2016 12:48:28 PM

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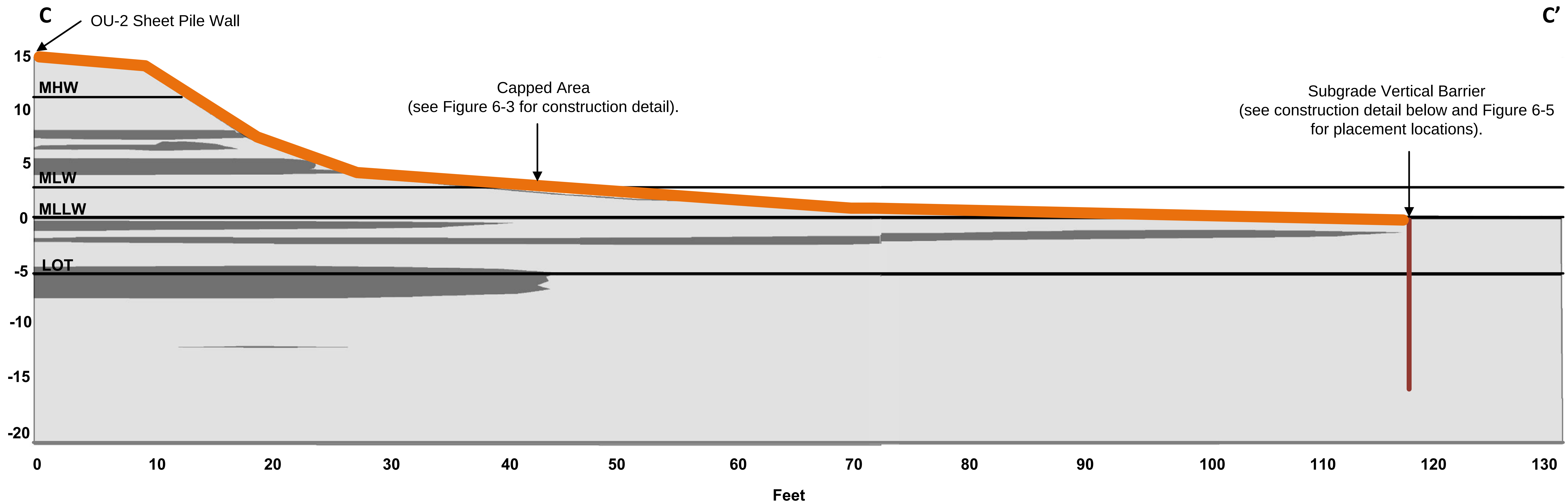
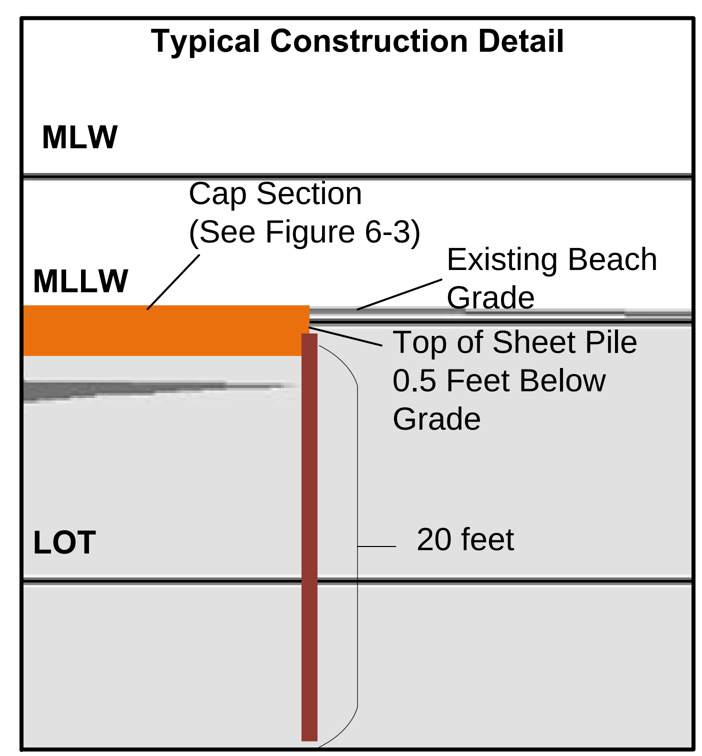


Indicates 50% or Greater Chance of Encountering NAPL Based on TarGOST responses >10% Reference Emitter (RE).

MHW – Mean High Water
MLW – Mean Low Water
MLLW – Mean Lower Low Water
LOT – Lowest Observed Tide

Vertical Elevations are in Feet (MLLW)



Note: Drawing is for conceptual illustration only.

Figure 6-6
Alternative 4: Vertical Containment with Partial Excavation and Capping Cross Section C-C'
Wyckoff OU-1 Focused Feasibility Study

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Simulated Head and Hydraulic Gradient at 2300 hrs on 12/13/2012 - Basecase

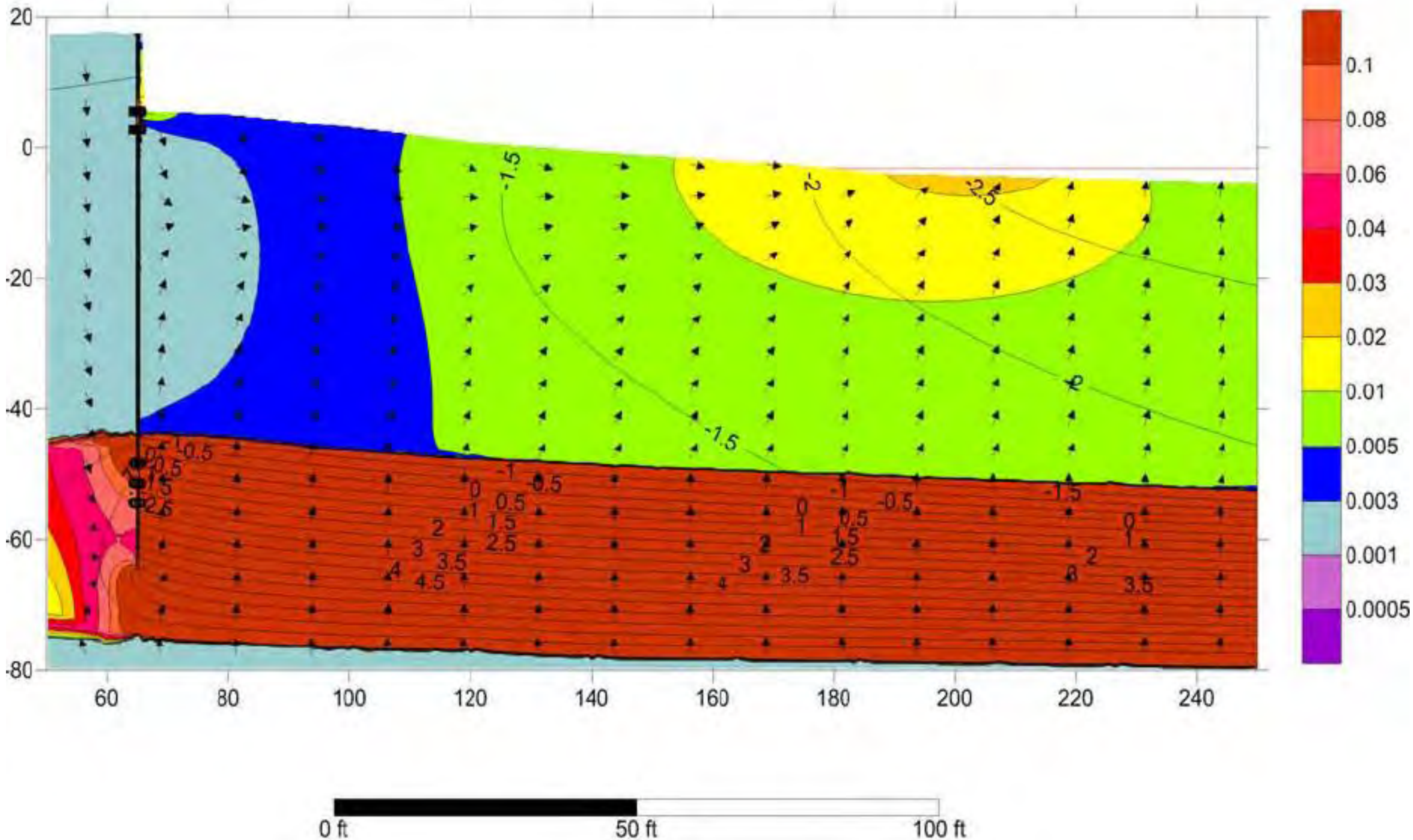

Figure 6-7
Alternative 4: Basecase Simulation at 2300 Hours
Wyckoff OU-1 Focused Feasibility Study

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Simulated Head and Hydraulic Gradient at 2300 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall – 0.3 ft/day Cap

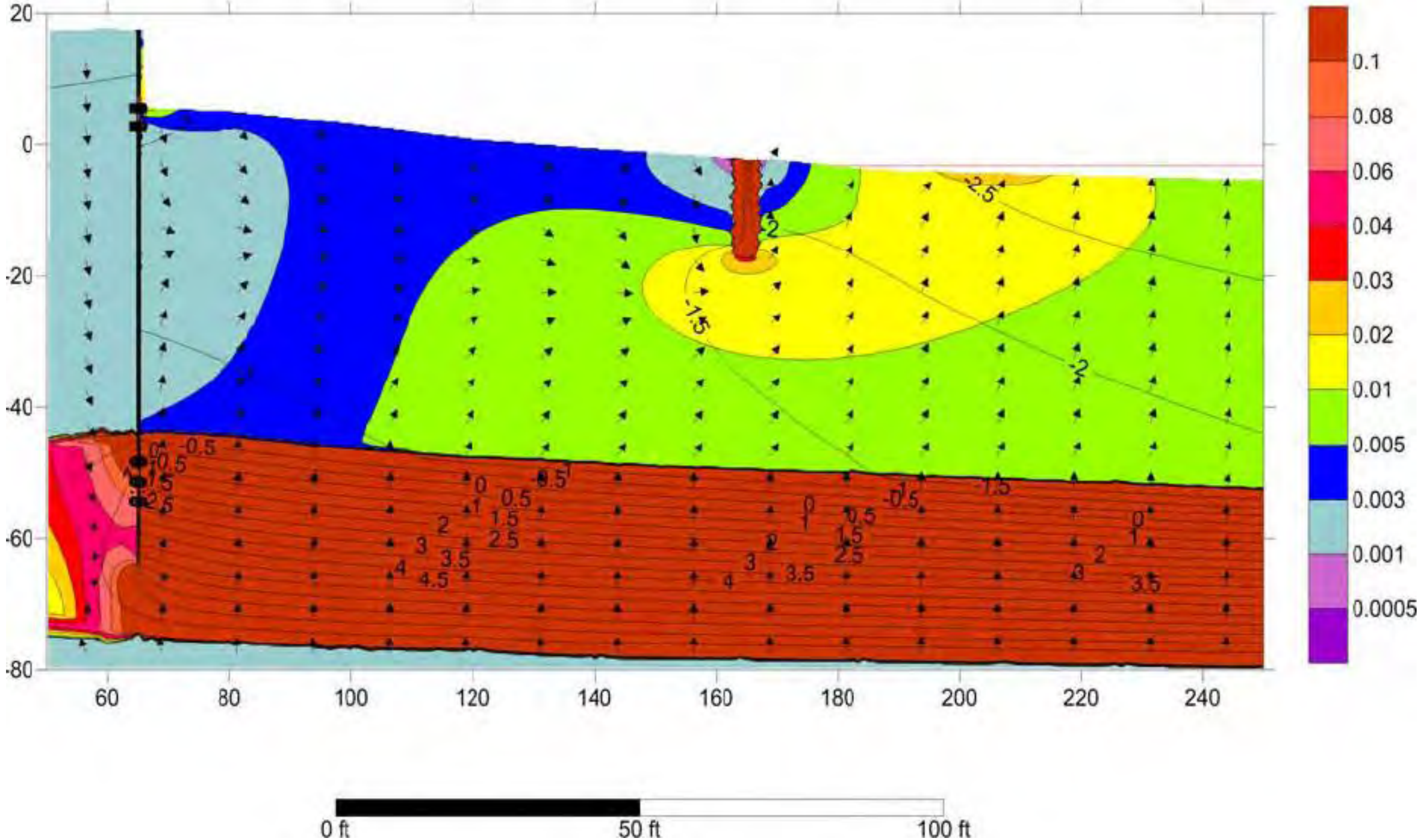

Figure 6-8

Alternative 4: Vertical Barrier Plus Capping

Simulation at 2300 Hours

Wyckoff OU-1 Focused Feasibility Study

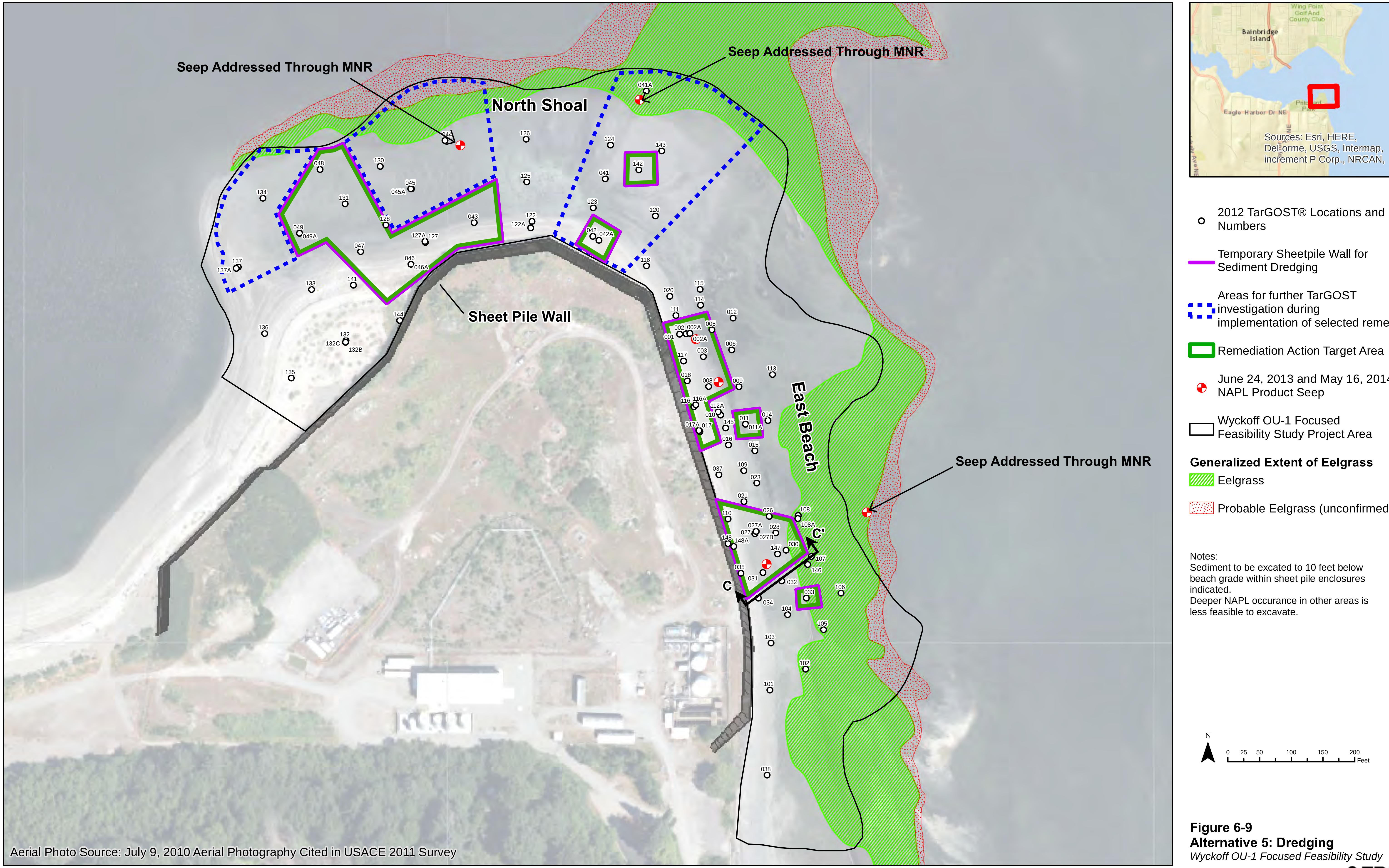

Figure 6-9
Alternative 5: Dredging
Wyckoff OU-1 Focused Feasibility Study

C:\USERS\GGEE\DOCUMENTS\GIS\WYCKOFF\MAPFILES\2016\OFFSHORE\PROPOSED PLAN\REVISED_032216\FIGURE6-9.MXD GGEE 4/4/2016 8:45:48 AM

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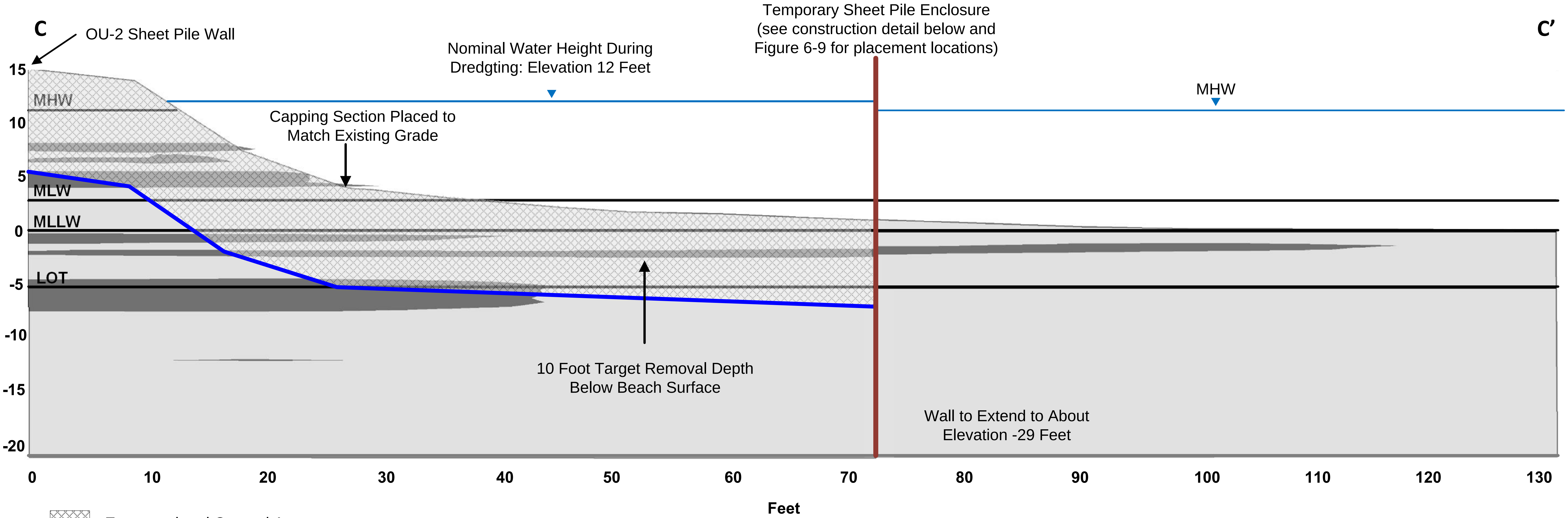

Excavated and Capped Area

Indicates 50% or Greater Chance of Encountering NAPL Based on TarGOST responses >10% Reference Emitter (RE).

MHW – Mean High Water
MLW – Mean Low Water
MLLW – Mean Lower Low Water
LOT – Lowest Observed Tide

Vertical Elevations are in Feet (MLLW)

Typical Range of Tidal Elevations Expected During Dredging are MHW (10.5 feet) to MLW (2.8 feet)

Cap to Consist of Gravelly Sand over 6-Inch Layer OC-Amended Sand.

Cap Placed Over 6-Inch Sand Layer for Settling Dredging Residuals.

Note: Drawing is for conceptual illustration only.

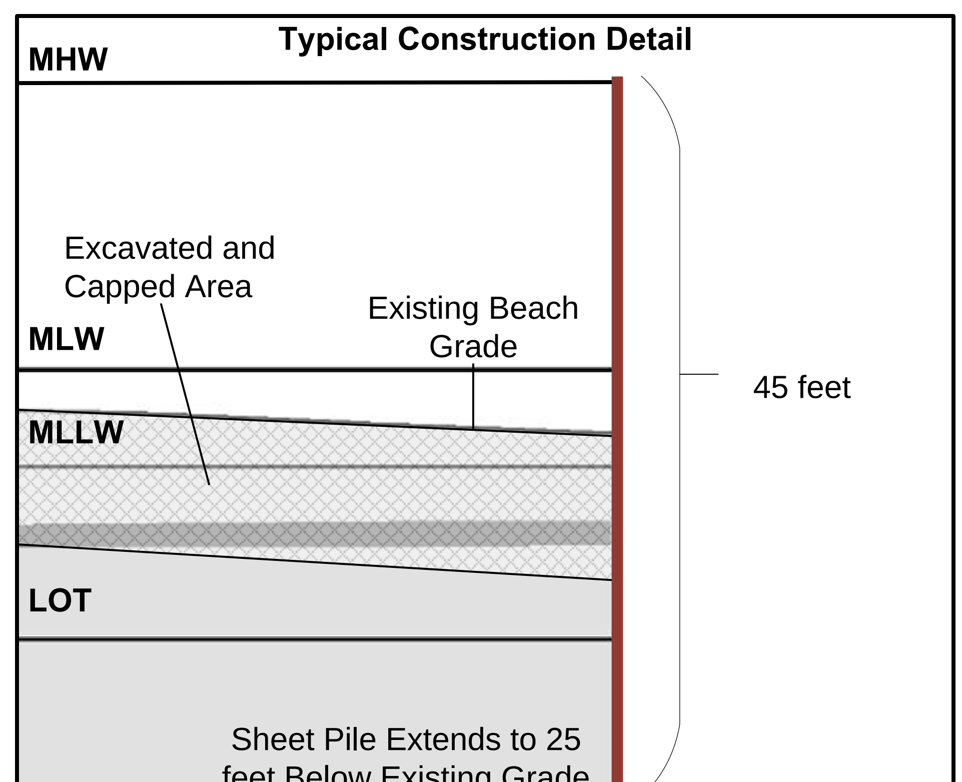

Figure 6-10
Alternative 5: Dredging Cross Section C-C’
Wyckoff OU-1 Focused Feasibility Study

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Appendix A
Interim Report—Solid Phase Microextraction Sampling Effort to Support the Focused Feasibility Study of Operable Unit 1, Wyckoff/ Eagle Harbor Superfund Site, Bainbridge Island, Washington

Final Report – Solid Phase Microextraction Sampling Effort to Support the Focused Feasibility Study of Operable Unit 1 Wyckoff/Eagle Harbor Superfund Site (Bainbridge Island, Washington)

Courtney Thomas and Danny D. Reible
March 28, 2014

Passive sampling sediment porewater and marine surface water samples were collected via solid phase microextraction (SPME) using a polydimethylsiloxane (PDMS) sorbent layer in December 2013 at thirteen shallow subsurface or surface water column locations within the East Harbor Operable Unit (OU-1) of the Wyckoff/Eagle Harbor Superfund Site (Bainbridge Island, Washington). The project area encompasses 11 acres of intertidal portions of the East Beach and North Shoal areas that are affected by known or suspected historical contamination of NAPL products that could potentially pose an exposure risk to human and ecological receptors. The SPME-PDMS sampling effort for the analytical testing of sediment porewater and marine surface water polycyclic aromatic hydrocarbon (PAH) concentrations was completed in support of a focused feasibility study (FSS) conducted by the USEPA to

1) obtain initial screening levels data on dissolved PAH concentrations in the sediment porewater and adjacent surface waters for baseline characterization purposes, and to
2) evaluate remedial alternatives proposed to address historic NAPL contamination from former wood treatment operations.

Nine shallow subsurface porewater samplers and four marine water column samplers were deployed on November 13, 2014. The nine shallow subsurface porewater samplers were deployed along three transects, while the four marine water column samplers were deployed at four deep intertidal to shallow subtidal zone locations adjacent to the OU-1 FSS project area as noted on Figure 1. All samplers were loaded with a SPME fiber manufactured by Polymicro Technologies (Phoenix, AZ) with a 30 +/- 2 μm PDMS coating on a 1000 +/- 2 μm cylindrical glass core. Prior to sampler assembly, the SPME fibers were impregnated with four deuterated PAHs as performance reference compounds (PRCs) to assess the fraction of steady state attained during the sampler deployment period. The four PRCs used during this study were fluoranthene-d10, chrysene-d12, benzo[b]fluoranthene-d12, and dibenz[a,h]anthracene-d14. Stock solutions of fluoranthene-d10, d12-benzo[b]fluoranthene-d12, and dibenz[a,h]anthracene-d14 were purchased from Cambridge Isotope Laboratories. A stock solution of chrysene-d12 was purchased from Ultra Scientific Analytical Solutions. The deuterated PAHs were selected as PRCs based on similarity to the target compounds, ease of detection, and coverage of a wide range of partition coefficients. Fibers are preloaded with the PRCs by exposure to a spiking solution with final aqueous concentrations of 30 μg/L fluoranthene-d10, 80 μg/L chrysene-d12, 50 μg/L benzo[b]fluoranthene-d12, and 25 μg/L dibenz[a,h]anthracene-d14 for seven days on a shaking table.

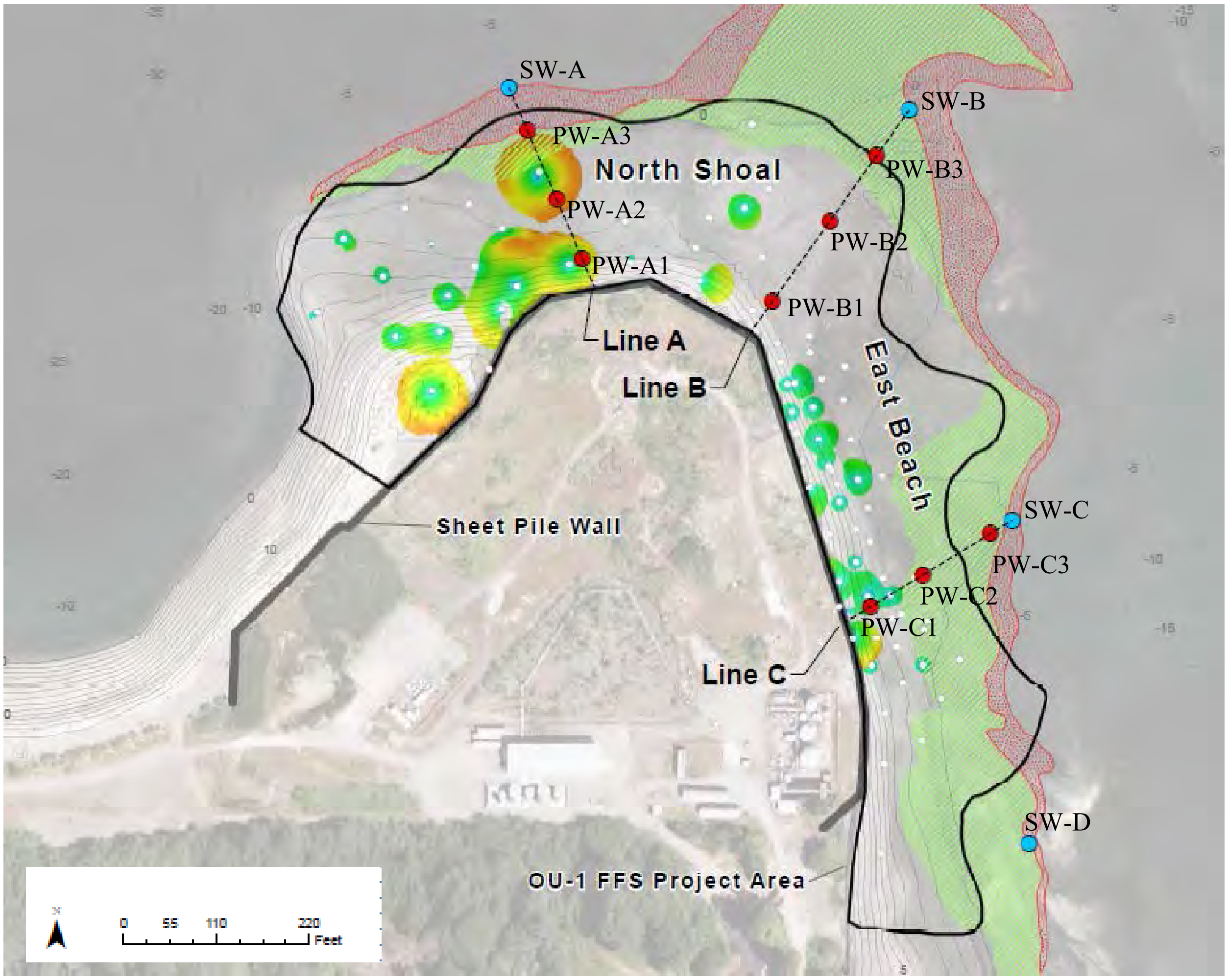


Figure 1. SPME sampling locations at OU-1 FFS Project Area

Retrieval of the samplers occurred on December 5, 2013. The SPME-PDMS fibers were sectioned into 2-cm segments and extracted in the field into vials with glass inserts prefilled with 250 µL of acetonitrile. The nine shallow subsurface porewater samplers were sectioned at 3-5 cm, 5-7 cm, 13-15 cm, 15-17 cm, 23-25 cm, 25-27 cm below sediment surface (BSS). The four marine water column samplers were sectioned at 3-5 cm, 5-7 cm, 13-15 cm, 15-17 cm, 23-25 cm, 25-27 cm below the top of the sampler. No deviations from the QAPP were made in terms of segmentation. Upon completion, the vials were shipped back to the University of Texas at Austin for analysis. All PDMS solvent extracts were analyzed using Waters 2795 High Performance Liquid Chromatography (HPLC) according to EPA Method 8310 using a 1.0 mL/min isocratic flow composed of 3:7 (v:v) water:acetonitrile at 40 ºC. Ultraviolet (UV) and fluorescence (FLD) detectors were used to quantify the contaminants of concern. Standards ranging in concentrations from 0.05 µg/L to 100 µg/L in solvent are used to determine calibration curves and each compound's response factor. Of the PAH_{16} compounds, naphthalene may underestimate actual concentrations because of the potential for loss from the PDMS fiber prior to extraction, acenaphthylene is not detectable by fluorescence detection and benzo[g,h,i]perylene and indeno[1,2,3-cd]pyrene coelute and are not analyzed independently. For every 10 field samples analyzed, a 5 or 20 µg/L standard (UltraScientific) containing 16 PAHs was analyzed to check proper running of the instrument.

The measurement of porewater concentrations (C_{pw}) using the passive sampler involves measurement of the concentration in the polymer sorbent (PDMS, C_{PDMS}) and conversion to a porewater concentration assuming equilibrium defined by a PDMS-water partition coefficient, K_{PDMS}. Consensus K_{PDMS} values for PAHs are reported by Ghosh et al. (2014) and are essentially those reported by Smedes et al. (2009).

$$C_{pw} = \frac{C_{PDMS}}{K_{PDMS}} \qquad \textbf{Eq. 1}$$

Definition of absolute porewater concentrations, however, generally requires a correction for non-equilibration in the PDMS fibers. If f_{ss} represents the estimated fraction of steady state uptake in a particular deployment, the absolute or equilibrium porewater concentration is given by

$$C_{pw,corr} = \frac{C_{PDMS}}{K_{PDMS} f_{ss}} \qquad \textbf{Eq. 2}$$

The PRCs are used as a means to indicate kinetics of uptake as the desorption of the PRCs in the field can be related to the fraction approach to steady state. The PRC concentrations in eight 2-cm fiber replicates of the PRC impregnated fibers, taken before deployment, were used to estimate the mean initial concentration for the four PRCs at time zero. After exposure in the environment, the PRC concentration should approach 0 at steady state. The ratio of the actual concentration of PRC remaining after exposure and the initial concentration defines the fractional approach to steady state (f_{ss}=1-C(t)/C_0=1-f_{PRC}). In this case, the PRC mass measured 22 days after deployment is compared to the initial mass to define f_{PRC}. The PRC release kinetics can be defined in a locally flat (i.e. Cartesian) coordinate system and if mass transfer processes external to the fiber control uptake. Both assumptions are valid for the fibers used in this study since the sorbent is very thin (30 µm) relative to the diameter of the glass core (1000 µm). The kinetics of PRC loss by this model is given by,

$$f_{PRC} = \exp\left(\frac{RDt}{L^2 K_{PDMS}^2}\right) erfc\left(\frac{\sqrt{RDt}}{LK_{PDMS}}\right) \qquad \textbf{Eq. 3}$$

where f_{PRC} is the fraction of mass remaining after the time of deployment, t. The PDMS thickness, L, and fiber-water partition coefficient, K_{PDMS}, are known quantities The parameter which controls contaminant uptake, RD, is the product of the medium retardation factor for the compound and the effective transport coefficient (modeled as a diffusive like process) in the media and can be determined by comparison to the PRC data. This parameter is largely compound independent under both diffusive and advective-influenced diffusive conditions. R, however, is typically proportional to the octanol-water partition coefficient K_{ow} as long as transport to the fibers is not controlled by particle movement. The value of RD is therefore expected to increase linearly with K_{ow} and K_{PDMS}. f_{PRC} values for the porewater samples were found to be significantly different by depth (i.e. the desorption of the PRCs was significantly different for the three different depth zones: 3-7 cm, 13-17 cm, and 23-27 cm) suggesting different transport rates as a function of depth in this near shore environment. Corrects were applied based upon the depth of the sample. The results of the ANOVA single factor significance tests for f_{PRC} values at the different depth zones are found in Appendix A. Note that surface water samples are effectively at steady state and no correction was calculated for those samples.

The mean RD values for each PRC and depth zone for the Wyckoff/Eagle Harbor OU-1 site can be fit to a linear relationship with K_{PDMS} as shown in Figure 2. Note that the while the estimated RD values for the most hydrophobic compound differs by approximately a factor of 3 between 3-7 cm and 23-27 cm (5.2 vs 1.8 m^2/d) , the resulting effect on estimated approach to steady state is <30% as will be shown in Table 1.

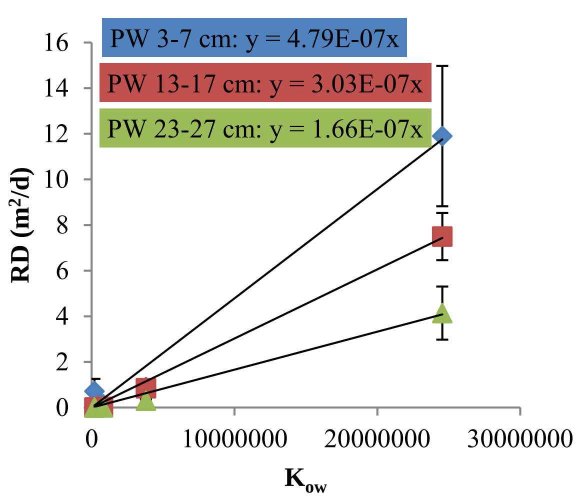


Figure 2. Mean RD values +/- Standard Error for each PRC and depth zone. Solid lines represent the line of best fit for the relationship between K_{ow} (SPARC estimates as used in Ghosh et al. (2014)) and RD for each depth zone.

The best-fit estimated of RD as a function of K_{PDMS} based upon the four PRCs allows for estimation of the non-equilibrium correction factor (f_{ss}) for each of the contaminants of concern using Equation 4. Non-equilibrium correction factors for each compound based upon depth zone are listed in Table 1.

$$\boldsymbol{f_{ss} = 1 - \exp\left(\frac{RD\,t}{L^2 K_{PDMS}^2}\right) erfc\left(\frac{\sqrt{RDt}}{LK_{PDMS}}\right)} \qquad \textbf{Eq. 4}$$

Table 1. Mean non-equilibrium correction factors (f_{ss}) .

Compound	$logK_f$ (Ghosh et al., 2014)	f_{ss} PW 3-7 cm	PW 13-17 cm	PW 23-27 cm	SW All Depths
Naphthalene	*2.95*	0.91	0.89	0.85	1
Fluorene	*3.52*	0.87	0.84	0.79	1
Acenaphthene	*3.42*	0.88	0.85	0.80	1
Phenanthrene	*3.91*	0.83	0.79	0.73	1
Anthracene	*3.88*	0.83	0.80	0.74	1
Fluoranthene	*4.31*	0.78	0.73	0.66	1
Pyrene	*4.28*	0.78	0.74	0.67	1
Chrysene	*4.76*	0.71	0.66	0.58	1
Benzo[a]anthracene	*4.72*	0.72	0.66	0.59	1
Benzo[b]fluoranthene	*5.25*	0.63	0.56	0.48	1
Benzo[k]fluoranthene	*5.19*	0.64	0.58	0.49	1
Benzo[a]pyrene	*5.22*	0.63	0.57	0.49	1
Dibenz[a,h]anthracene	*5.84*	0.51	0.45	0.37	1
Benzo[ghi]perylene + Indeno(1,2,3-cd)pyrene	*5.58*	0.56	0.50	0.42	1

Appendix A contains the results of statistical tests of depth dependent PRC results as previously mentioned. Appendix B contains concentration profiles for each transect. Plots for dibenz[a,h]anthracene and benzo[g,h,i]perylene+indeno [1,2,3-cd]pyrene are not included as these compounds were not detected in any of the samples. Note that the SPME PDMS method can typically detect contaminants of concern at far below conventional analytical methods and well below concentrations of concern. Concentrations can be compared to chronic surface water quality criteria as a screening criteria (from the Model Toxics Control Act Method B Surface Water (WAC 173-340) and Marine National Toxics Rule (WAC 173-201A-240(5)) (see Table B1). Surface water quality criteria (SWQC) are noted on each plot. The comparison of pore water concentrations directly to surface water quality criteria is very conservative in that substantial dilution would be expected between porewater and surface water. In general, only surficial samples that exceed screening criteria may be of concern in that only these samples are exposed to surface waters and benthic organisms. No surface water samples exceeded surface water criteria as shown in Table B1. Some porewater samples, particularly at depth, exceeded surface water screening criteria. Appendix C contains tables reporting the PAH concentrations measured for each transect location. Appendix D contains quality assurance quality control information.

Analysis of the collected data is continuing. In general only very low concentrations were detected of any compound in surface water and concentrations in porewaters along transect C were relatively uniform and quite low. Concentrations along transect A were substantially higher but generally only exceeding surface water criteria at the bottom sample, 23-27 cm in depth. Concentrations along transect B were generally intermediate between the two other transects.

References

Ghosh, U., Driscoll, S.K., Burgess,R.M., Jonker, M.T., Reible, D., Gobas,F., Choi, Y. , Apitz, S., Maruya, K.A, Gala, W.R., Mortimer, M. and Beegan, C. Passive Sampling Methods for Contaminated Sediments: Practical Guidance for Selection, Calibration, and Implementation , Accepted for publication Integrated Environmental Assessment and Management (IEAM) 2014

Smedes, F., Geertsma, R.W., van der Zande, T., Booij, K., 2009. Polymer-Water Partition Coefficients of Hydrophobic Compounds for Passive Sampling: Application of Cosolvent Models for Validation. Environmental science & technology 43, 7047-7054.

Appendix A

Table A1. Results for a Single Factor ANOVA Significance Test ($\alpha = 0.05$) for C/C_o values of fluoranthene-d10 grouped by depth (BSS)

Anova: Single Factor

Statistically Significant

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
3-7 cm fluoranthene	18	6.4912432	0.3606246	0.0605645
13-17 cm fluoranthene	18	11.4649	0.6369389	0.0209462
23-27 cm fluoranthene	15	10.895895	0.726393	0.009698

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.2356894	2	0.6178447	19.492255	6.356E-07	3.1907273
Within Groups	1.5214528	48	0.0316969			
Total	2.7571422	50				

Table A2. Results for a Single Factor ANOVA Significance Test ($\alpha = 0.05$) for C/C_o values of chrysene-d12 grouped by depth (BSS)

Anova: Single Factor

Statistically Significant

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
3-7 cm -chrysene	14	6.8877602	0.4919829	0.0284847
13-17 cm - chrysene	11	7.2989343	0.6635395	0.0109953
23-27 cm - chrysene	11	9.294395	0.844945	0.0010958

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.7694447	2	0.3847223	25.845892	1.762E-07	3.2849177
Within Groups	0.491213	33	0.0148852			
Total	1.2606577	35				

Table A3. Results for a Single Factor ANOVA Significance Test (α = 0.05) for C/C_o values of benzo[b]fluoranthene-d12 grouped by depth (BSS)

Anova: Single Factor

Statistically Significant

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
3-7 cm – B(b)F	12	6.2914731	0.5242894	0.0198714
13-17 cm - B(b)F	10	4.9460456	0.4946046	0.0057823
23-27 cm – B(b)F	7	4.5268953	0.6466993	0.0124427

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.1028866	2	0.0514433	3.8737218	0.0336916	3.3690164
Within Groups	0.3452819	26	0.0132801			
Total	0.4481685	28				

Table A3. Results for a Single Factor ANOVA Significance Test (α = 0.05) for C/C_o values of dibenz[a,h]anthracene-d14 grouped by depth (BSS)

Anova: Single Factor

Not Statistically Significant

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
3-7 cm - dibenz	14	8.0851028	0.5775073	0.0350832
13-17 cm - dibenz	10	5.6065154	0.5606515	0.0032331
23-27 cm - dibenz	16	10.670373	0.6668983	0.0094365

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.0908961	2	0.0454481	2.6831099	0.0816333	3.2519238
Within Groups	0.6267273	37	0.0169386			
Total	0.7176234	39				

Appendix B

Table B1. Surface water quality criteria (SWQC) and detection frequencies for the contaminants of concern in this study.

	Surface Water Quality Criteria[2] (ng/L)	MDL by SPME for 1060/1000 um fiber (ng/L)	PQL by SPME for 1060/1000 µm fiber (ng/L)	Percent Detected (%)	> PQL (%)	Max Blank Concentration (ng/L)
PAHs (SW-8310)						
Low Molecular Weight PAHs						
Acenaphthene[1]	$6.40x10^5$	0.39	233.7	14.1%	6.4%	0
Anthracene[1]	$2.64x10^7$	0.17	7.7	48.7%	34.6%	0
Fluorene[1]	$3.46\ x10^6$	1.2	177.3	10.2%	6.4%	0
Naphthalene	$4.9x10^6$	1.8	339.4	100%	84.6%	0
Phenanthrene	n/a	0.19	93	75.6%	7.7%	0
High Molecular Weight PAHs						
Benzo(a)anthracene	18	0.019	0.182	100%	98.7%	0
Benzo(a)pyrene	18	0.008	0.078	98.7%	83.3%	0
Benzo(g,h,i)perylene+Indeno(1,2,3 -cd)pyrene[a]	18	0.003	0.034	---	---	0
Benzo(b)fluoranthene	18	0.008	0.072	97.4%	96.1%	0
Benzo(k)fluoranthene	18	0.003	0.071	100%	78.2%	0
Chrysene	18	0.022	0.199	94.9%	79.5%	0
Dibenz(a,h)anthracene	18	0.002	0.026	---	---	0
Fluoranthene	$9x10^4$	0.056	3.2	98.7%	89.7%	0
Pyrene	$2.59x10^6$	0.077	2.7	100%	98.7%	0

[a] – Benzo(g,h,i) perylene and Indeno(1,2,3-cd) pyrene co-elute and may not be analytically separated by the laboratory, although efforts are underway to separate them.

1 – Model Toxics Control Act Method B Surface Water (WAC 173-340)

2 – Marine National Toxics Rule – 40 CFR 131-36 – WAC 173-201A-240(5) "Concentrations of toxic, and other substances with toxic propensities not listed in subsection (3) of this section shall be determined in consideration of USEPA Quality Criteria for Water, 1986, and other relevant information as appropriate. Human health-based water quality criteria used by the state are contained in 40 CFS 131-36 (known as the national toxics rule)"

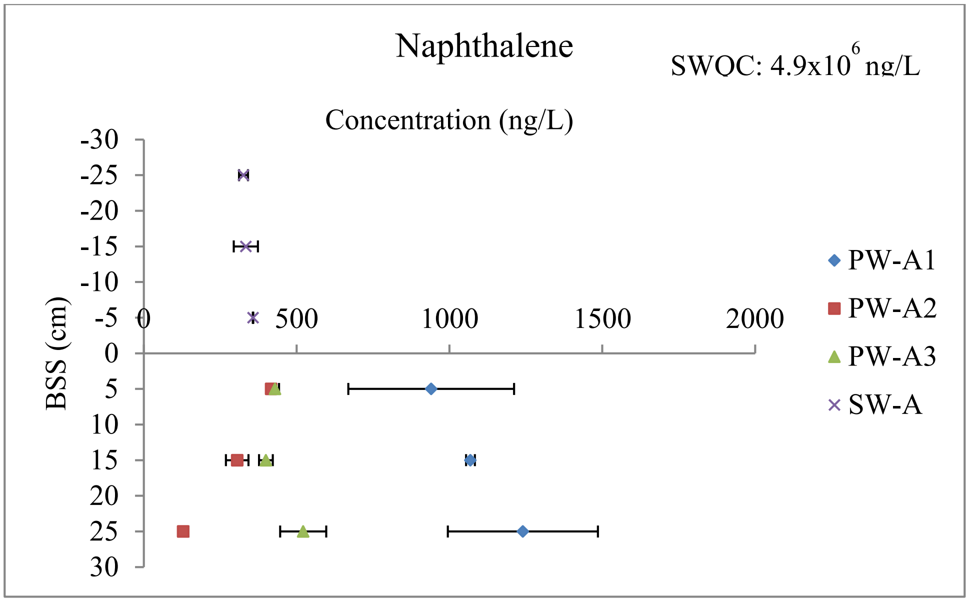


Figure B1. Naphthalene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect A. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

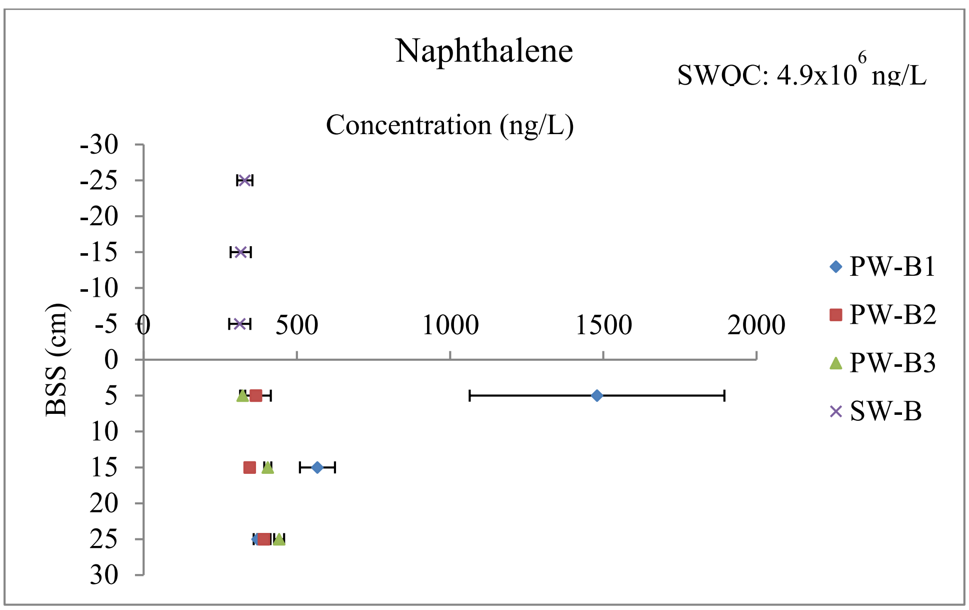


Figure B2. Naphthalene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect B. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

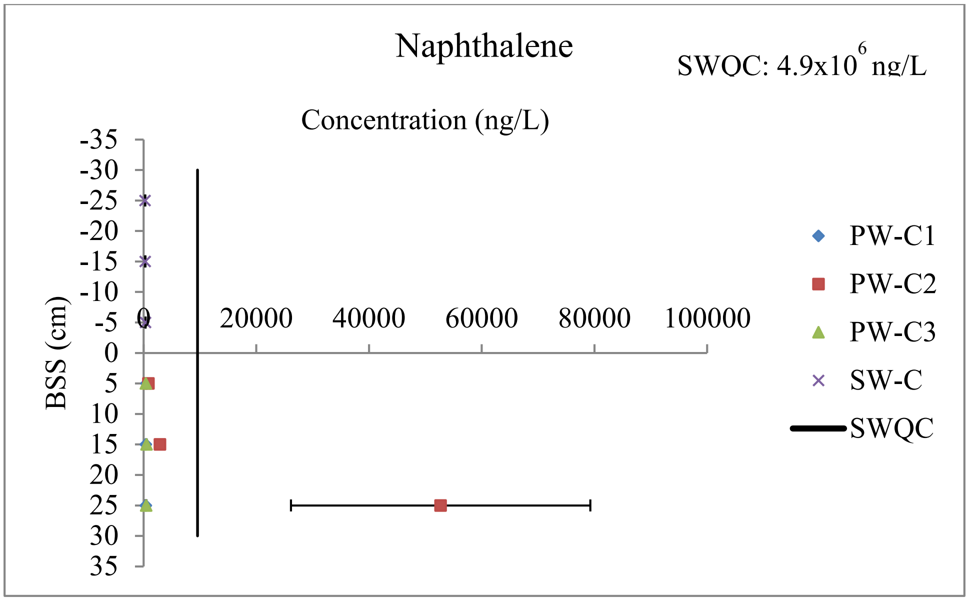


Figure B3. Naphthalene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect C. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

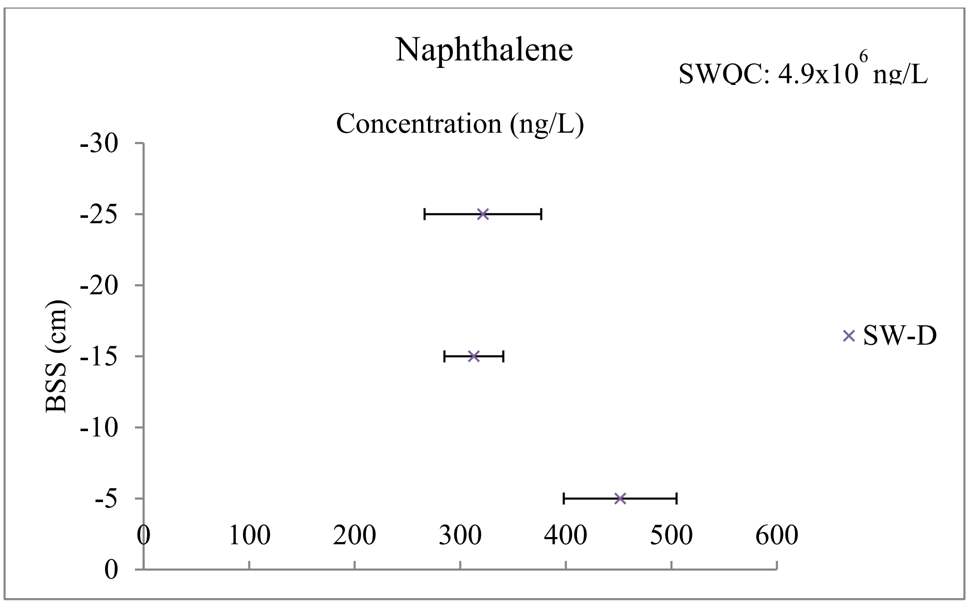


Figure B4. Naphthalene concentration profiles for the surface water (SW) sampler deployed along Transect D. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth

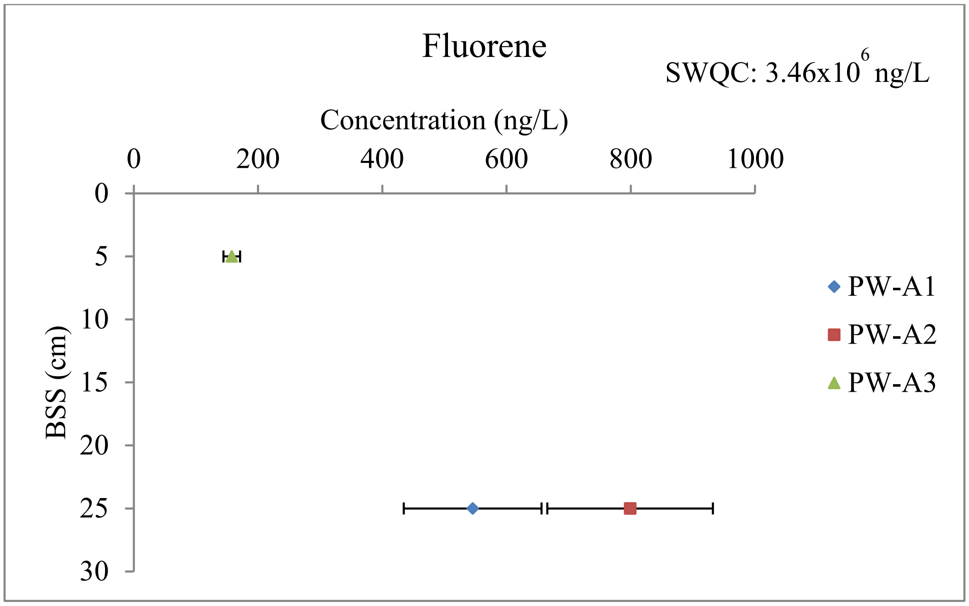


Figure B5. Fluorene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect A. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

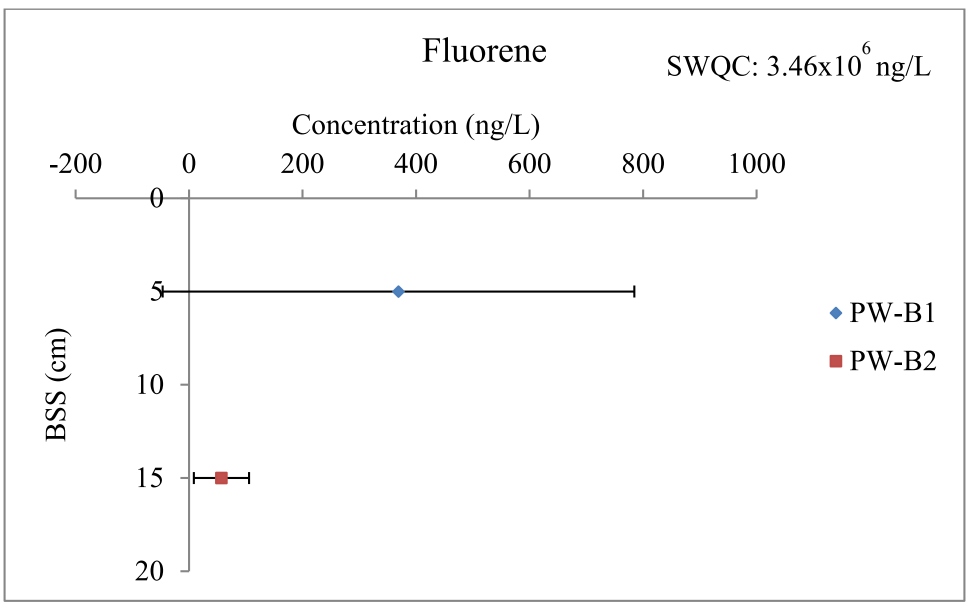


Figure B6. Fluorene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect B. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

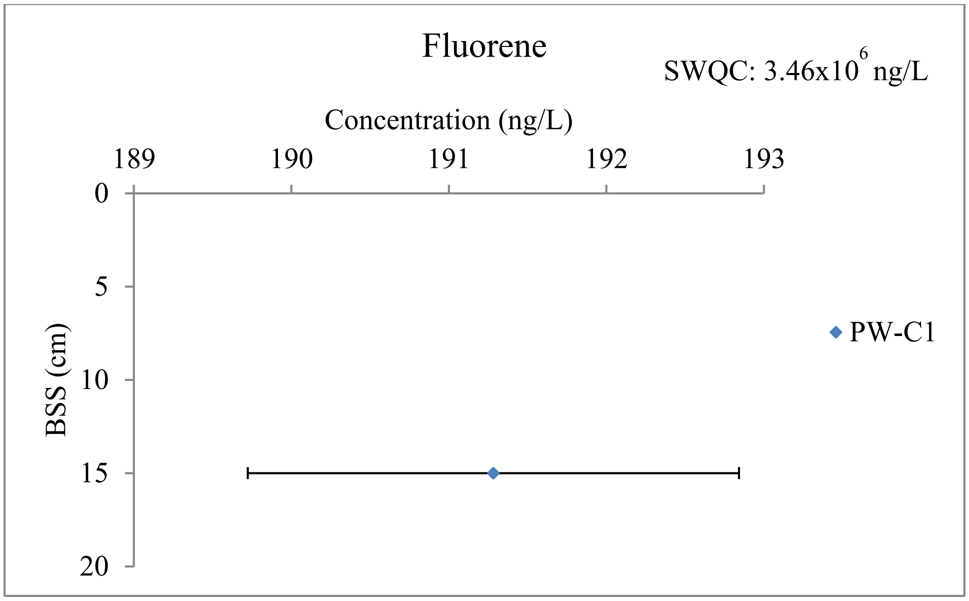


Figure B7. Fluorene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect C. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

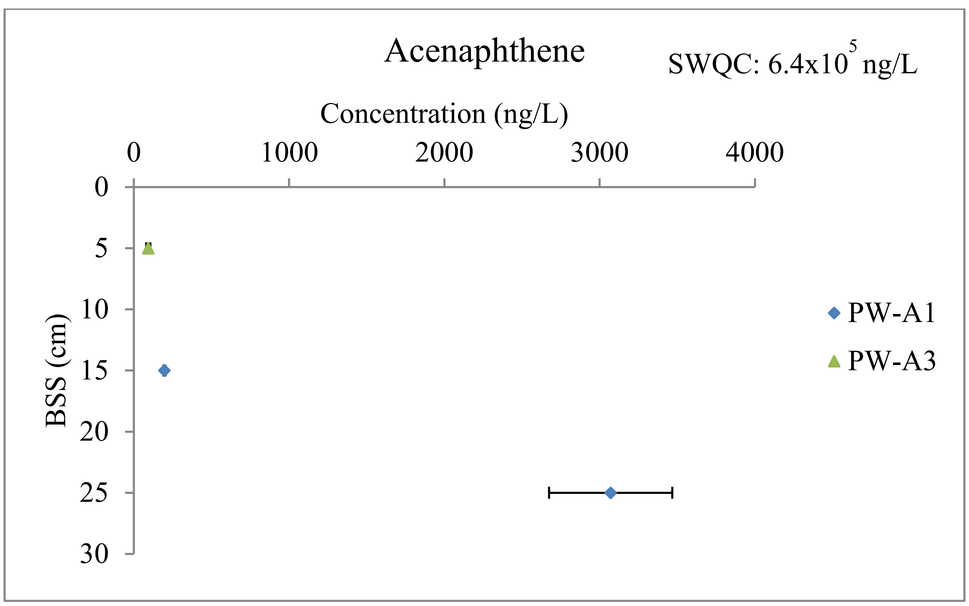


Figure B8. Acenaphthene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect A. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

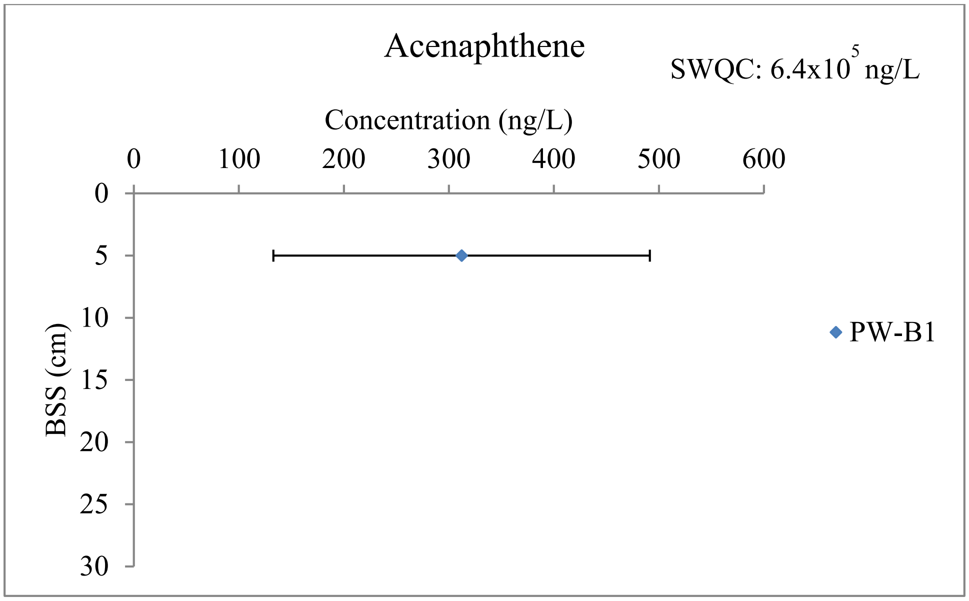


Figure B9. Acenaphthene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect B. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

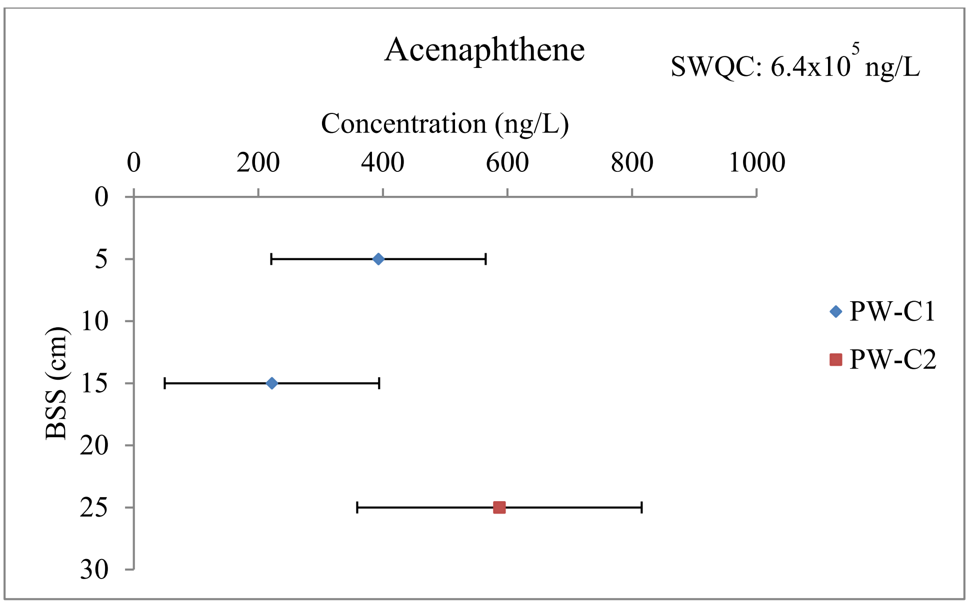


Figure B10. Acenaphthene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect C. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

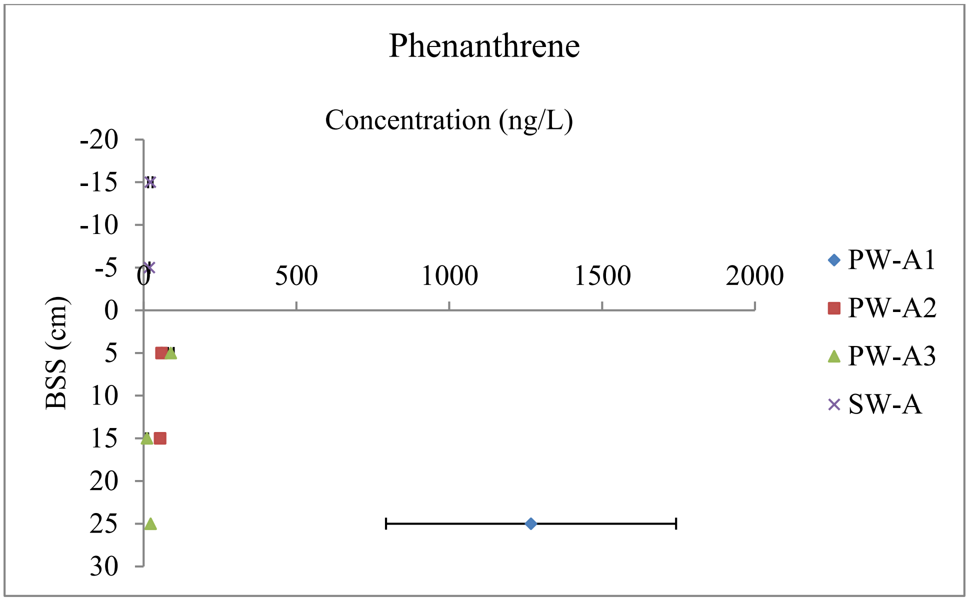


Figure B11. Phenanthrene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect A. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

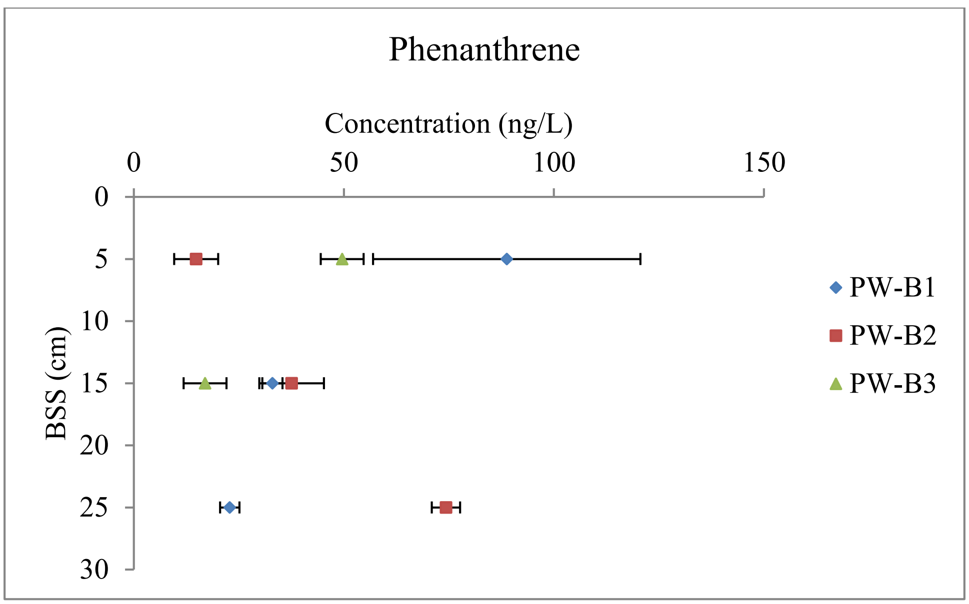


Figure B12. Phenanthrene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect B. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

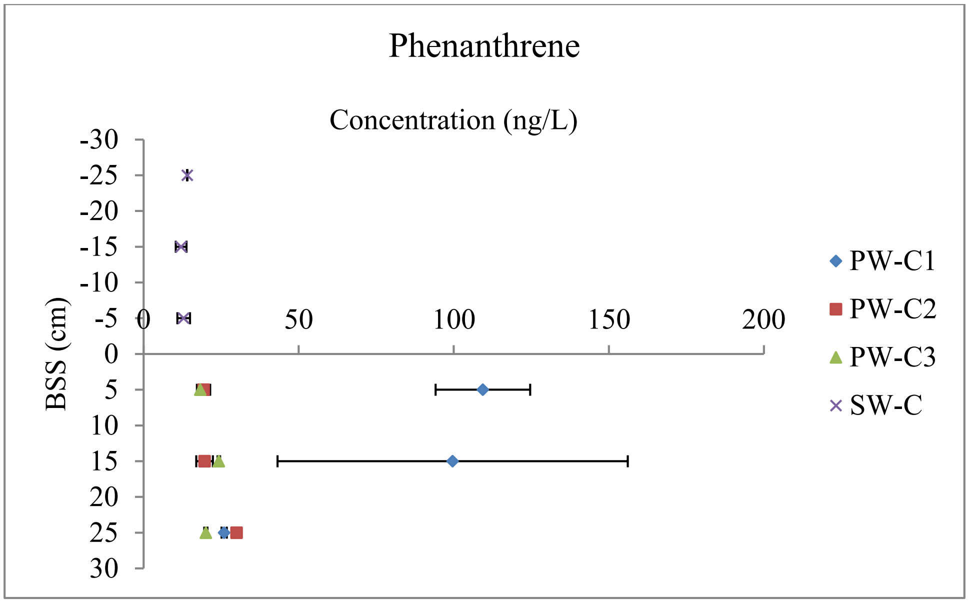


Figure B13. Phenanthrene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect C. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

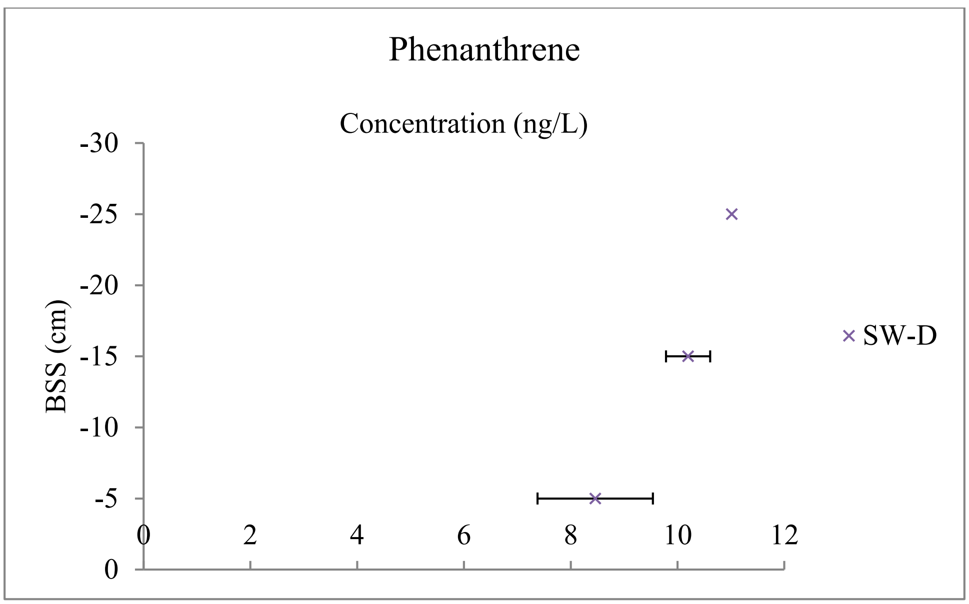


Figure B14. Phenanthrene concentration profiles for the surface water (SW) sampler deployed along Transect D. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

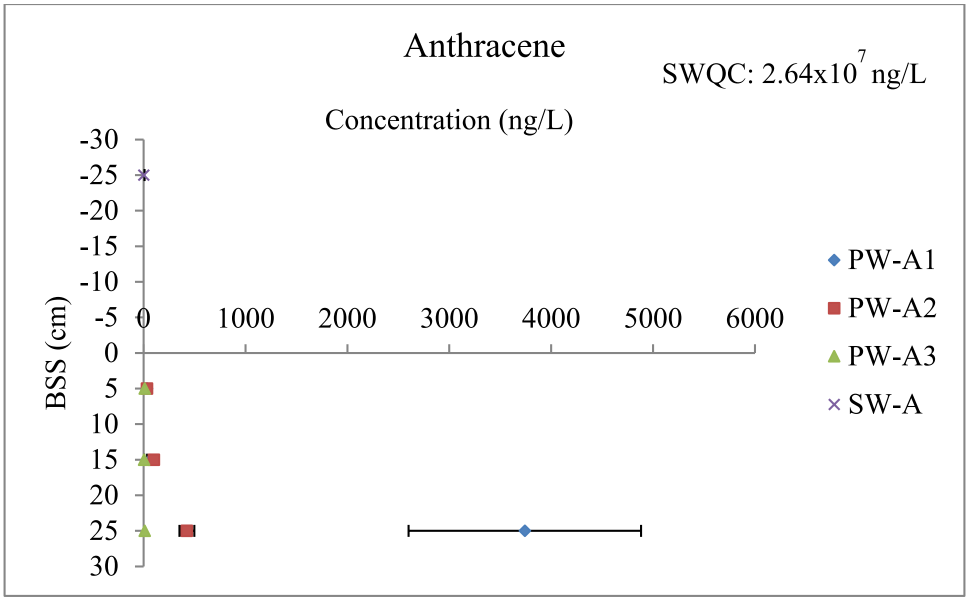


Figure B15. Anthracene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect A. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

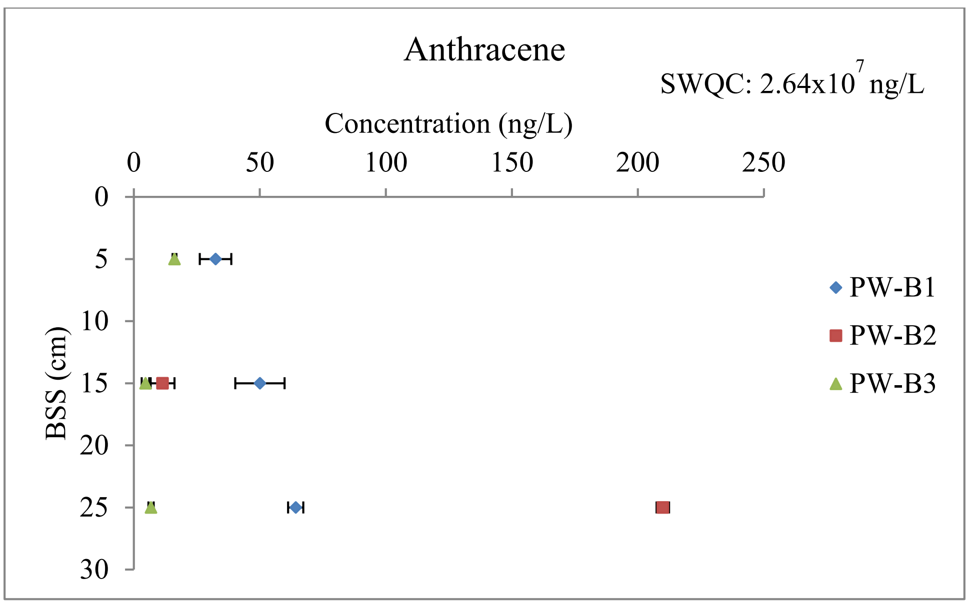


Figure B16. Anthracene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect B. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

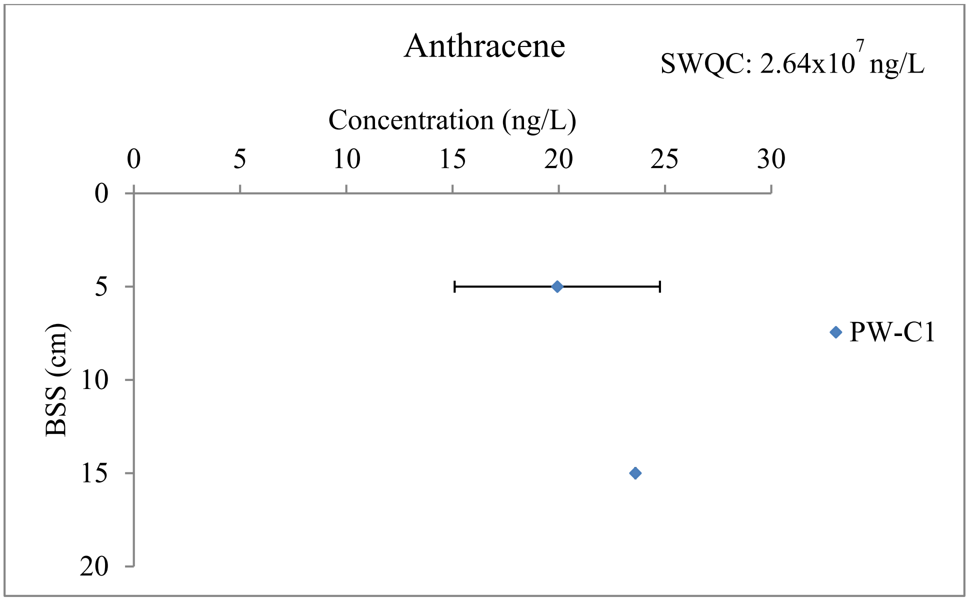


Figure B17. Anthracene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect C. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

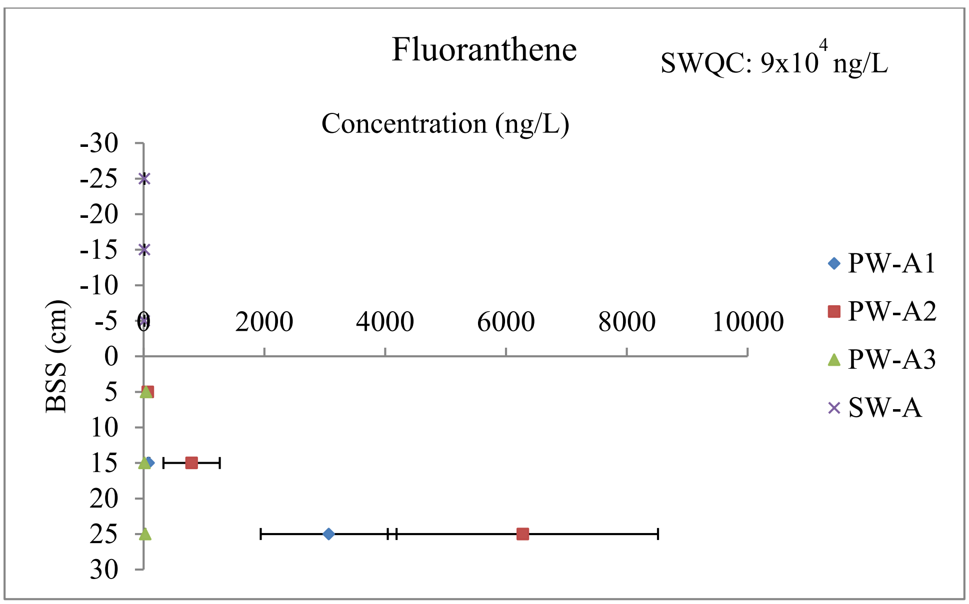


Figure B18. Fluoranthene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect A. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

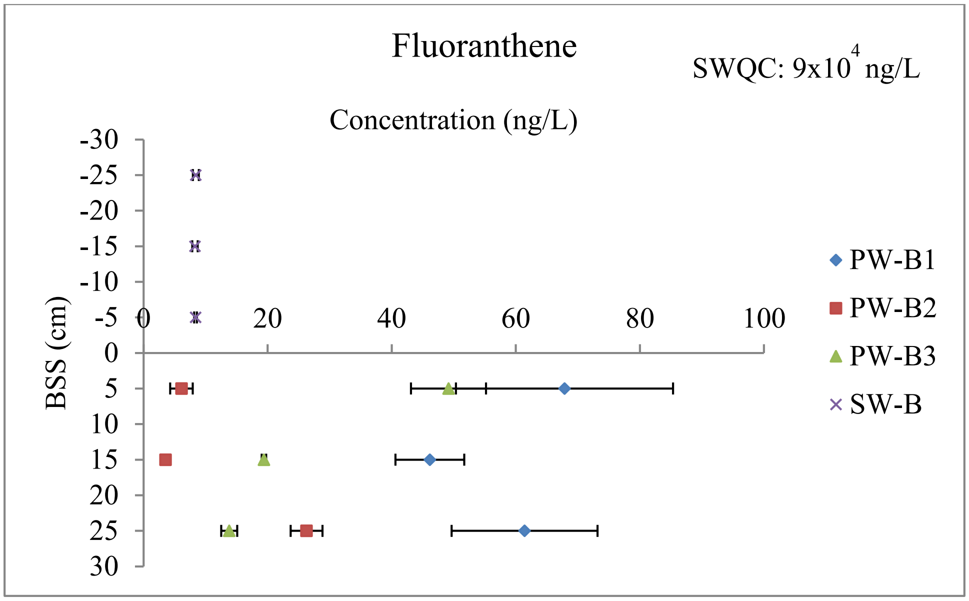


Figure B18. Fluoranthene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect B. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

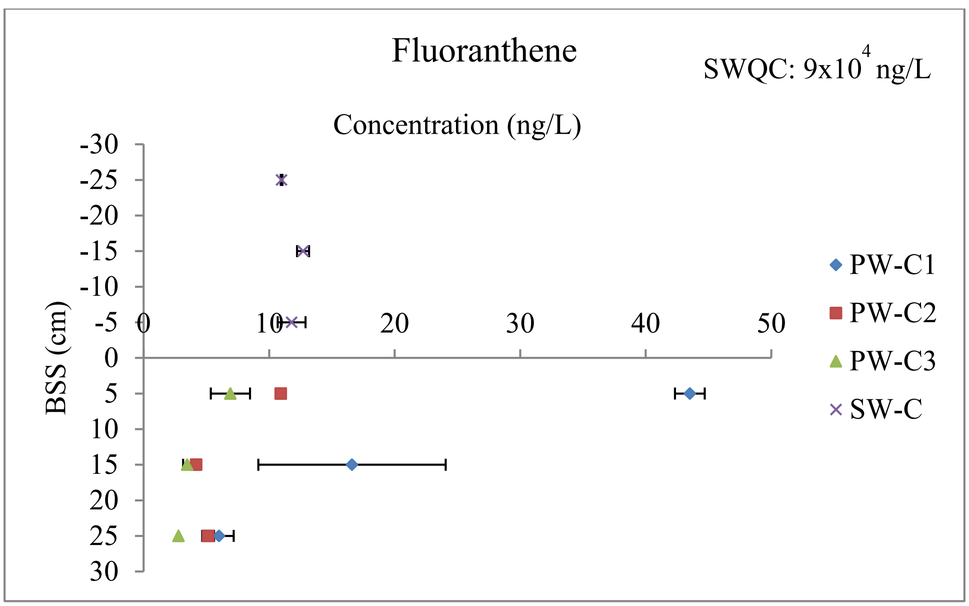


Figure B19. Fluoranthene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect C. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

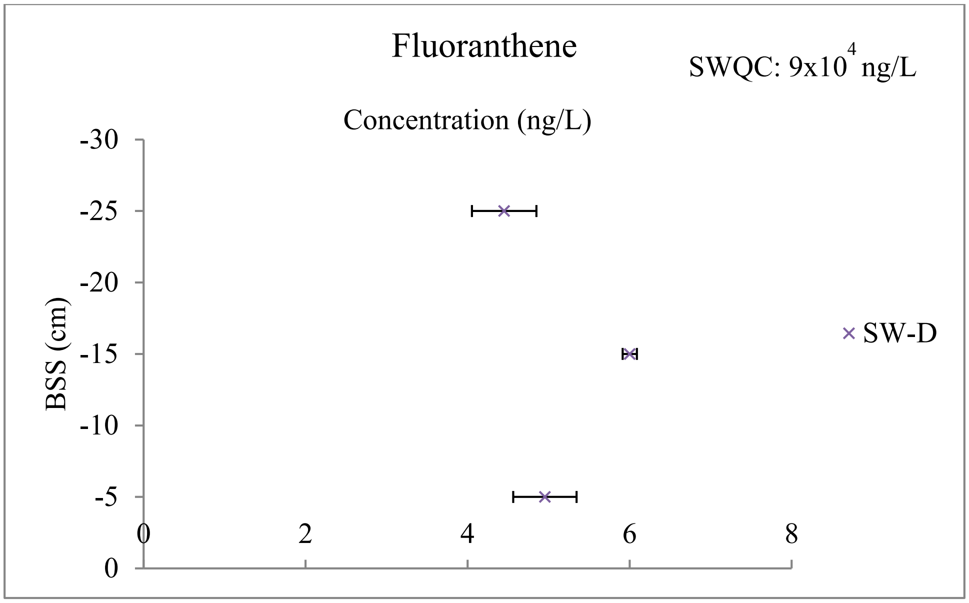


Figure B20. Fluoranthene concentration profiles for the surface water (SW) sampler deployed along Transect D. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

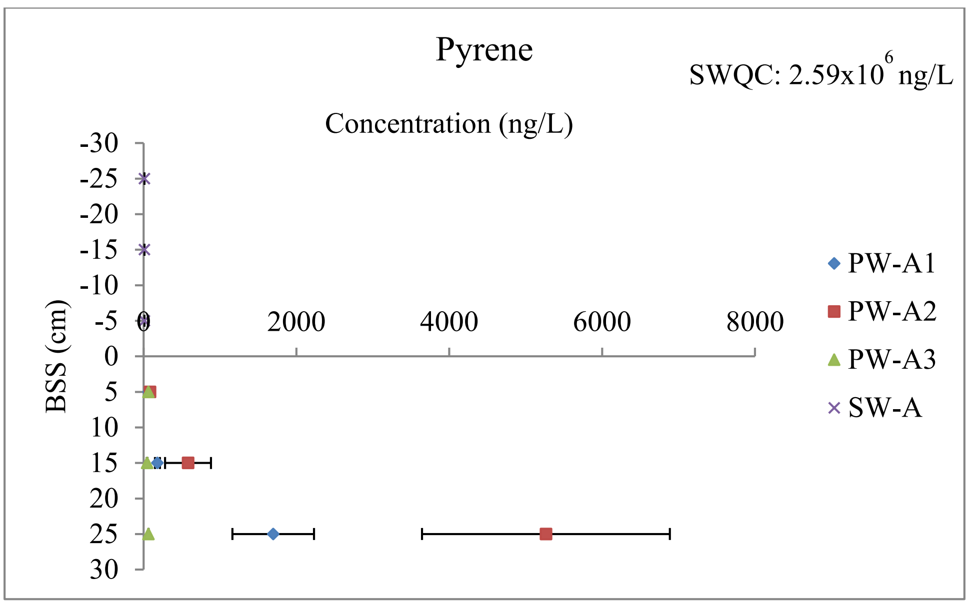


Figure B21. Pyrene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect A. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

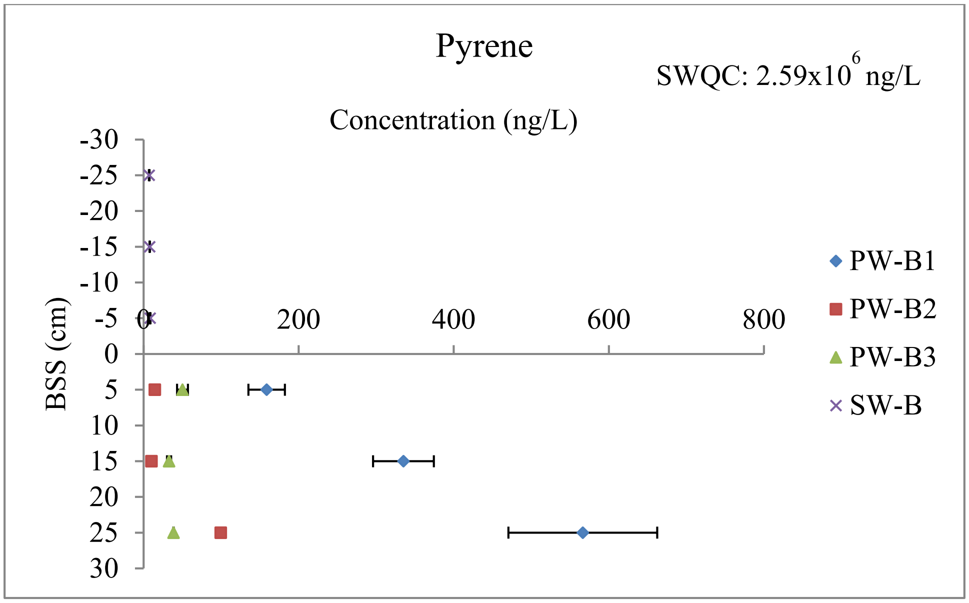


Figure B22. Pyrene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect B. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

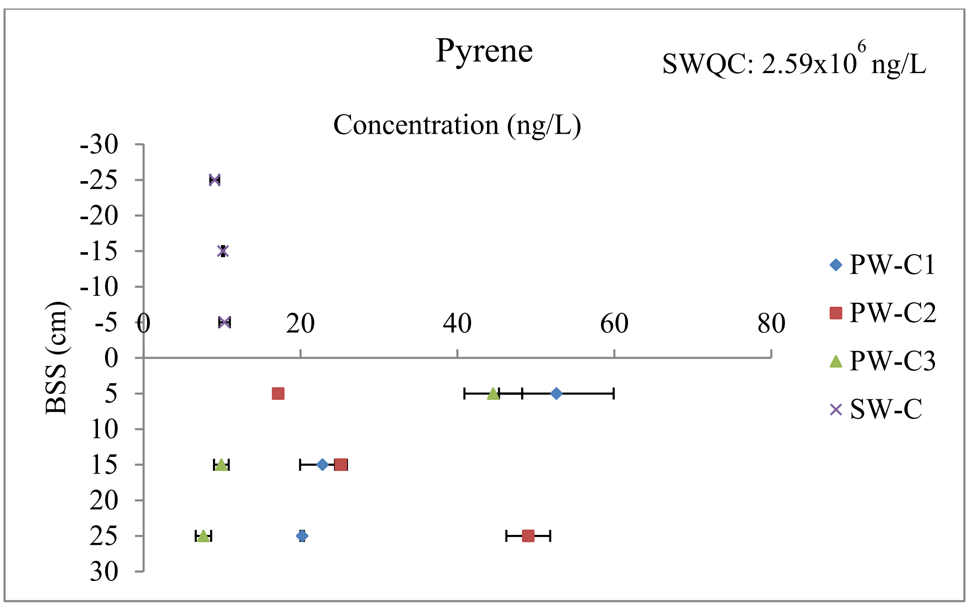


Figure B23. Pyrene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect C. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

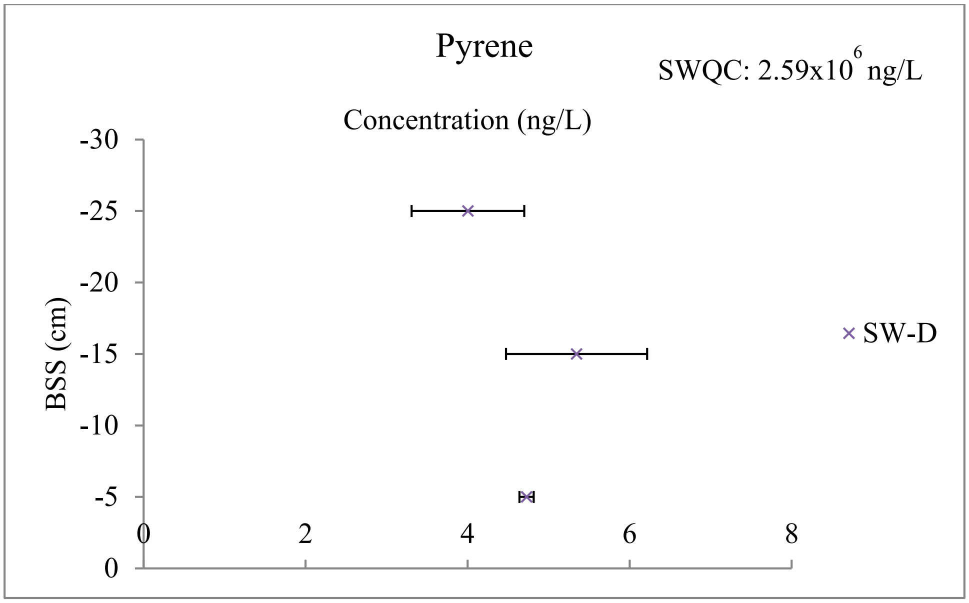


Figure B24. Pyrene concentration profiles for the surface water (SW) sampler deployed along Transect D. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

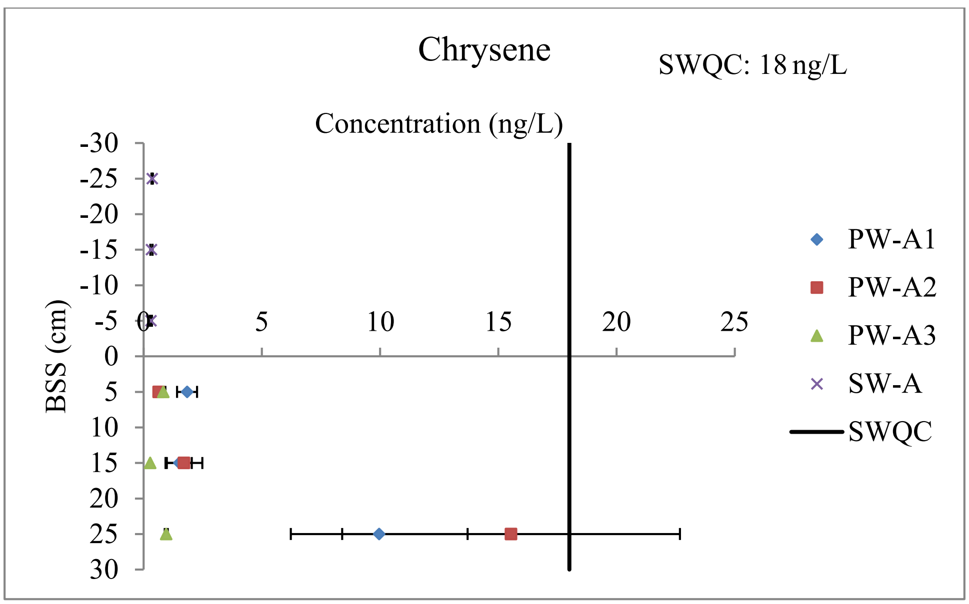


Figure B25. Chrysene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect A. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

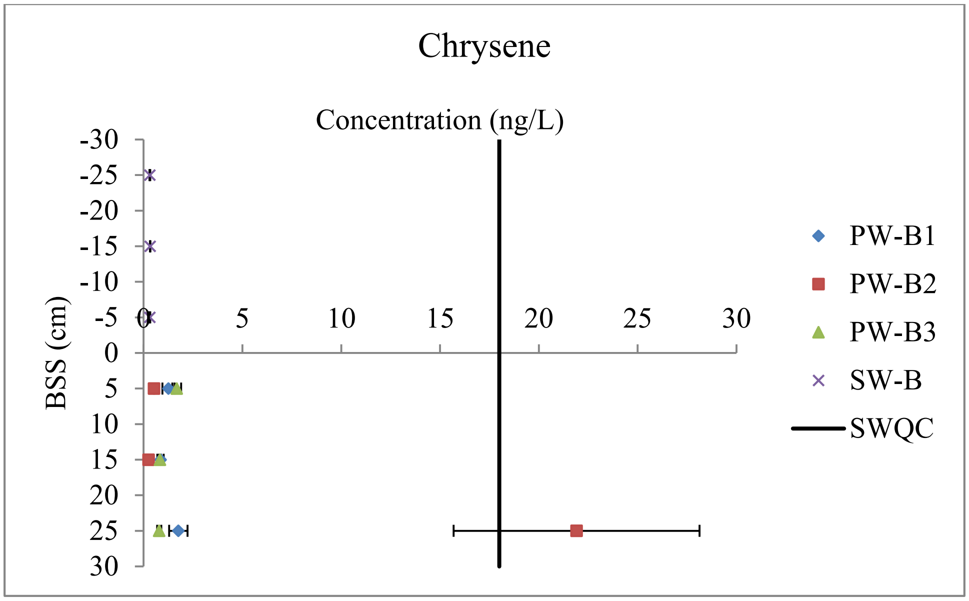


Figure B26. Chrysene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect B. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

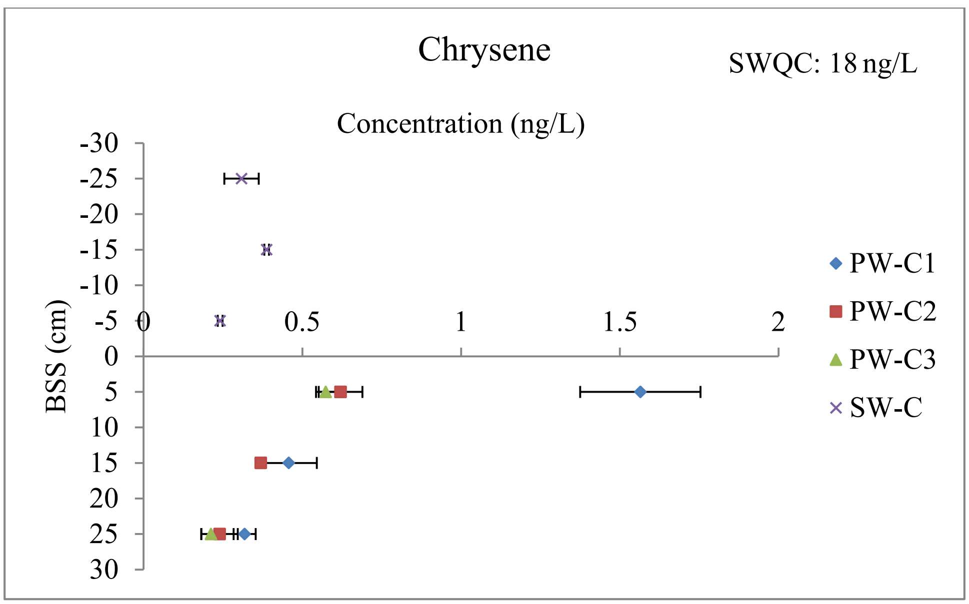


Figure B27. Chrysene concentration profiles for porewater (PW) and surface water (SW) samplers deployed along Transect C. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

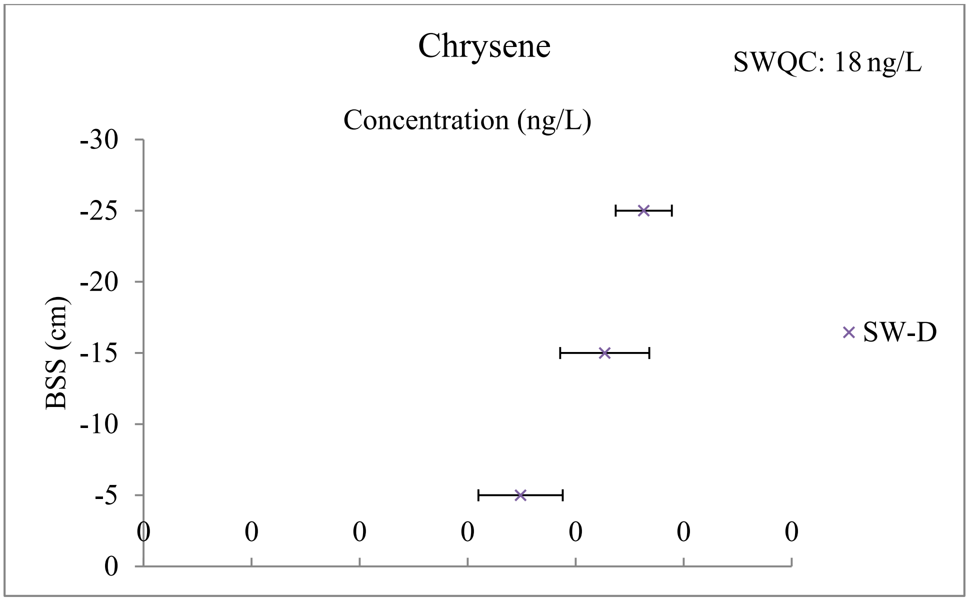


Figure B28. Chrysene concentration profiles for the surface water (SW) sampler deployed along Transect D. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

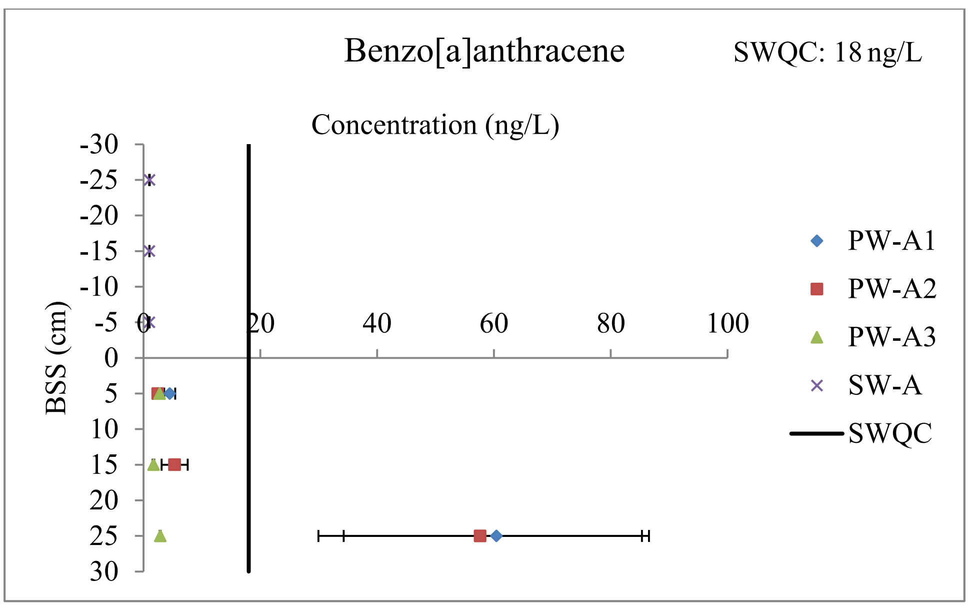


Figure B29. Benzo[a]anthracene concentration profiles for the porewater (PW) and surface water (SW) samplers deployed along Transect A. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

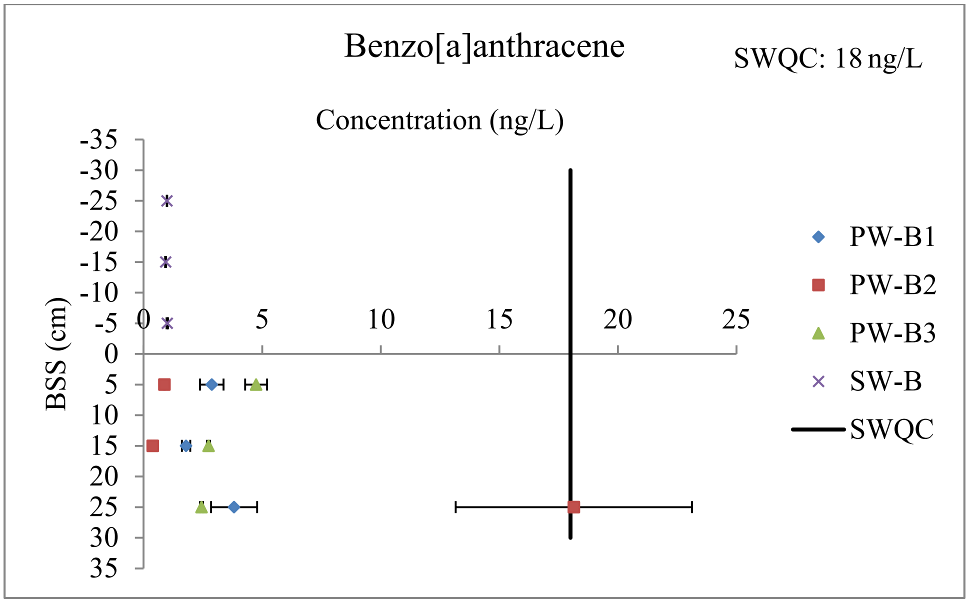


Figure B30. Benzo[a]anthracene concentration profiles for the porewater (PW) and surface water (SW) samplers deployed along Transect B. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

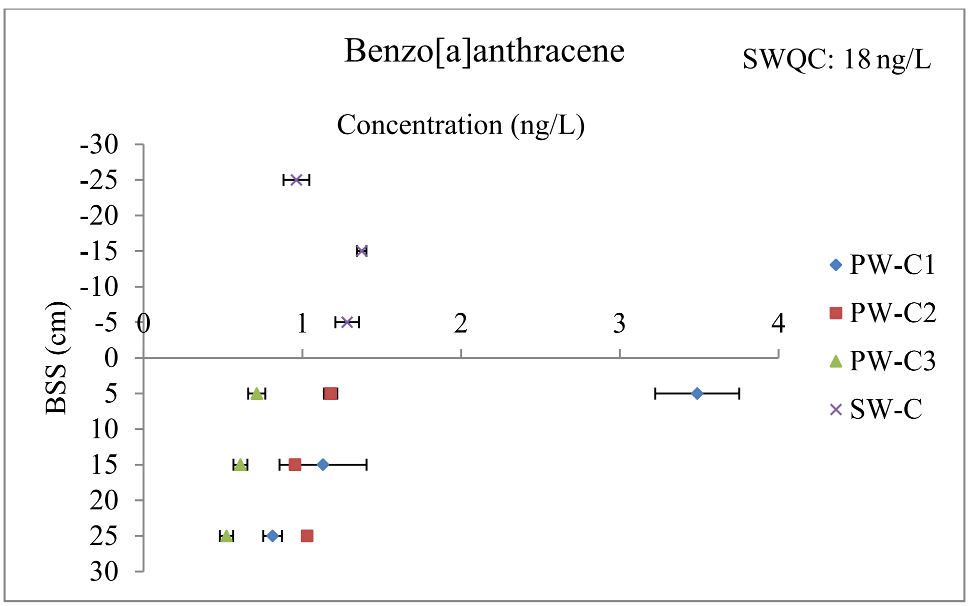


Figure B31. Benzo[a]anthracene concentration profiles for the porewater (PW) and surface water (SW) samplers deployed along Transect C. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

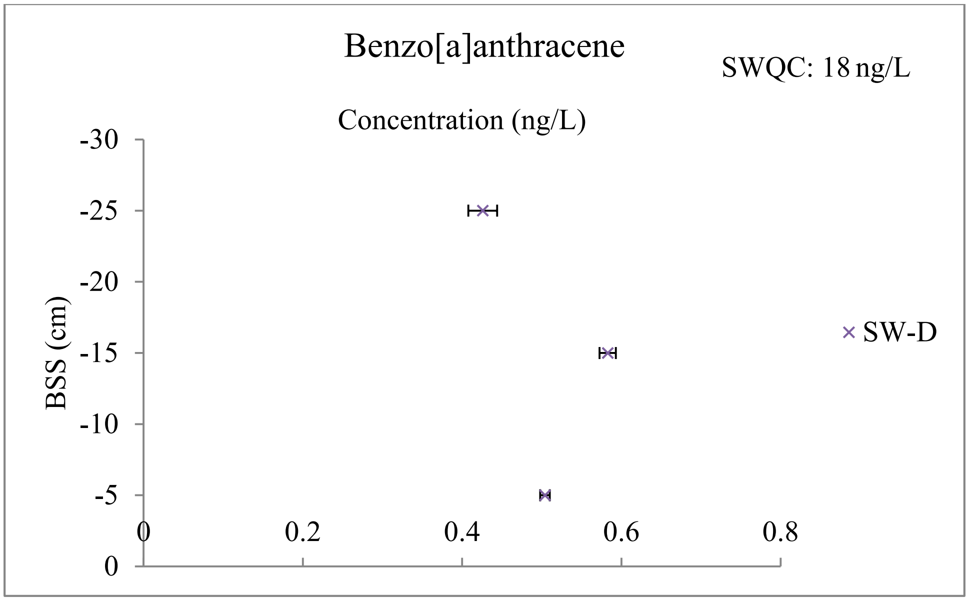


Figure B32. Benzo[a]anthracene concentration profiles for the surface water (SW) sampler deployed along Transect D. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of the measured concentrations at each depth.

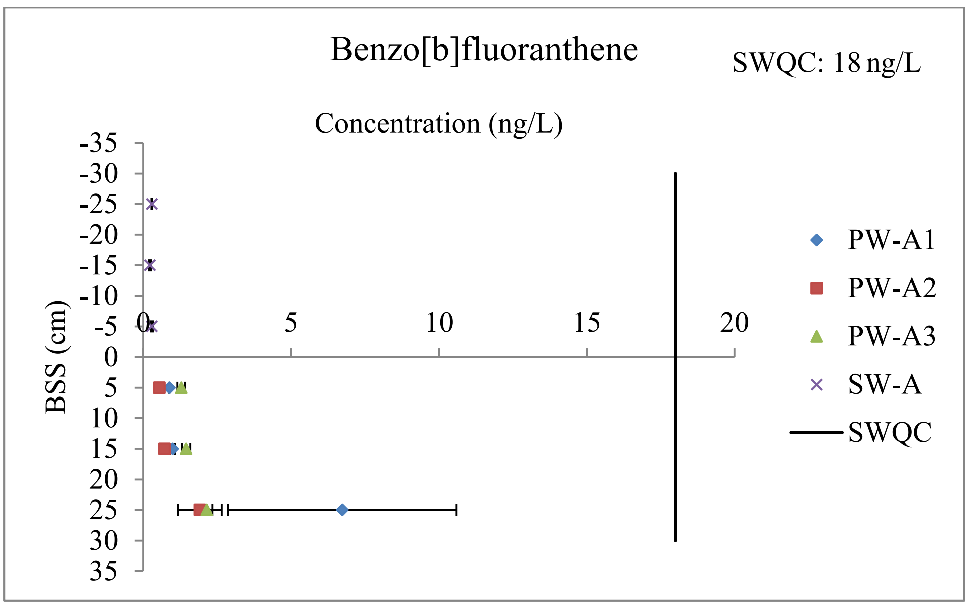


Figure B33. Benzo[b]fluoranthene concentration profiles for the porewater (PW) and surface water (SW) samplers deployed along Transect A. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of he measured concentrations at each depth.

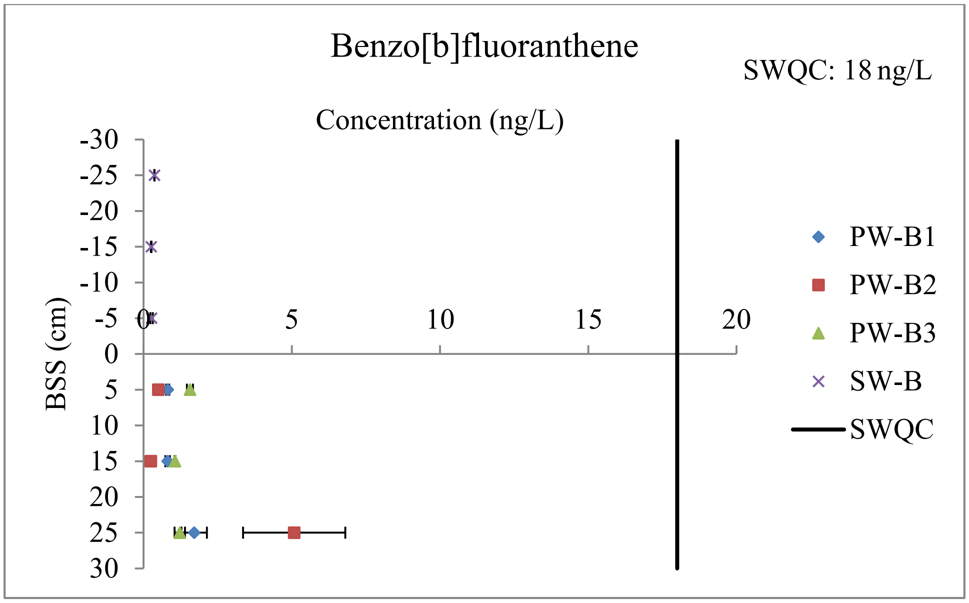


Figure B34. Benzo[b]fluoranthene concentration profiles for the porewater (PW) and surface water (SW) samplers deployed along Transect B. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of he measured concentrations at each depth.

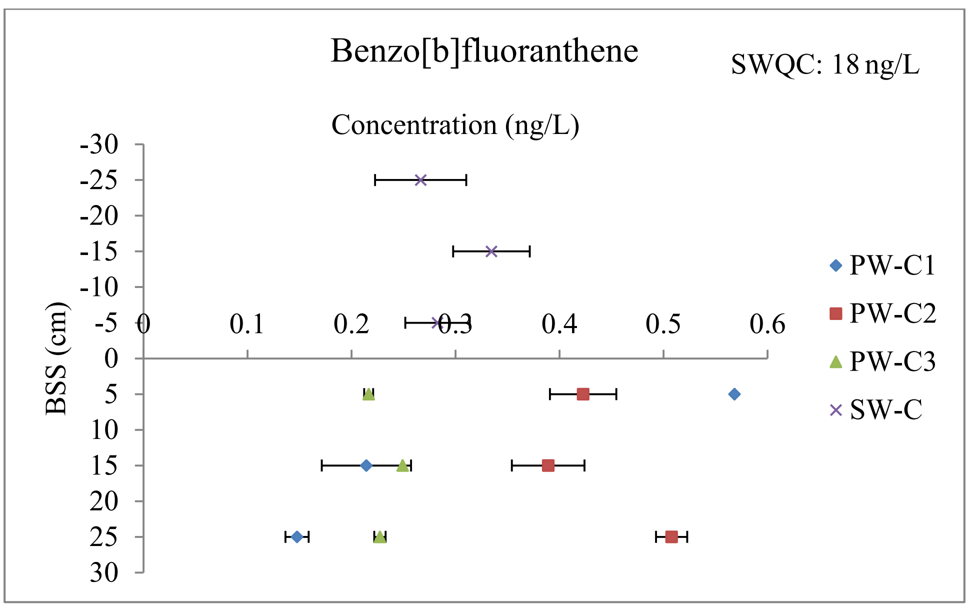


Figure B35. Benzo[b]fluoranthene concentration profiles for the porewater (PW) and surface water (SW) samplers deployed along Transect C. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of he measured concentrations at each depth.

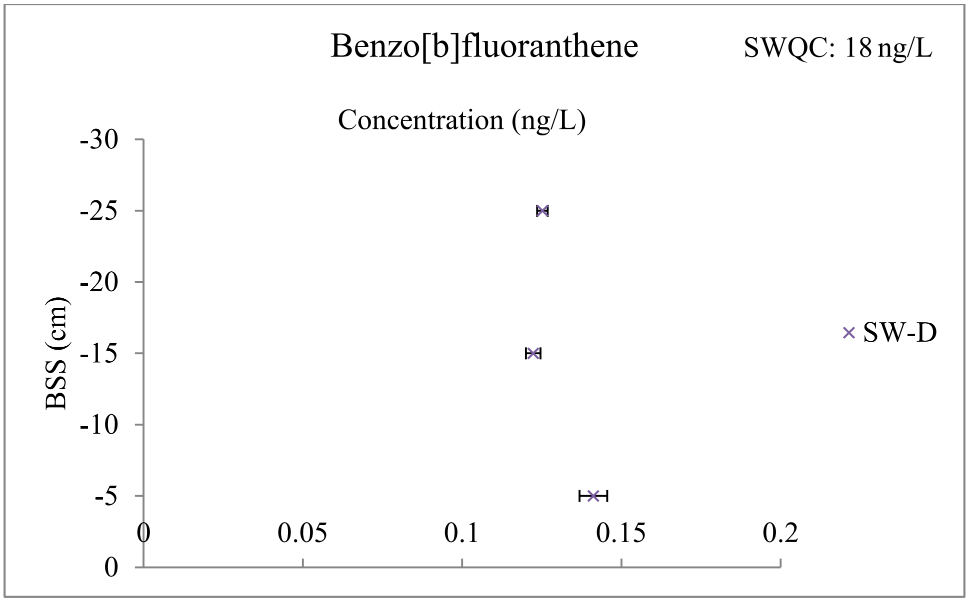


Figure B36. Benzo[b]fluoranthene concentration profiles for the surface water (SW) sampler deployed along Transect D. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of he measured concentrations at each depth.

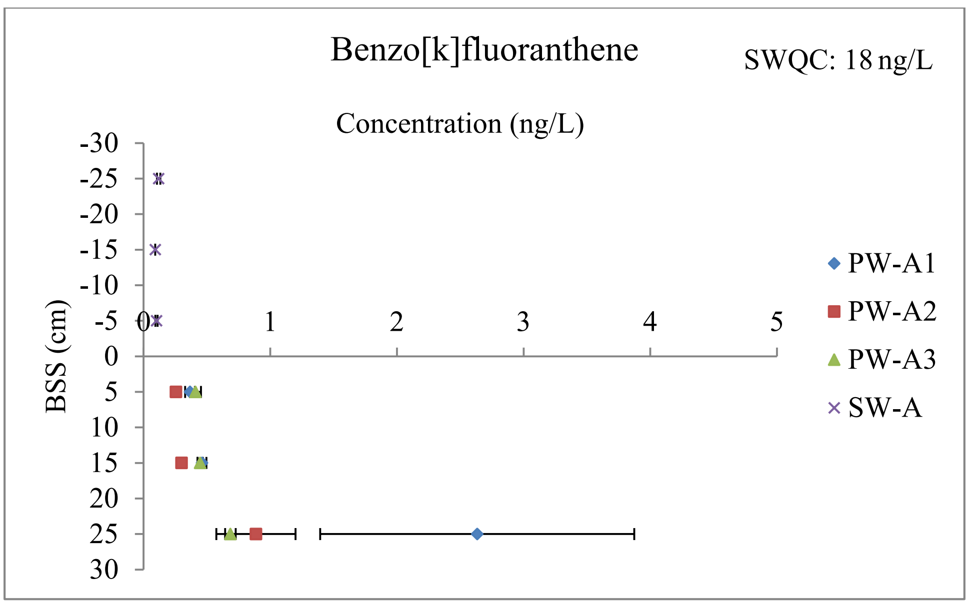


Figure B37. Benzo[k]fluoranthene concentration profiles for the porewater (PW) and surface water (SW) samplers deployed along Transect A. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of he measured concentrations at each depth.

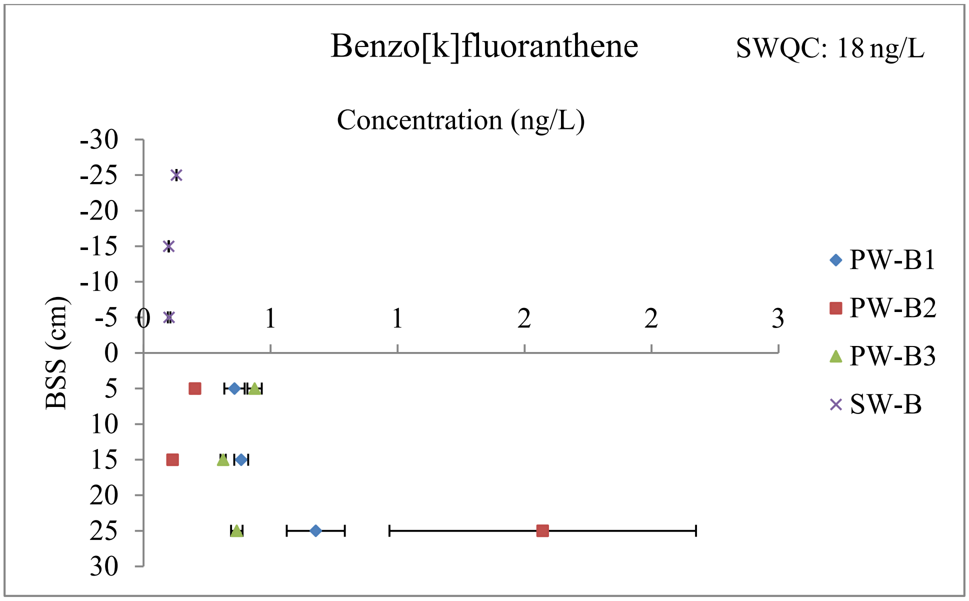


Figure B38. Benzo[k]fluoranthene concentration profiles for the porewater (PW) and surface water (SW) samplers deployed along Transect B. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of he measured concentrations at each depth.

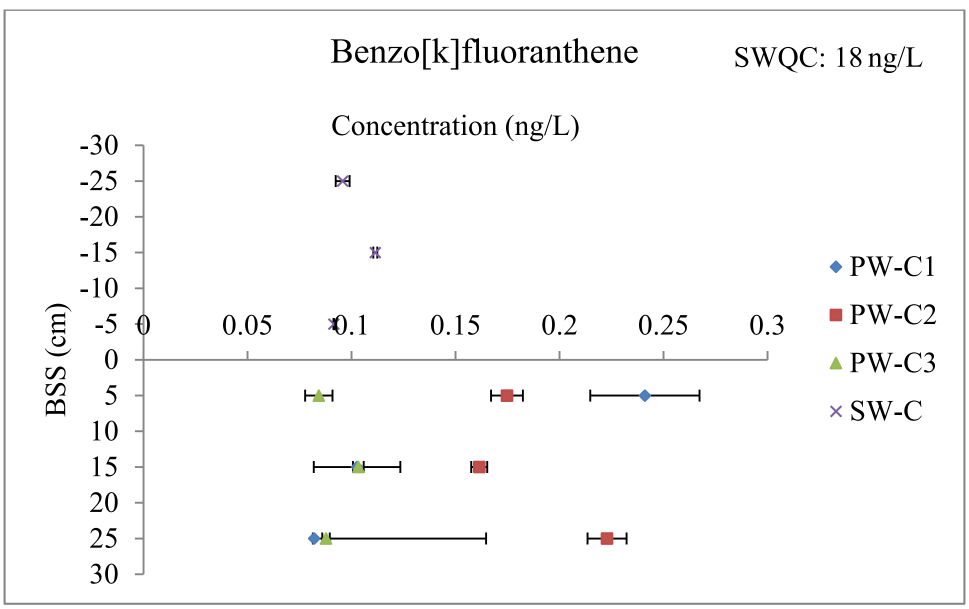


Figure B39. Benzo[k]fluoranthene concentration profiles for the porewater (PW) and surface water (SW) samplers deployed along Transect C. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of he measured concentrations at each depth.

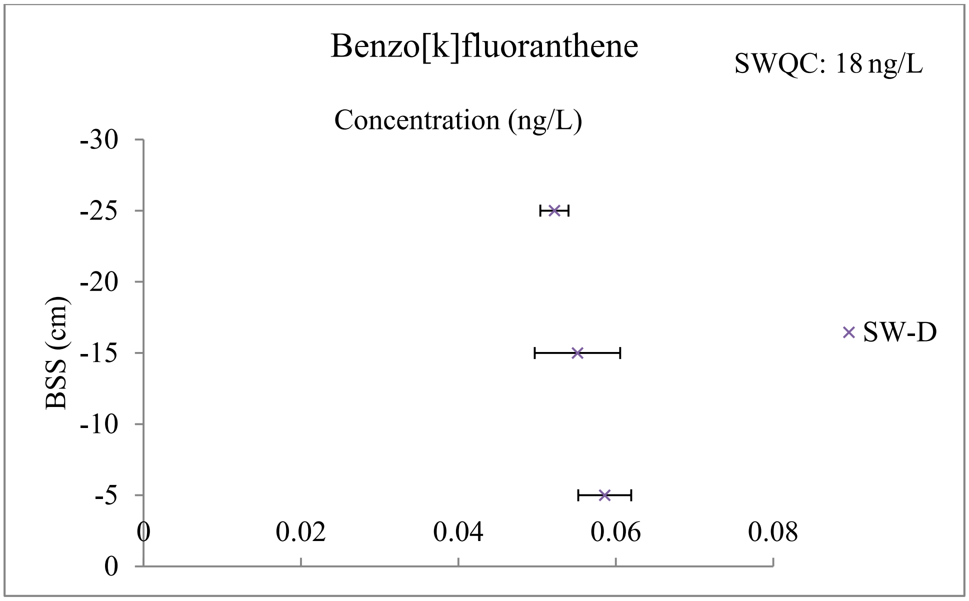


Figure B40. Benzo[k]fluoranthene concentration profiles for the surface water (SW) sampler deployed along Transect D. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of he measured concentrations at each depth.

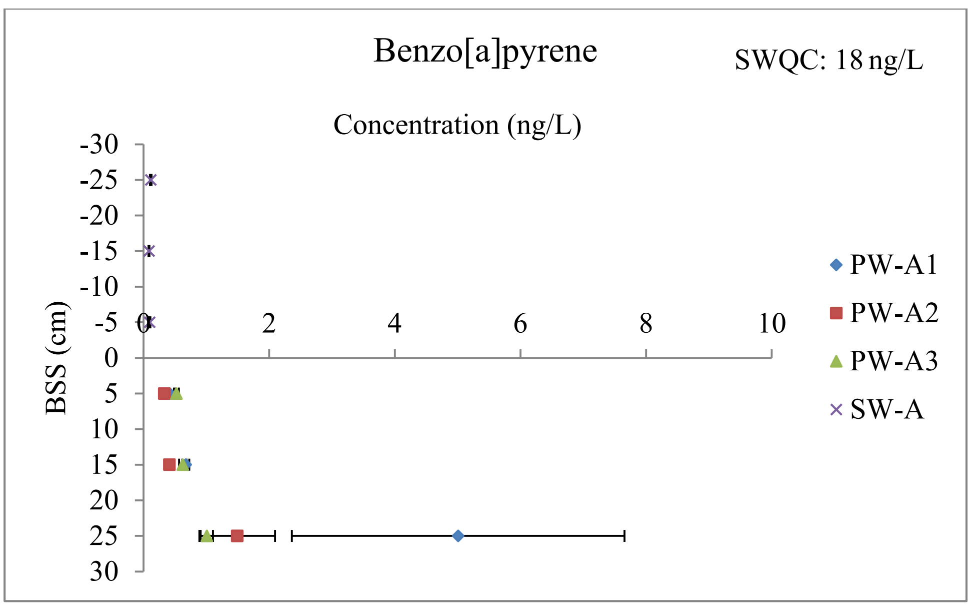


Figure B41. Benzo[a]pyrene concentration profiles for the porewater (PW) and surface water (SW) samplers deployed along Transect A. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of he measured concentrations at each depth.

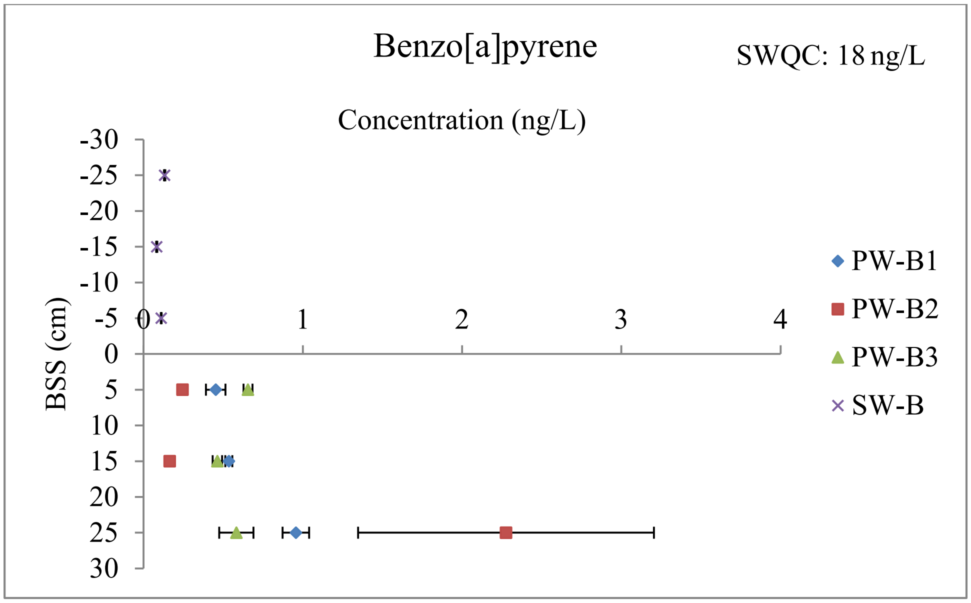


Figure B42. Benzo[a]pyrene concentration profiles for the porewater (PW) and surface water (SW) samplers deployed along Transect B. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of he measured concentrations at each depth.

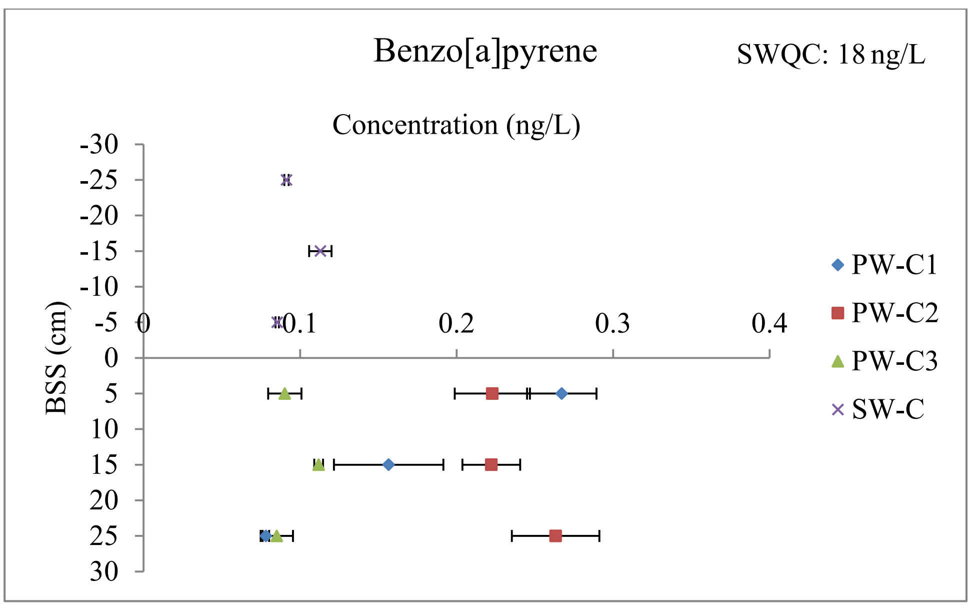


Figure B43. Benzo[a]pyrene concentration profiles for the porewater (PW) and surface water (SW) samplers deployed along Transect C. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of he measured concentrations at each depth.

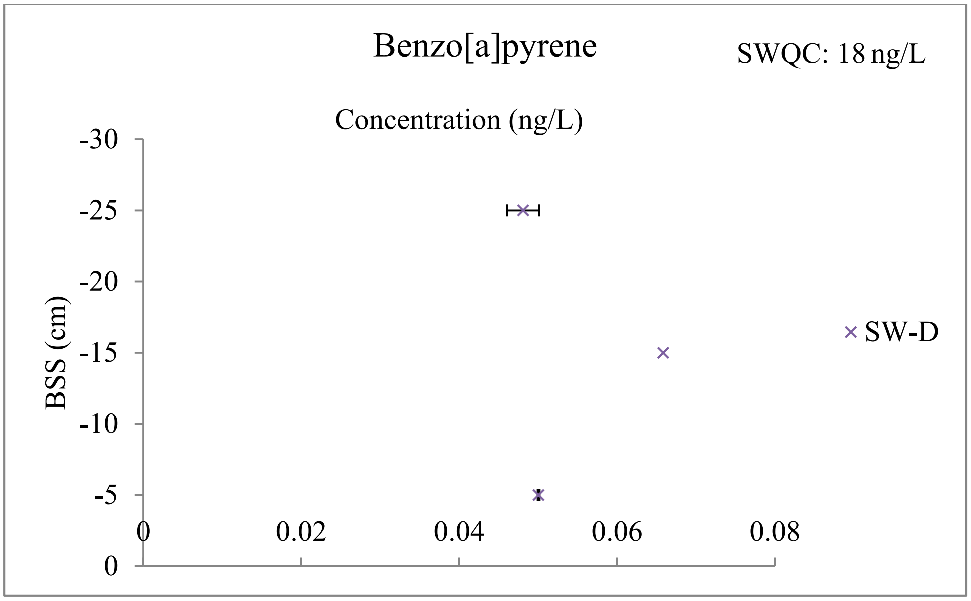


Figure B44. Benzo[a]pyrene concentration profiles for the surface water (SW) sampler deployed along Transect D. Data points represent the mean concentration (n=2) at each depth with the error bars representing the range of he measured concentrations at each depth.

Appendix C
Abbreviations:
Ace: Acenaphthene; Ant: Anthracene; Baa: Benzo [a]anthracene; Bap: Benzo [a]pyrene; Bbf: Benzo [b]fluoranthene; Bkf: Benzo [k]fluoranthene; BghiP: Benzo [g.h.i]perylene; Chry Chrysene; Daa: Dibenzo [ah]anthracene, Flt: Fluoranthene; Flu: Fluorene; Ind: Indeno [1,2,3-cd]pyrene; Nap: Naphthalene; Phe: Phenanthrene; Pyr: Pyrene; ND: Non-detect; PQL: Practical Quantitation Limit

Table C1. PAH concentrations measured with in the porewater at location A1.

Station ID	**WYOU-PW-A1**
Sampler ID	**WYOU-PW-A1**
Sampler Deployment Date	**11/13/2013**
Sample Collection Date	**12/5/2013**
Matrix	**SPME**
Units	**ng/L**

Sample Name	**NAP**	**FLU**	**ACE**	**PHE**	**ANT**	**FLT**	**PYR**	**CHRY**	**BAA**	**BBF**	**BKF**	**BAP**	**DAA**	**BghiP + IND**
WYOU-PW-A1-3/5	669	ND	ND	ND	33	78	72	2.3	5.4	0.9	0.4	0.5	ND	ND
WYOU-PW-A1-5/7	1212	ND	ND	ND	38	54	57	1.4	3.5	ND	0.3	0.3	ND	ND
WYOU-PW-A1-13/15	1054	ND	192 J	ND	35	69	148	1.0	4.4	0.9	0.4	0.6	ND	ND
WYOU-PW-A1-15/17	1083	ND	202 J	ND	100	95	213	2.0	6.2	1.1	0.5	0.7	ND	ND
WYOU-PW-A1-23/25	1485	434	2674	793	2601	1939	1161	6.2	34	2.9	1.4	2.4	ND	ND
WYOU-PW-A1-25/27	994	656	3467	1742	4882	4188	2231	14	87	11	3.9	7.7	ND	ND

Quantifiers	
J	MDL<C< PQL
U	C < MDL

Table C2. PAH concentrations measured with in the porewater at location A2.

Station ID	**WYOU-PW-A2**
Sampler ID	**WYOU-PW-A2**
Sampler Deployment Date	**11/13/2013**
Sample Collection Date	**12/5/2013**
Matrix	**SPME**
Units	**ng/L**

Sample Name	**NAP**	**FLU**	**ACE**	**PHE**	**ANT**	**FLT**	**PYR**	**CHRY**	**BAA**	**BBF**	**BKF**	**BAP**	**DAA**	**BghiP + IND**
WYOU-PW-A2-3/5	425	ND	ND	57 J	32	55	75	0.5	2.3	0.5	0.3	0.3	ND	ND
WYOU-PW-A2-5/7	410	ND	ND	60 J	34	81	92	0.8	2.6	0.6	0.3	0.4	ND	ND
WYOU-PW-A2-13/15	343 J	ND	ND	60 J	69	328	280	0.9	3.1	0.8	0.3	0.4	ND	ND
WYOU-PW-A2-15/17	269 J	ND	ND	48 J	131	1261	883	2.5	7.5	0.7	0.3	0.4	ND	ND
WYOU-PW-A2-23/25	146 J	666	ND	ND	351	4042	3644	8	30	1.2	0.6	0.9	ND	ND
WYOU-PW-A2-25/27	113 J	932	ND	ND	498	8516	6887	23	85	2.6	1.2	2.1	ND	ND

Quantifiers	
J	MDL<C< PQL
U	C < MDL

Table C3. PAH concentrations measured with in the porewater at location A3.

Station ID	**WYOU-PW-A3**
Sampler ID	**WYOU-PW-A3**
Sampler Deployment Date	**11/13/2013**
Sample Collection Date	**12/5/2013**
Matrix	**SPME**
Units	**ng/L**

Sample Name	**NAP**		**FLU**		**ACE**		**PHE**		**ANT**		**FLT**		**PYR**		**CHRY**		**BAA**		**BBF**		**BKF**		**BAP**		**DAA**		**BghiP + IND**	
WYOU-PW-A3-3/5	443		158	J	93	J	80	J	9	J	47		64		0.7		2.6		1.1		0.4		0.5			ND		ND
WYOU-PW-A3-5/7	416			ND		ND	98	J	15		35		63		0.9		2.9		1.4		0.5		0.6			ND		ND
WYOU-PW-A3-13/15	422			ND		ND	7	J	4	J	13		41			ND	1.5		1.3		0.4		0.6			ND		ND
WYOU-PW-A3-15/17	377	J		ND		ND	14	J	5	J	11		51		0.3	J	1.8		1.6		0.5		0.7			ND		ND
WYOU-PW-A3-23/25	446			ND		ND	23	J		ND	27		64		1.0		2.9		2.3		0.7		1.1			ND		ND
WYOU-PW-A3-25/27	597			ND		ND		ND	11		24		63		0.9		2.8		2.0		0.6		0.9			ND		ND

Quantifiers	
J	MDL<C< PQL
U	C < MDL

Table C4. PAH concentrations measured with in the surface water at transect A.

Station ID	**WYOU-SW-A**
Sampler ID	**WYOU-SW-A**
Sampler Deployment Date	**11/13/2013**
Sample Collection Date	**12/5/2013**
Matrix	**SPME**
Units	**ng/L**

Sample Name	**NAP**		**FLU**	**ACE**	**PHE**		**ANT**		**FLT**	**PYR**	**CHRY**	**BAA**	**BBF**	**BKF**	**BAP**	**DAA**	**BghiP + IND**
WYOU-SW-A-3/5	325	J	ND	ND	ND		2.3	J	14	11	0.4	1.1	0.3	0.1	0.1	ND	ND
WYOU-SW-A-5/7	327	J	ND	ND	ND		ND		13	11	0.3	0.9	0.3	0.1	0.1	ND	ND
WYOU-SW-A-13/15	374		ND	ND	29	J	2.1	J	14	11	0.3	1.0	0.3	0.1	0.1	ND	ND
WYOU-SW-A-15/17	294	J	ND	ND	15	J	ND		11	11	0.4	1.0	0.2	0.1	0.1	ND	ND
WYOU-SW-A-23/25	343		ND	ND	19	J	ND		11	10	0.3	1.0	0.3	0.1	0.1	ND	ND
WYOU-SW-A-25/27	372		ND	ND	19	J	ND		12	10	0.4	1.0	0.3	0.1	0.1	ND	ND

Quantifiers

J	MDL<C< PQL
U	C < MDL

Table C5. PAH concentrations measured with in the surface water at location B1.

Station ID	**WYOU-PW-B1**
Sampler ID	**WYOU-PW-B1**
Sampler Deployment Date	**11/13/2013**
Sample Collection Date	**12/5/2013**
Matrix	**SPME**
Units	**ng/L**

Sample Name	**NAP**	**FLU**	**ACE**	**PHE**	**ANT**	**FLT**	**PYR**	**CHRY**	**BAA**	**BBF**	**BKF**	**BAP**	**DAA**	**BghiP + IND**
WYOU-PW-B1-3/5	1895	369	491	121	39	50	135	1.6	3.4	0.9	0.4	0.5	ND	ND
WYOU-PW-B1-5/7	1064	ND	133 J	57 J	26	85	182	0.9	2.4	0.8	0.3	0.4	ND	ND
WYOU-PW-B1-13/15	510	ND	ND	35 J	40	52	296	0.7	1.6	0.7	0.4	0.5	ND	ND
WYOU-PW-B1-15/17	624	ND	ND	31 J	60	41	374	1.0	2.0	0.9	0.4	0.6	ND	ND
WYOU-PW-B1-23/25	385 J	ND	ND	21 J	61	50	471	1.3	2.8	1.3	0.6	0.9	ND	ND
WYOU-PW-B1-25/27	359 J	ND	ND	25 J	67	73	662	2.2	4.8	2.1	0.8	1.0	ND	ND

Quantifiers

J	MDL<C< PQL
U	C < MDL

Table C6. PAH concentrations measured with in the surface water at location B2.

Station ID	**WYOU-PW-B2**
Sampler ID	**WYOU-PW-B2**
Sampler Deployment Date	**11/13/2013**
Sample Collection Date	**12/5/2013**
Matrix	**SPME**
Units	**ng/L**

Sample Name	NAP	FLU	ACE	PHE	ANT	FLT	PYR	CHRY	BAA	BBF	BKF	BAP	DAA	BghiP + IND
WYOU-PW-B2-3/5		ND	ND	20 J	ND	7.9	16	0.5	0.9	0.5	0.2	0.2	ND	ND
WYOU-PW-B2-5/7	318 J	ND	ND	10 J	ND	4.3	13	0.5	0.8	0.5	0.2	0.3	ND	ND
WYOU-PW-B2-13/15	359 J	57 J	ND	30 J	6.7 J	2.9 J	10	0.3	0.4	0.3	0.1 J	0.2	ND	ND
WYOU-PW-B2-15/17	333 J	ND	ND	45 J	16	4.1 J	10	0.2 J	0.3	0.2	0.1 J	0.1	ND	ND
WYOU-PW-B2-23/25	371 J	ND	ND	78 J	212	29	98	16	13	3.4	1.0	1.3	ND	ND
WYOU-PW-B2-25/27	414	ND	ND	71 J	207	24	101	28	23	6.8	2.2	3.2	ND	ND

Quantifiers

J	MDL<C< PQL
U	C < MDL

Table C7. PAH concentrations measured with in the surface water at location B3.

Station ID	**WYOU-PW-B3**
Sampler ID	**WYOU-PW-B3**
Sampler Deployment Date	**11/13/2013**
Sample Collection Date	**12/5/2013**
Matrix	**SPME**
Units	**ng/L**

Sample Name	**NAP**		**FLU**	**ACE**	**PHE**		**ANT**		**FLT**	**PYR**	**CHRY**	**BAA**	**BBF**	**BKF**	**BAP**	**DAA**	**BghiP + IND**
WYOU-PW-B3-3/5	315	J	ND	ND	44	J	17		55	57	1.9	5.2	1.7	0.5	0.7	ND	ND
WYOU-PW-B3-5/7	332	J	ND	ND	55	J	15		43	43	1.4	4.3	1.5	0.4	0.6	ND	ND
WYOU-PW-B3-13/15	417		ND	ND	17	J	3	J	20	30	0.9	2.8	1.0	0.3	0.4	ND	ND
WYOU-PW-B3-15/17	393		ND	ND	ND		6	J	19	36	0.8	2.7	1.1	0.3	0.5	ND	ND
WYOU-PW-B3-23/25	459		ND	ND	ND		8	J	15	39	0.9	2.5	1.4	0.4	0.7	ND	ND
WYOU-PW-B3-25/27	426		ND	ND	ND		6	J	13	38	0.7	2.4	1.0	0.3	0.5	ND	ND

Quantifiers	
J	MDL<C< PQL
U	C < MDL

Table C8. PAH concentrations measured with in the surface water at transect B.

Station ID	**WYOU-SW-B**
Sampler ID	**WYOU-SW-B**
Sampler Deployment Date	**11/13/2013**
Sample Collection Date	**12/5/2013**
Matrix	**SPME**
Units	**ng/L**

Sample Name	**NAP**		**FLU**	**ACE**	**PHE**	**ANT**	**FLT**	**PYR**	**CHRY**	**BAA**	**BBF**	**BKF**	**BAP**	**DAA**	**BghiP + IND**
WYOU-SW-B-3/5	296	J	ND	ND	ND	ND	8	7	0.3	1.0	0.4	0.1	0.1	ND	ND
WYOU-SW-B-5/7	364		ND	ND	ND	ND	9	8	0.3	1.0	0.4	0.1	0.1	ND	ND
WYOU-SW-B-13/15	350		ND	ND	ND	ND	8	8	0.3	0.9	0.2	0.1	0.1	ND	ND
WYOU-SW-B-15/17	284	J	ND	ND	ND	ND	9	8	0.3	0.9	0.3	0.1	0.1	ND	ND
WYOU-SW-B-23/25	289	J	ND	ND	ND	ND	8	8	0.3	1.0	0.2	0.1	0.1	ND	ND
WYOU-SW-B-25/27	338	J	ND	ND	ND	ND	9	9	0.3	1.0	0.3	0.1	0.1	ND	ND

Table C8. PAH concentrations measured with in the porewater water at location C1.

Station ID	**WYOU-PW-C1**
Sampler ID	**WYOU-PW-C1**
Sampler Deployment Date	**11/13/2013**
Sample Collection Date	**12/5/2013**
Matrix	**SPME**
Units	**ng/L**

Sample Name	**NAP**	**FLU**	**ACE**	**PHE**	**ANT**	**FLT**	**PYR**	**CHRY**	**BAA**	**BBF**	**BKF**	**BAP**	**DAA**	**BghiP + IND**
WYOU-PW-C1-3/5	517	ND	221 J	94 J	15	45	45	1.8	3.8	0.6	0.3	0.3	ND	ND
WYOU-PW-C1-5/7	520	ND	565	125	25	42	60	1.4	3.2	0.6	0.2	0.2	ND	ND
WYOU-PW-C1-13/15	399	191 J	222 J	156	24	24	26	0.5	1.4	0.3	0.1	0.2	ND	ND
WYOU-PW-C1-15/17	423	ND	ND	43 J	ND	9	20	0.4	0.9	0.2	0.1 J	0.1 J	ND	ND
WYOU-PW-C1-23/25	349 J	ND	ND	25 J	ND	5 J	20	0.3 J	0.8	0.2	0.1 J	0.1 J	ND	ND
WYOU-PW-C1-25/27	464	ND	ND	27 J	ND	7	20	0.4	0.9	0.1 J	0.1 J	0.1 J	ND	ND

Quantifiers

J	MDL<C< PQL
U	C < MDL

Table C9. PAH concentrations measured with in the porewater water at location C2.

Station ID	**WYOU-PW-C2**
Sampler ID	**WYOU-PW-C2**
Sampler Deployment Date	**11/13/2013**
Sample Collection Date	**12/5/2013**
Matrix	**SPME**
Units	**ng/L**

Sample Name	**NAP**	**FLU**	**ACE**	**PHE**	**ANT**	**FLT**	**PYR**	**CHRY**	**BAA**	**BBF**	**BKF**	**BAP**	**DAA**	**BghiP + IND**
WYOU-PW-C2-3/5	615	ND	ND	21 J	ND	11	18	0.6	1.2	0.5	0.2	0.2	ND	ND
WYOU-PW-C2-5/7	1072	ND	ND	17 J	ND	11	17	0.7	1.1	0.4	0.2	0.2	ND	ND
WYOU-PW-C2-13/15	2347	ND	ND	22 J	ND	4	26	0.4	1.0	0.4	0.2	0.2	ND	ND
WYOU-PW-C2-15/17	3444	ND	ND	17 J	ND	4 J	24	0.4	0.9	0.4	0.2	0.2	ND	ND
WYOU-PW-C2-23/25	26144	ND	ND	30 J	ND	6	46	0.2 J	1.0	0.5	0.2	0.2	ND	ND
WYOU-PW-C2-25/27	79273	ND	587	30 J	ND	5 J	52	0.3 J	1.0	0.5	0.2	0.3	ND	ND

Quantifiers

J	MDL<C< PQL
U	C < MDL

Table C10. PAH concentrations measured with in the porewater water at location C3.

Station ID	**WYOU-PW-C3**
Sampler ID	**WYOU-PW-C3**
Sampler Deployment Date	**11/13/2013**
Sample Collection Date	**12/5/2013**
Matrix	**SPME**
Units	**ng/L**

Sample Name	**NAP**	**FLU**	**ACE**	**PHE**	**ANT**	**FLT**	**PYR**	**CHRY**	**BAA**	**BBF**	**BKF**	**BAP**	**DAA**	**BghiP + IND**
WYOU-PW-C3-3/5	402	ND	ND	18 J	ND	8	48	0.6	0.8	0.2	0.1	0.1	ND	ND
WYOU-PW-C3-5/7	419	ND	ND	18 J	ND	5	41	0.5	0.7	0.2	0.1	0.1	ND	ND
WYOU-PW-C3-13/15	533	ND	ND	24 J	ND	4 J	11	ND	0.6	0.2	0.1 J	0.1 J	ND	ND
WYOU-PW-C3-15/17	488	ND	ND	25 J	ND	3 J	9	ND	0.7	ND	0.1 J	0.1 J	ND	ND
WYOU-PW-C3-23/25	486	ND	ND	21 J	ND	3 J	7	0.2 J	0.6	0.2	0.1 J	0.1 J	ND	ND
WYOU-PW-C3-25/27	432	ND	ND	20 J	ND	ND ND	9	ND	0.5	0.2	0.1 J	0.1 J	ND	ND

Quantifiers	
J	MDL<C< PQL
U	C < MDL

Table C11. PAH concentrations measured with in the surface water at transect C.

Station ID	**WYOU-SW-C**
Sampler ID	**WYOU-SW-C**
Sampler Deployment Date	**11/13/2013**
Sample Collection Date	**12/5/2013**
Matrix	**SPME**
Units	**ng/L**

Sample Name	**NAP**		**FLU**	**ACE**	**PHE**		**ANT**	**FLT**	**PYR**	**CHRY**	**BAA**	**BBF**	**BKF**	**BAP**	**DAA**	**BghiP + IND**
WYOU-SW-C-3/5	258	J	ND	ND	14	J	ND	11	8	0.3	0.9	0.2	0.1	0.1	ND	ND
WYOU-SW-C-5/7	271	J	ND	ND	14	J	ND	11	10	0.4	1.0	0.3	0.1	0.1	ND	ND
WYOU-SW-C-13/15	313	J	ND	ND	14	J	ND	12	10	0.4	1.4	0.3	0.1	0.1	ND	ND
WYOU-SW-C-15/17	262	J	ND	ND	10	J	ND	13	10	0.4	1.3	0.4	0.1	0.1	ND	ND
WYOU-SW-C-23/25	320	J	ND	ND	15	J	ND	11	10	0.2	1.2	0.3	0.1	0.1	ND	ND
WYOU-SW-C-25/27	356		ND	ND	11	J	ND	13	11	0.2	1.4	0.3	0.1	0.1	ND	ND

Quantifiers

J	MDL<C< PQL
U	C < MDL

Table C12. PAH concentrations measured with in the surface water at transect D.

Station ID	**WYOU-SW-D**
Sampler ID	**WYOU-SW-D**
Sampler Deployment Date	**11/13/2013**
Sample Collection Date	**12/5/2013**
Matrix	**SPME**
Units	**ng/L**

Sample Name	**NAP**		**FLU**	**ACE**	**PHE**		**ANT**	**FLT**	**PYR**	**CHRY**		**BAA**	**BBF**	**BKF**		**BAP**		**DAA**	**BghiP + IND**
WYOU-SW-D-3/5	377		ND	ND	ND		ND	4	3	0.2		0.4	0.1	0.1	J	0.0	J	ND	ND
WYOU-SW-D-5/7	266	J	ND	ND	11	J	ND	5	5	0.2		0.4	0.1	0.1	J	0.1	J	ND	ND
WYOU-SW-D-13/15	341		ND	ND	10	J	ND	6	4	0.2	J	0.6	0.1	0.0	J	ND		ND	ND
WYOU-SW-D-15/17	285	J	ND	ND	11	J	ND	6	6	0.2		0.6	0.1	0.1	J	0.1	J	ND	ND
WYOU-SW-D-23/25	505		ND	ND	7	J	ND	5	5	0.2	J	0.5	0.1	0.1	J	0.1	J	ND	ND
WYOU-SW-D-25/27	398		ND	ND	10	J	ND	5	5	0.2	J	0.5	0.1	0.1	J	0.0	J	ND	ND

Quantifiers		
	J	MDL<C< PQL
	U	C < MDL

Appendix D.

Precision

Precision was calculated from duplicate measurements (e.g. WYOU-PW-A1-3/5 and WYOU-PW-A1-5/7) using the following equation

$$RPD = \frac{|(C_1 - C_2)| x 100\%}{(C_1 + C_2)/2}$$

Where:
RPD = relative percent difference
C_1 and C_2 = observed values

The range of precision was between 0.009% to 117% with a mean precision of 24.4%.

Accuracy

No matrix spikes were used so this measurement of quality assurance is not valid for this data set.

Completeness

In terms of processing the SPME fiber on site, all fiber segments were obtained and completed according to the QAPP.

Appendix B
Documentation of the Cross-Sectional Groundwater Flow Model for the Wyckoff/Eagle Harbor Superfund Site, Operable Unit 1 Focused Feasibility Study

Documentation of the Cross-Sectional Groundwater Flow Model for the Wyckoff/Eagle Harbor Superfund Site Operable Unit 1 Focused Feasibility Study

PREPARED FOR: Wyckoff Project File

PREPARED BY: From Fritz Carlson/RDD/CH2M HILL

DATE: February 24, 2014

Model Objectives

The Wyckoff OU-1 Focused Feasibility Study Project Area is affected by zones of subsurface NAPL and localized seepage to the beach at low tide. The physics of NAPL flow suggests that NAPL in a groundwater system can become mobile when the hydraulic gradient is high. The objective of the modeling is to examine the location and timing of high hydraulic gradient areas during a representative tidal cycle. Gradient changes were also evaluated for Alternative 4 of the Focused Feasibility Study (FFS) for off-shore Operable Unit OU-1, Wyckoff/Eagle Harbor Superfund Site. This alternative involves placing a vertical subsurface barrier to control lateral NAPL migration and sheening (Alternative 4). Amended carbon caps will be placed behind (shoreward) of the wall to control NAPL migration to the beach surface. To simulate groundwater conditions in the area of NAPL occurrence, a finite element cross-sectional groundwater flow model was developed. The cross section model was run on an hourly time step for representative conditions during a typical tidal cycle on December 13 and 14, 2012. These conditions represent a tidal elevation swing of more than 15 feet to capture a suitable range of gradient changes throughout the tidal cycle.

Model Geometry and Grid

The cross-section groundwater flow model was developed along the line shown on Figure B-1. A diagram of the model grid is presented on Figure B-2. The top of the model was set at the elevation of the land/beach surface based on the topography and bathymetry of the area. The model extends from 65 feet inland of the sheet pile wall between the upland and beach area, to 1,935 feet beyond the sheet pile. The model extends downward to an elevation of -277 feet Mean Lower Low Water (MLLW).

The finite element model grid was generated by MicroFEM (Hemker, 2013) using the FeMesh package that enables gridding of high contrasts in node spacing. The nodal spacing ranges from 0.1 feet in and along the sheet pile wall to 20 feet at the northeastern margin of the model. The model has 42,606 nodes and 84,437 triangular elements.

Properties of the Hydrostratigraphic Units

There are three hydrostratigraphic units in the model: the Upper Aquifer, the Lower Aquifer, and the Aquitard that separates the Upper and Lower Aquifers. These units are described in the April 2007 *Groundwater Conceptual Site Model Update Report for the Former Process Area* (CH2M HILL, 2007). In addition, the sheet pile wall is included in the model. The properties of these units are tabulated in Table B-1 below.

TABLE B-1
Hydrostratigraphic Unit Properties

Unit	Hydraulic Conductivity (feet/day)	Thickness	Kh/Kv ratio
Upper Aquifer	26	Approximately 50 feet but variable	5
Aquitard	0.2	Approximately 30 feet but variable	1
Lower Aquifer	24	200 feet	5
Sheet Pile	0.000972	3 inches	1

Kh hydraulic conductivity (horizontal)
Kv hydraulic conductivity (vertical)

The Storativity (S) assigned to each model cell by using the van der Gun equation (van der Gun 1979):

S = 0.0000018*(depth_top-depth_bottom) + 0.00086*(depth_bottom^0.3-depth_top^0.3)

Where:

Depth_top = depth to the top of the nodal area in meters
Depth bottom = depth to the bottom of the nodal area in meters
Typical values of S range from 10-4 to 10-5.

Boundary Conditions

Head boundary conditions were assigned for each hour of the simulation based on the observed water levels in two upland monitoring wells (PO03 and CDMW02, see Figure B-1) and published tidal stages for Eagle Harbor. The three zones with assigned head boundary conditions are shown in Figure B-2. Water levels measured in PO03 were assigned to the uppermost nodes on the upland part of the Wyckoff site inside the sheet pile. The fixed heads in the lower aquifer are based on the observed heads in CDMW02. The uppermost model node in the lower aquifer along the left side of the model was set at the level measured in CDMW02. The other fixed heads in the lower aquifer along the left side of the model were based on the CDMW02 head but increased under the assumption of a vertically increasing head at a gradient of 0.01605 feet/foot. This means that the fixed head at the bottom left hand corner of the model would be 3.21 feet higher than the measured head in CDMW02. The assumed increase in head with depth in the Lower Aquifer is based on past regional modeling results from the Wyckoff site.

Along the top of the model beyond the sheet pile wall, two types of boundary conditions are possible. In areas where the elevation of the model node is higher than the tide, groundwater can only leave the model domain, not enter the domain. This type of “one-way” boundary is implemented in MicroFEM as a drain. In areas where the elevation of the model is below the tide elevation, it is possible for groundwater to enter or leave the model depending on the local hydraulic gradient. This type of “two-way” boundary is implemented as a river boundary condition in MicroFEM. The determination of whether nodes at the top of the model are “drains” (out only) or “rivers” (in or out) is based on the tidal stage at a given time step.

The model simulates the groundwater conditions for typical representative tidal cycle between December 13, 2012 at 10:00 hours to December 14, 2012 at 15:00 hours. The measured groundwater levels and tidal stages during this period are tabulated below in Table B-2.

TABLE B-2
Boundary Head Elevations

Date and Time (Hours)	Tide Elevation in Feet	Well CDMW02 Elevation in Feet (Lower Aquifer)	Well PO03 Elevation in Feet (Upper Aquifer)
December 13, 2012 10:00	7.364	10.76012	8.22
11:00	7.272	10.53393	8.21
12:00	8.194	10.68019	8.20
13:00	9.539	11.10812	8.19
14:00	10.976	11.67806	8.18
15:00	12.167	12.2599	8.18
16:00	12.38	12.56923	8.17
17:00	11.344	12.4139	8.17
18:00	9.293	11.79628	8.17
19:00	6.255	10.74581	8.15
20:00	2.669	9.451739	8.13
21:00	-0.431	8.244172	8.11
22:00	-2.708	7.417347	8.09
23:00	-3.122	6.969096	8.07
December 14, 2012 0:00	-1.56	6.872412	8.05
1:00	1.065	7.183316	8.03
2:00	4.467	8.109916	8.01
3:00	7.748	9.396482	8.00

All elevations are referenced to MLLW.

Model Output

The model was run for three different conditions:

1. Base case condition with no new features;
2. Alternative 4 condition with a vertical barrier 15 feet deep placed 100 feet seaward of the sheet pile wall; and
3. Alternative 4 condition with vertical barrier and a 0.3 feet/day cap placed between the sheet pile and the vertical barrier.

During each model run, the simulated groundwater levels and hydraulic gradient at all the model nodes are saved. These results are processed in the program “Surfer” using a script. The results are presented graphically on the attached Tidal Time Step Model Simulation Cross-Sections, with water level contours, color mapping of the hydraulic gradient, flow vectors and tidal stages.

References

CH2M HILL. 2007. *Groundwater Conceptual Site Model Update Report for the Former Process Area*. Prepared for the U.S. Environmental Protection Agency. April.

Hemker, C.J. 2013. MicroFEM Version 4.10.59 for Windows. Available at http://www.microfem.com/. Hemker Geohydroloog Amsterdam, Elandsgracht 83, 1016 TR Amsterdam.

Gun, J.A.M. van der. 1979. Schatting van de elastische bergingscoefficient van zandige watervoerende pakketten. TNO Jaarverslag 1979: 51-61.

Figures

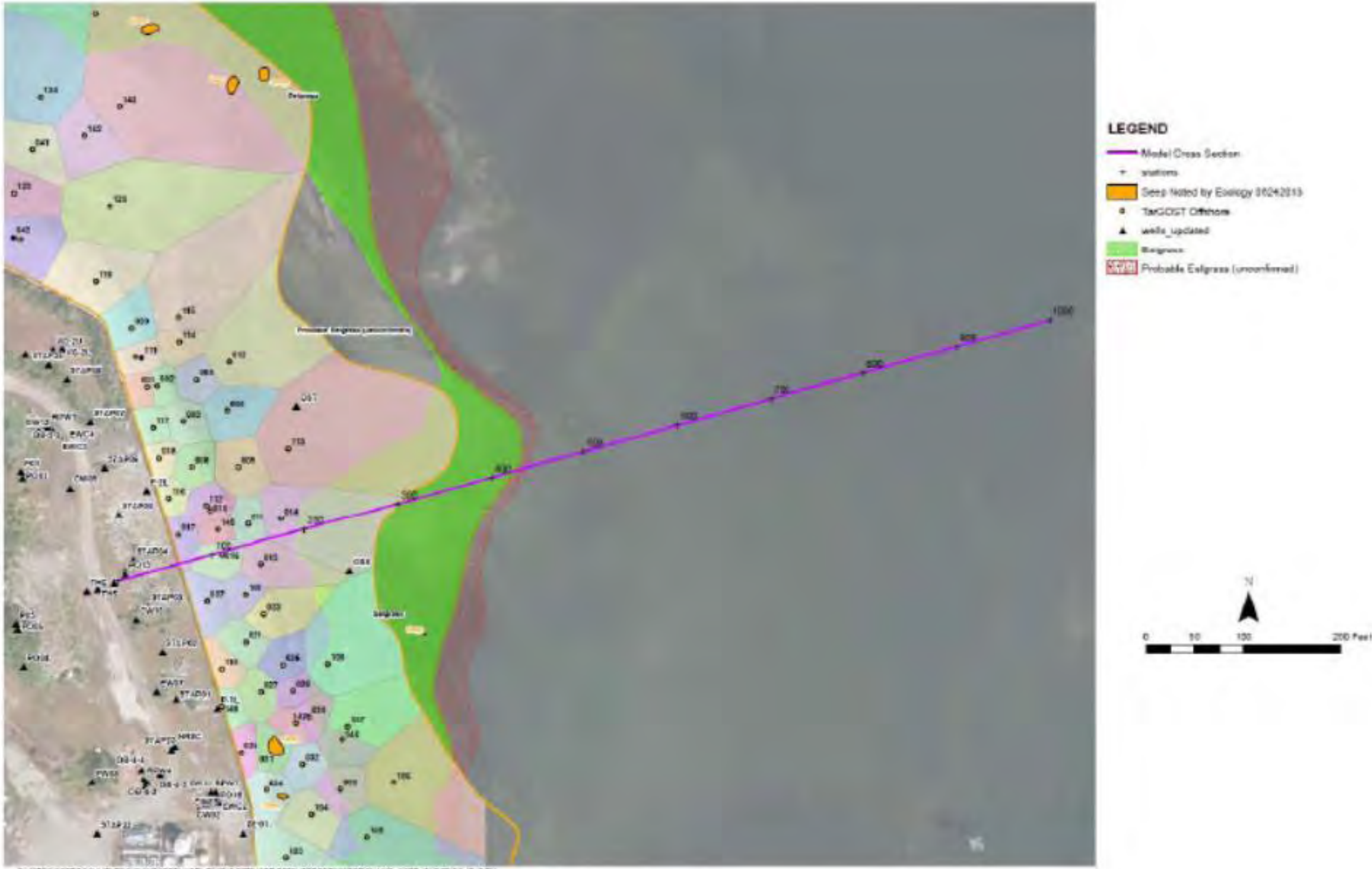


Figure B-1
Cross Section Location
Wyckoff OU-1 Focused Feasibility Study

Wyckoff Cross Section Groundwater Model

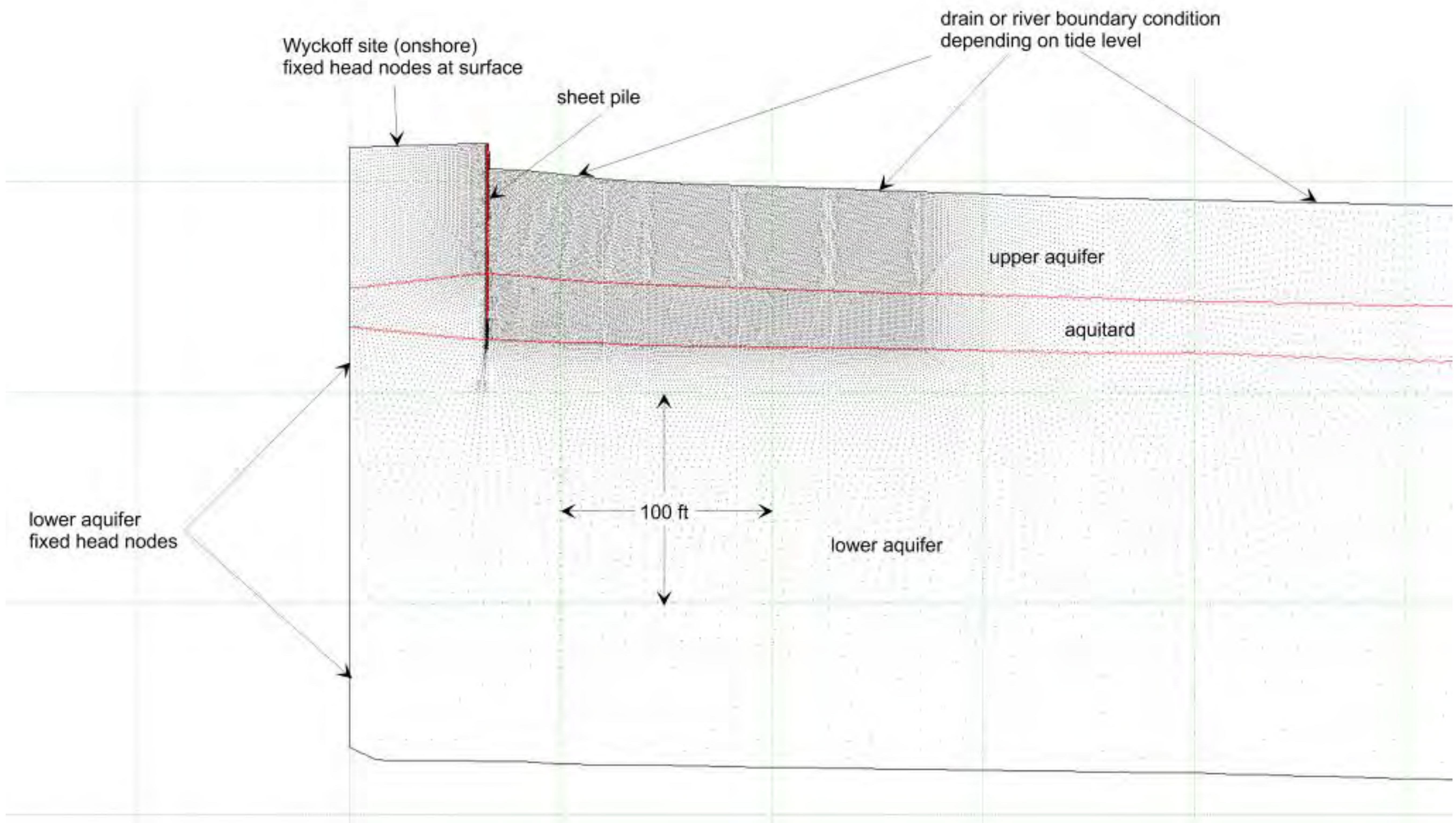


Figure B-2
Cross Section Groundwater Model
Wyckoff OU-1 Focused Feasibility Study

Tides and Groundwater Levels – 12/13/12 through 12/14/12

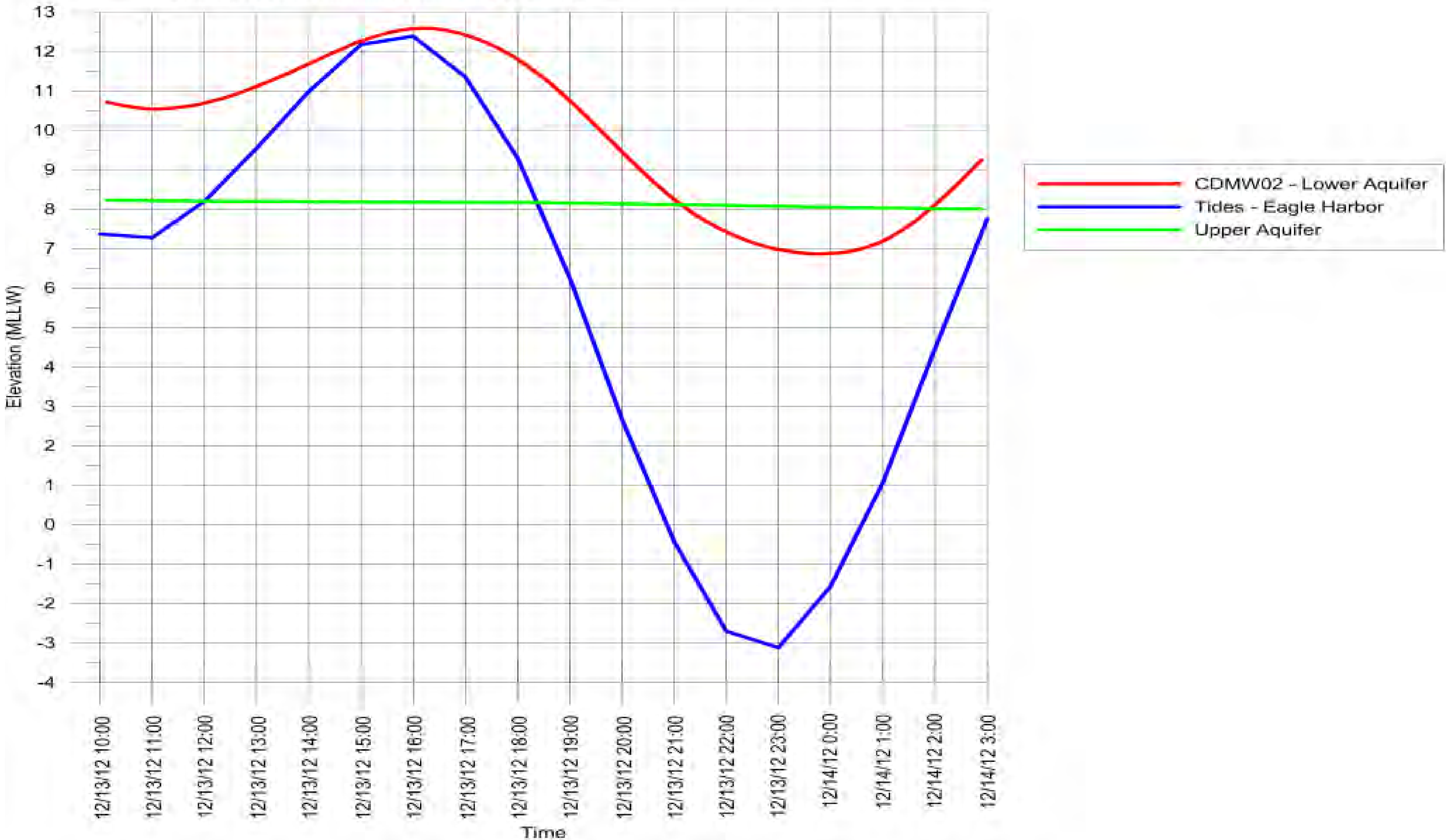


Figure B-3
Tides and Groundwater Levels with Time during Model Simulation
Wyckoff OU-1 Focused Feasibility Study

Simulated Head and Hydraulic Gradient at 1000 hrs on 12/13/2012 - Basecase

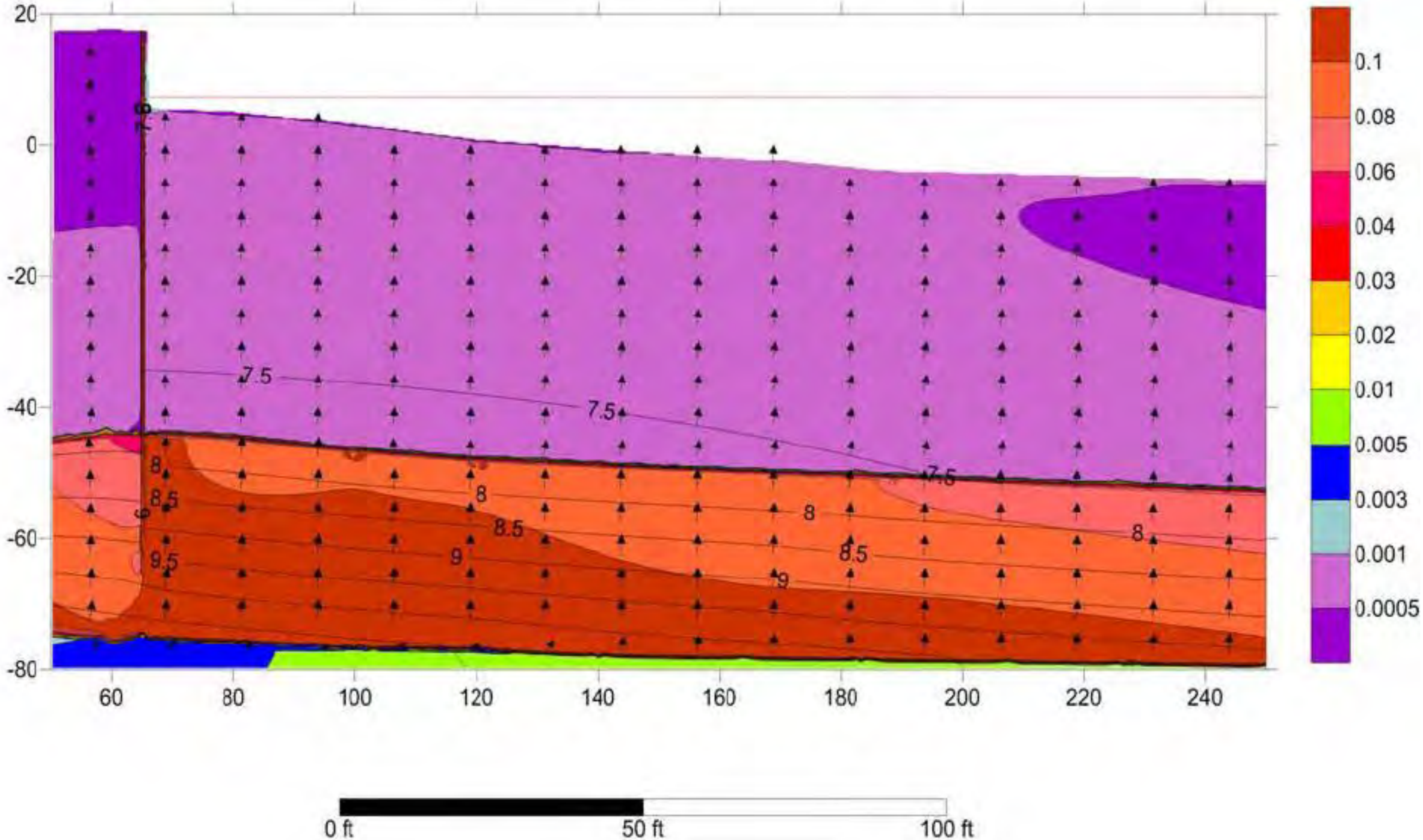


Figure B-4
Basecase Simulation at 1000 Hours
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 1000 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall

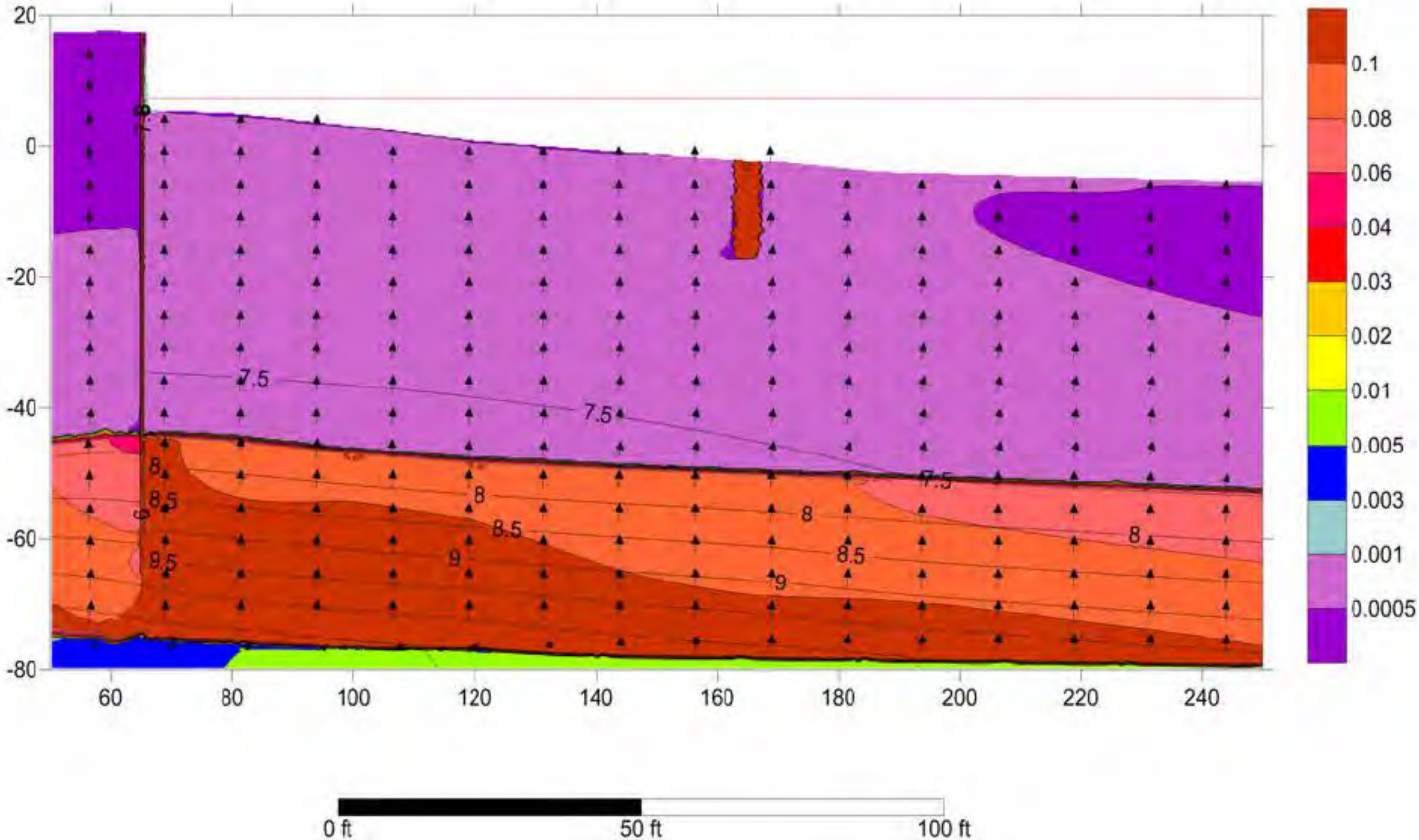


Figure B-5
Vertical Barrier Simulation at 1000 Hrs
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 1000 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall – 0.3 ft/day Cap

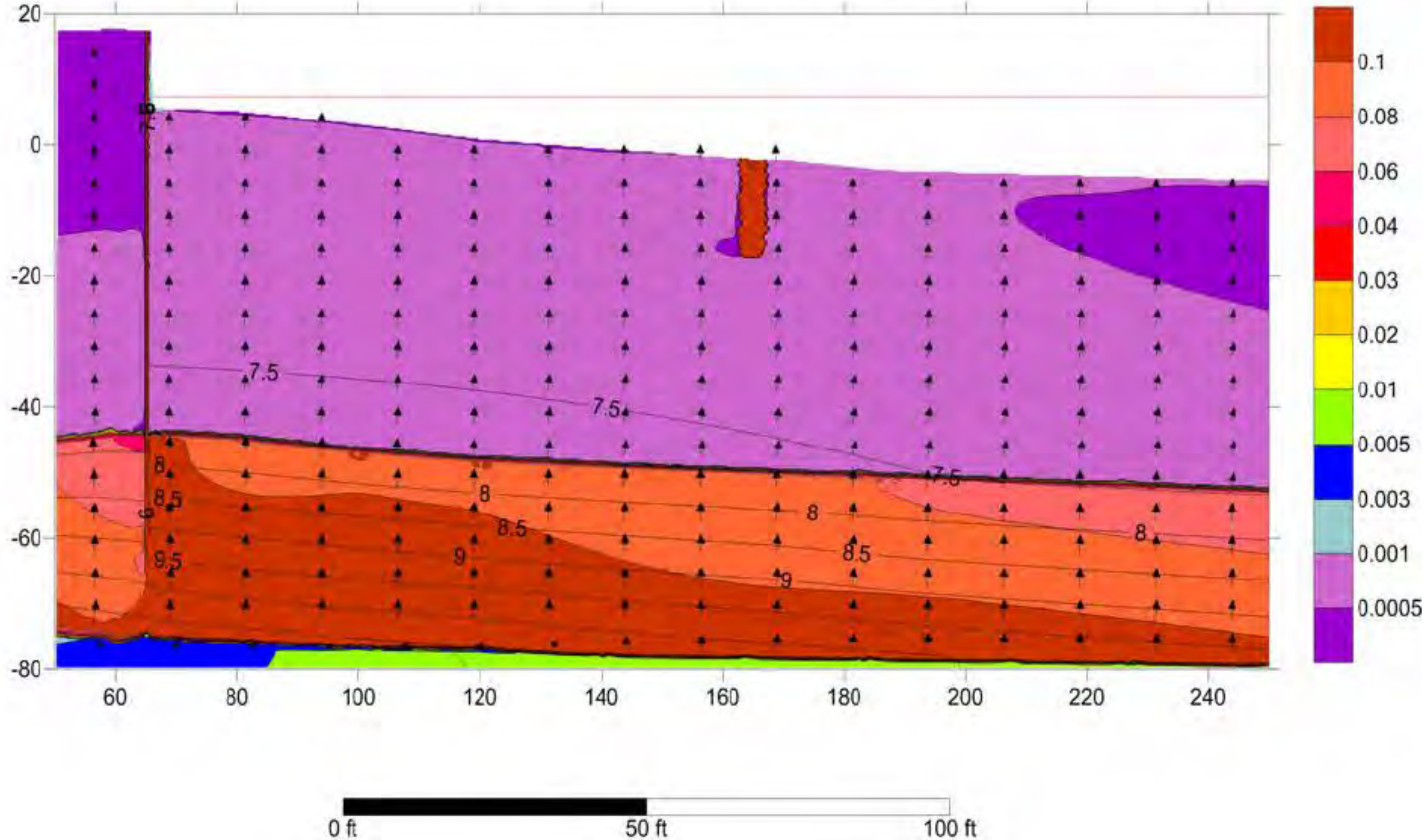


Figure B-6
Vertical Barrier plus Capping Simulation at 1000 Hrs
Wyckoff OU-1 Focused Feasibility Study

Simulated Head and Hydraulic Gradient at 1100 hrs on 12/13/2012 - Basecase

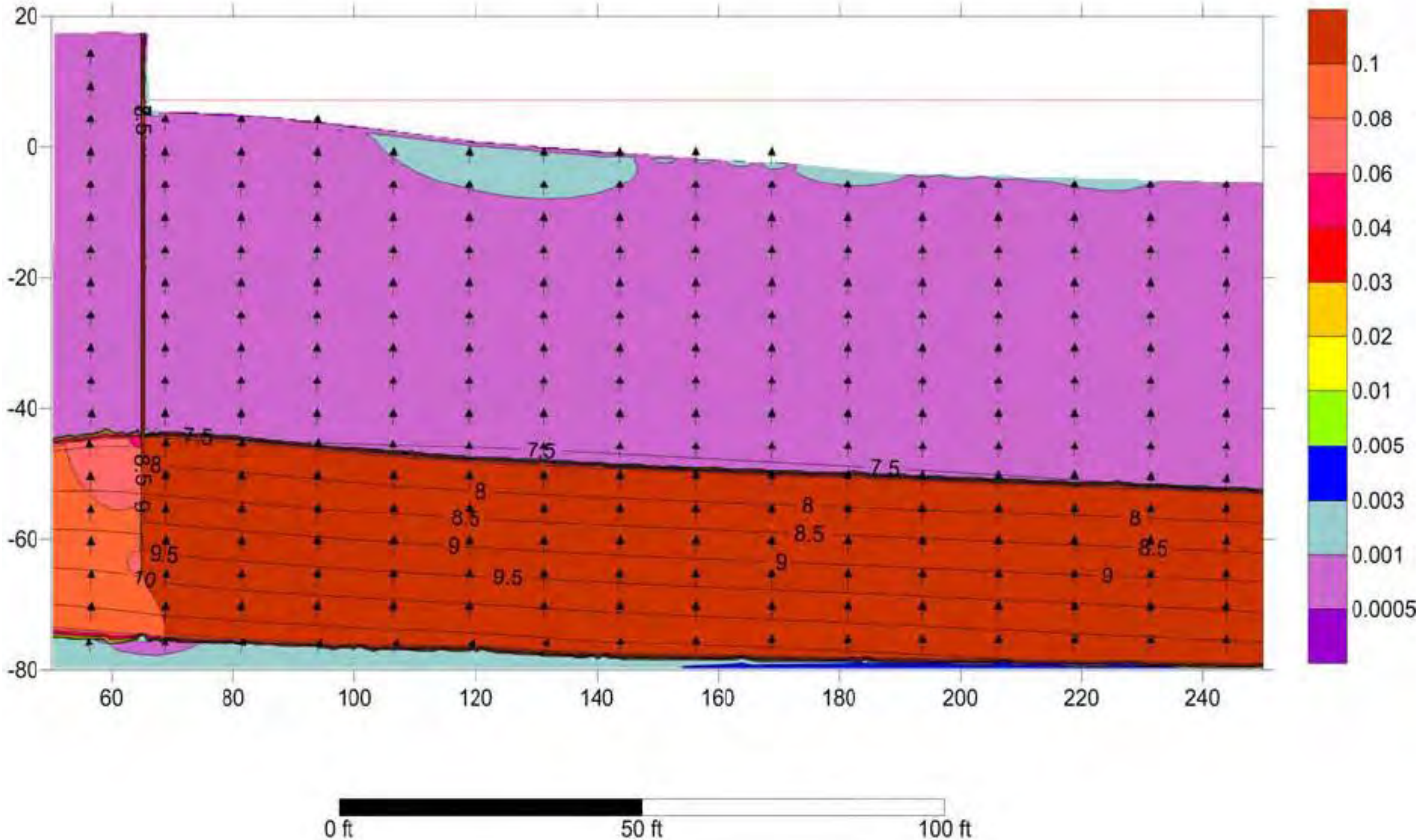
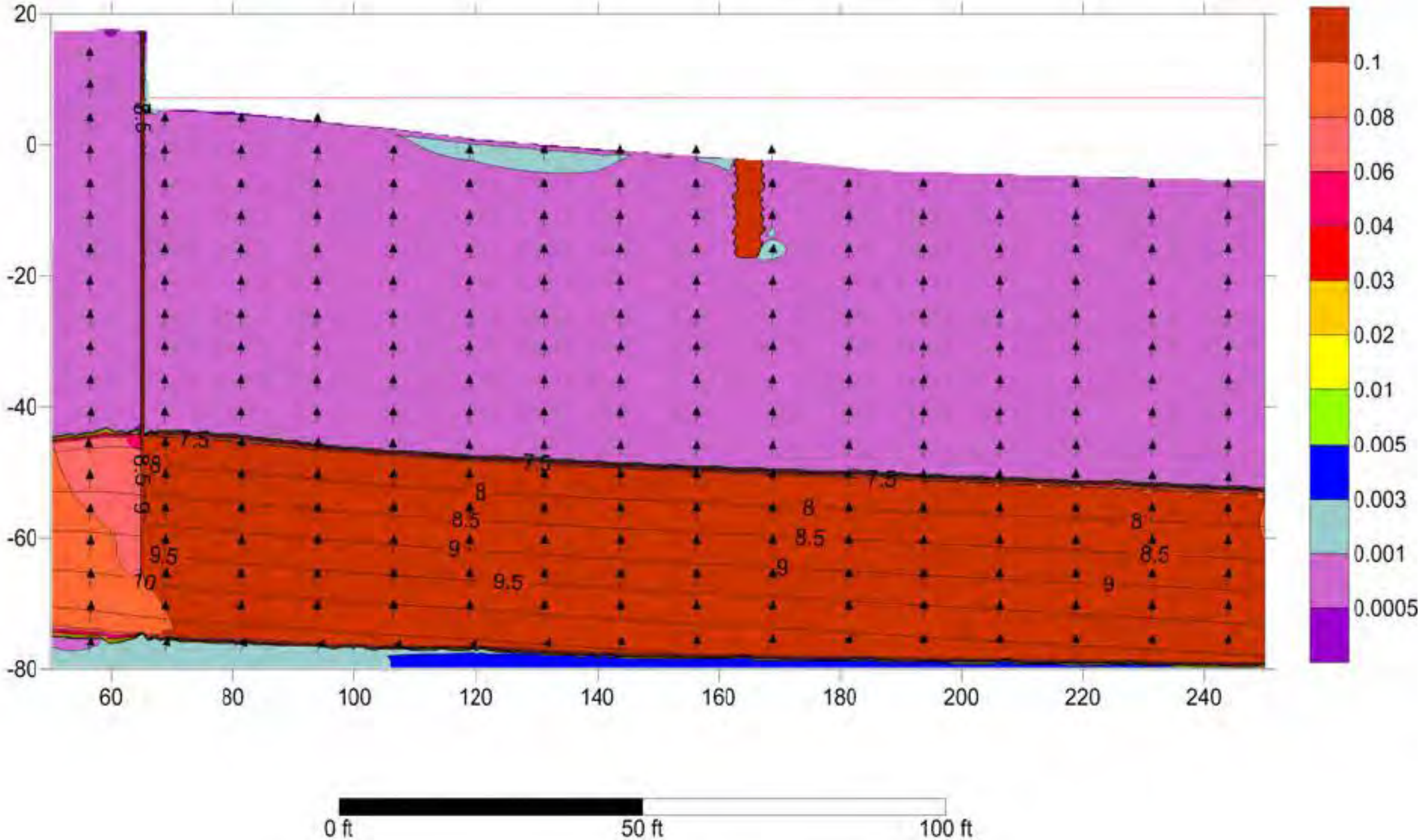


Figure B-7
Basecase Simulation at 1100 Hours
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 1100 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall



FigureB-8
Vertical Barrier Simulation at 1100 Hrs
Wyckoff OU-1 Focused Feasibility Study

Simulated Head and Hydraulic Gradient at 1100 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall – 0.3 ft/day Cap

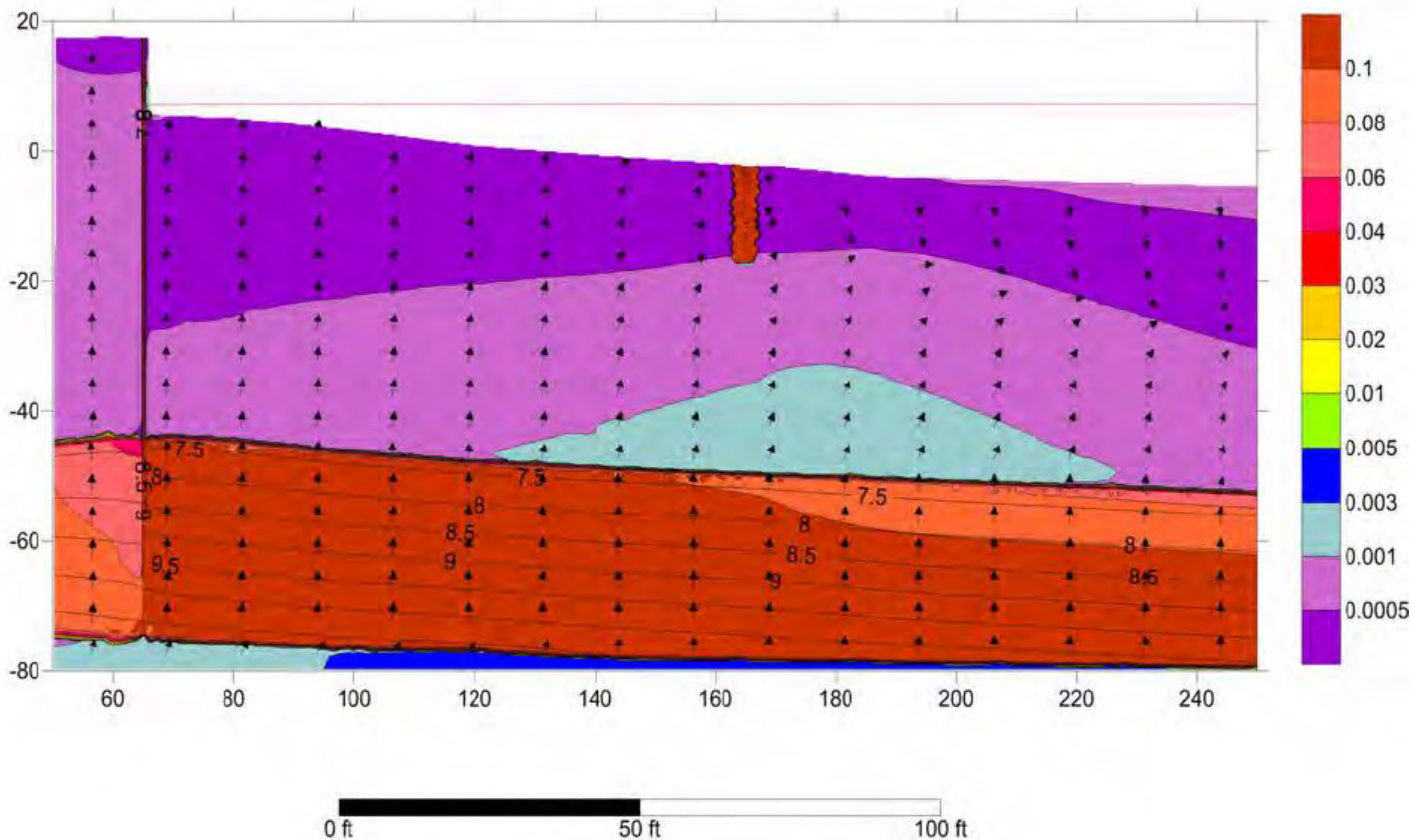


Figure B-9
Vertical Barrier plus Capping Simulation at 1100 Hrs
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 1200 hrs on 12/13/2012 - Basecase

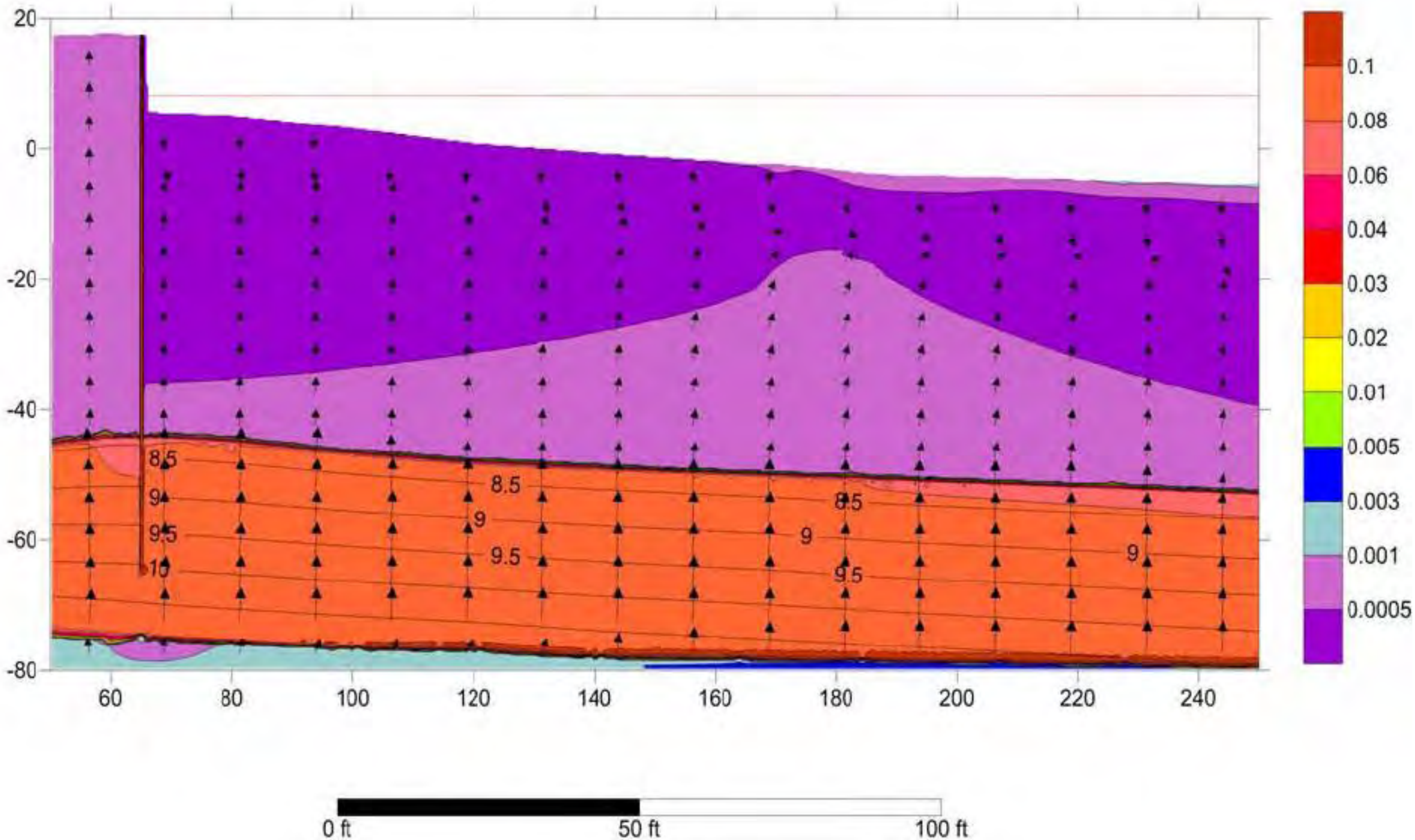


Figure B-10
Basecase Simulation at 1200 Hours *Wyckoff OU-1 Focused Feasibility Study*

Simulated Head and Hydraulic Gradient at 1200 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall

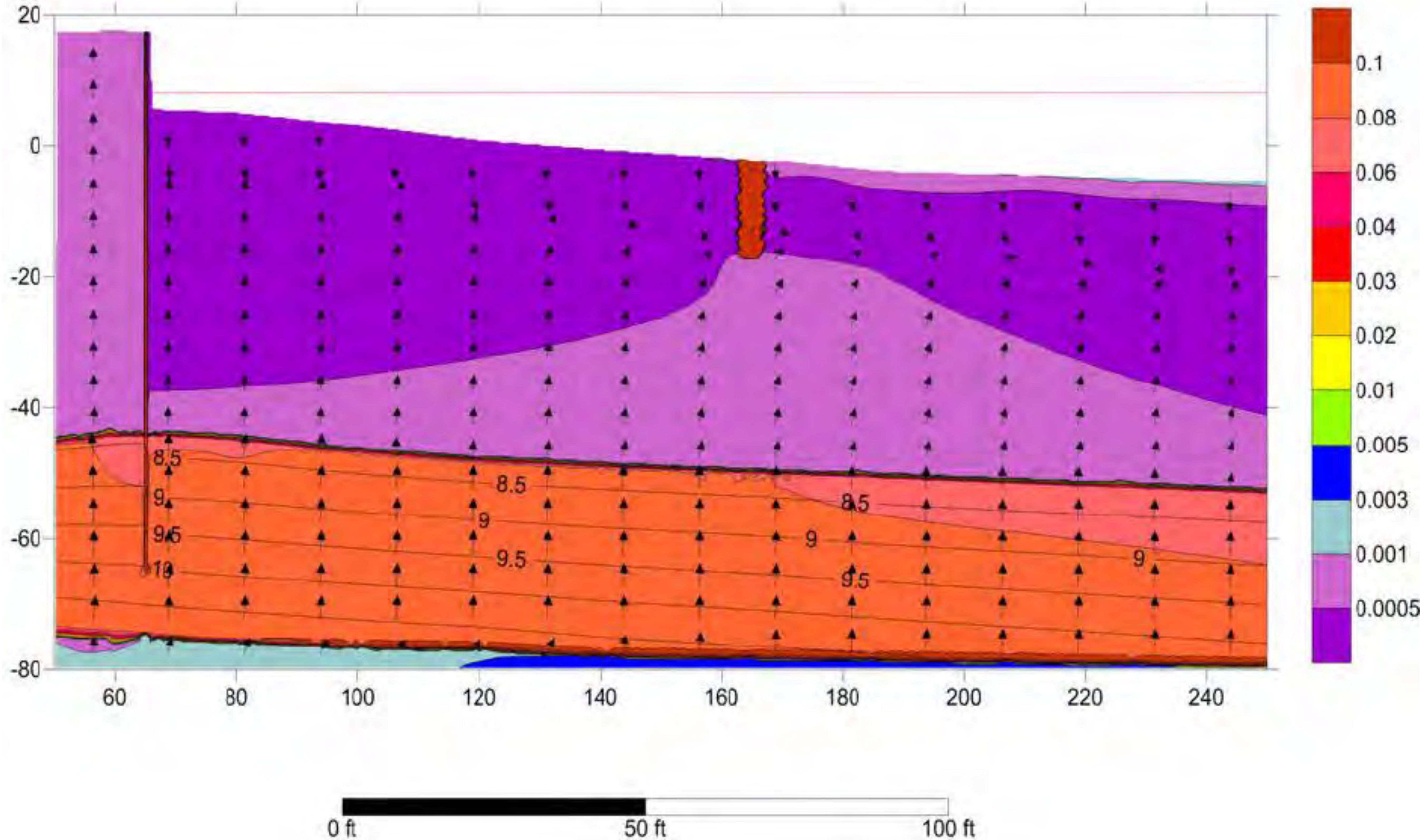


Figure B-11
Vertical Barrier Simulation 1200 Hrs
Wyckoff OU-1 Focused Feasibility Study

Simulated Head and Hydraulic Gradient at 1200 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall – 0.3 ft/day Cap

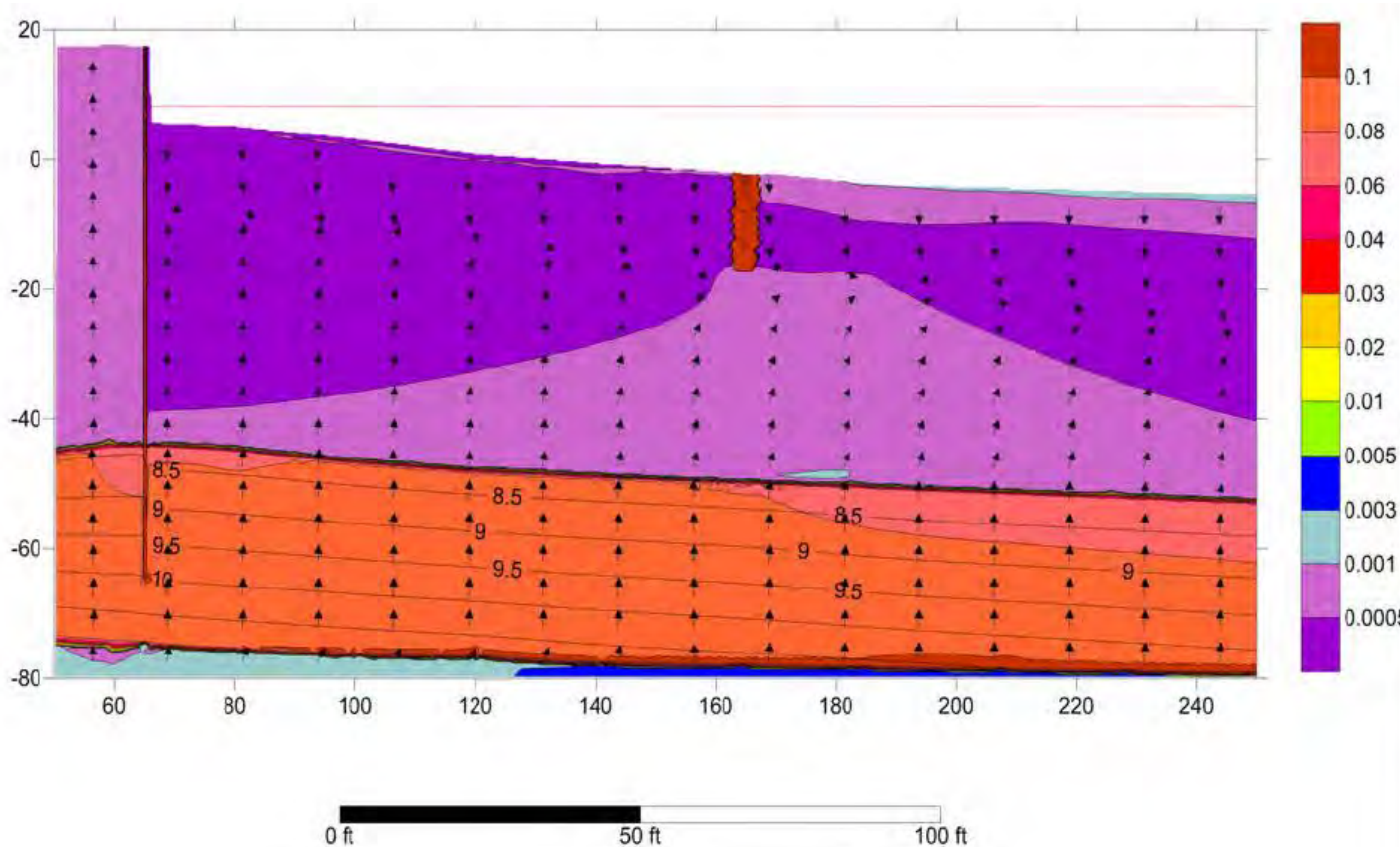


Figure B-12
Vertical Barrier plus Capping Simulation 1200 Hrs
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 1300 hrs on 12/13/2012 - Basecase

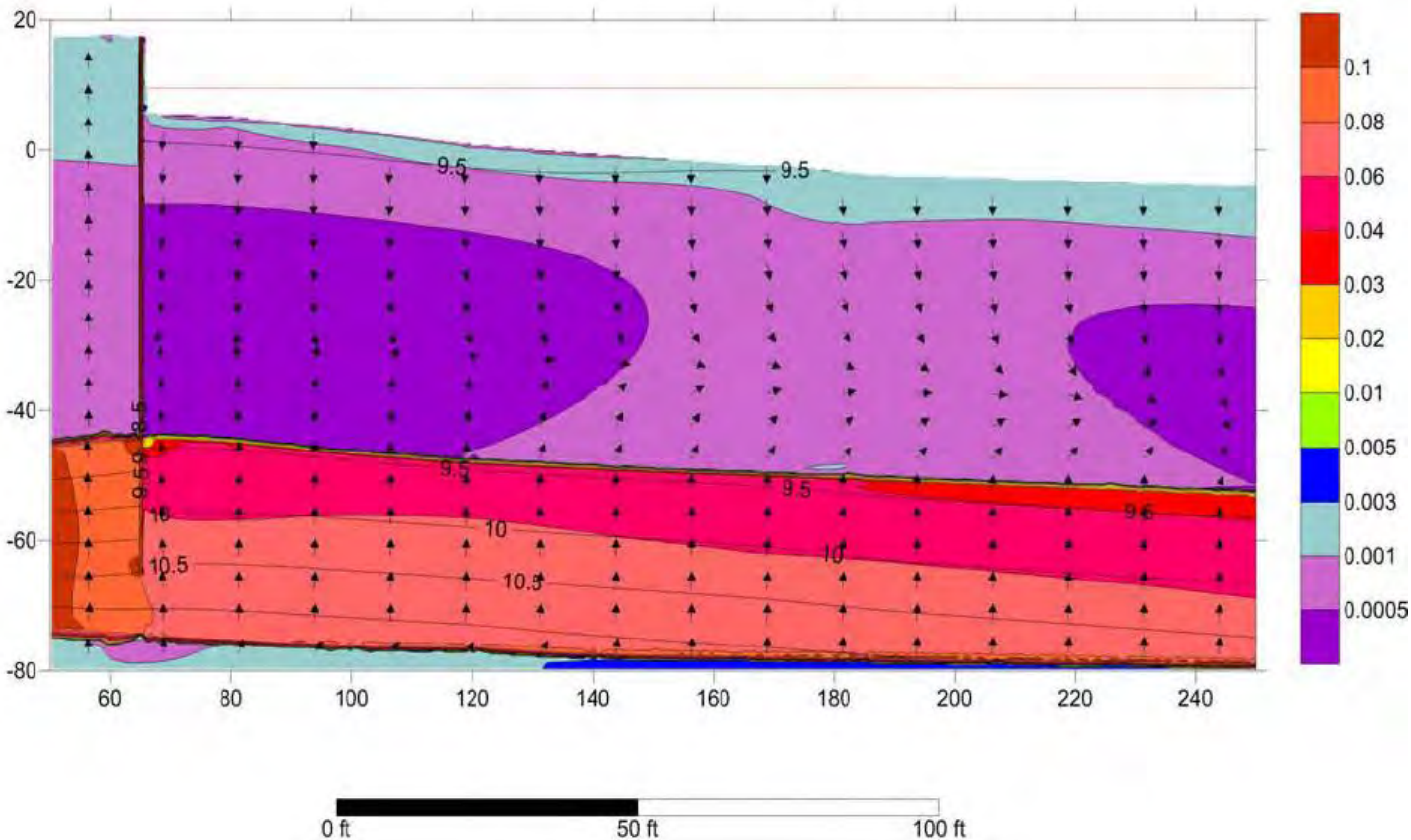


Figure B-13
Basecase Simulation at 1300 Hours
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 1300 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall

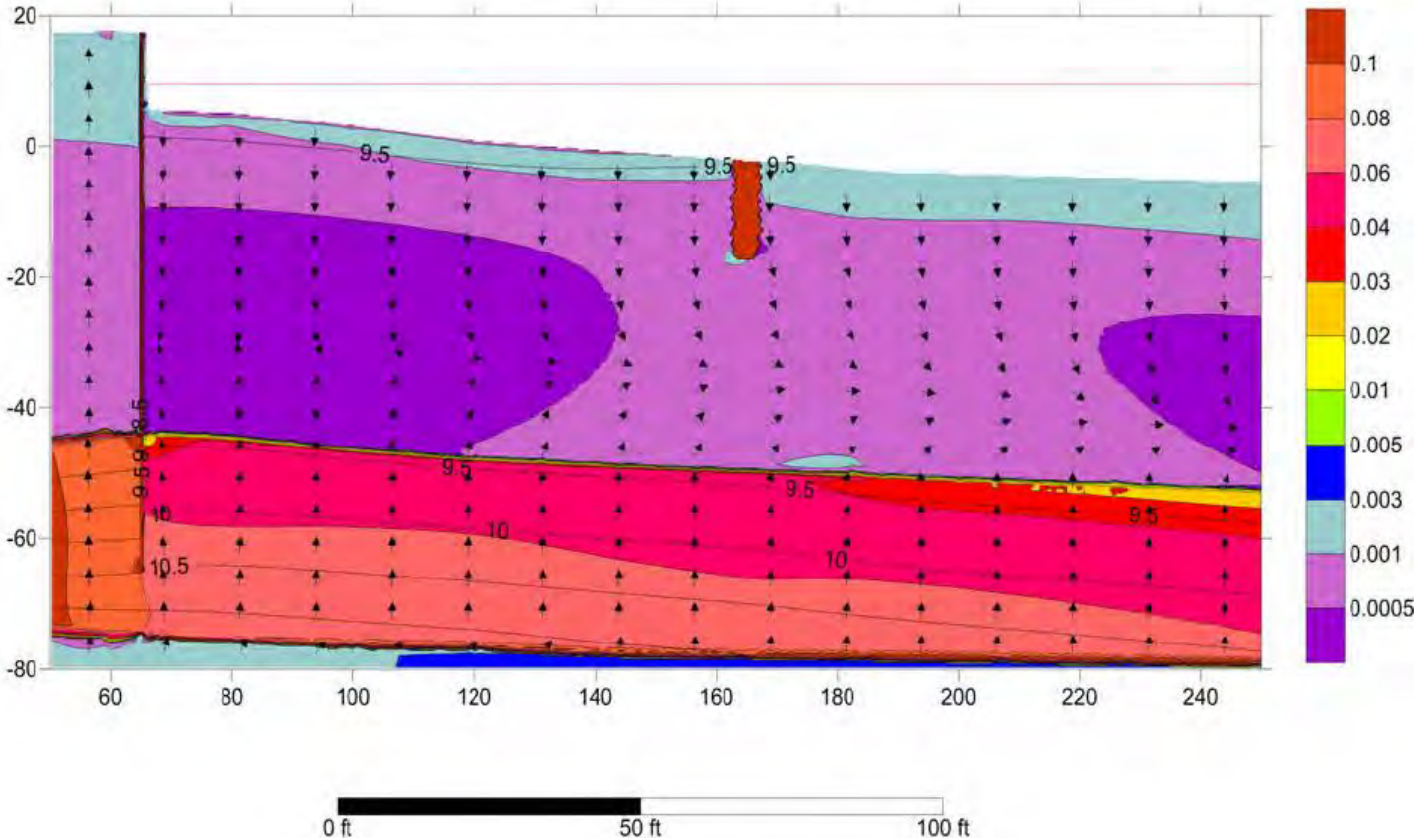


Figure B-14
Vertical Barrier Simulation 1300 Hrs
Wyckoff OU-1 Focused Feasibility Study

Simulated Head and Hydraulic Gradient at 1300 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall – 0.3 ft/day Cap

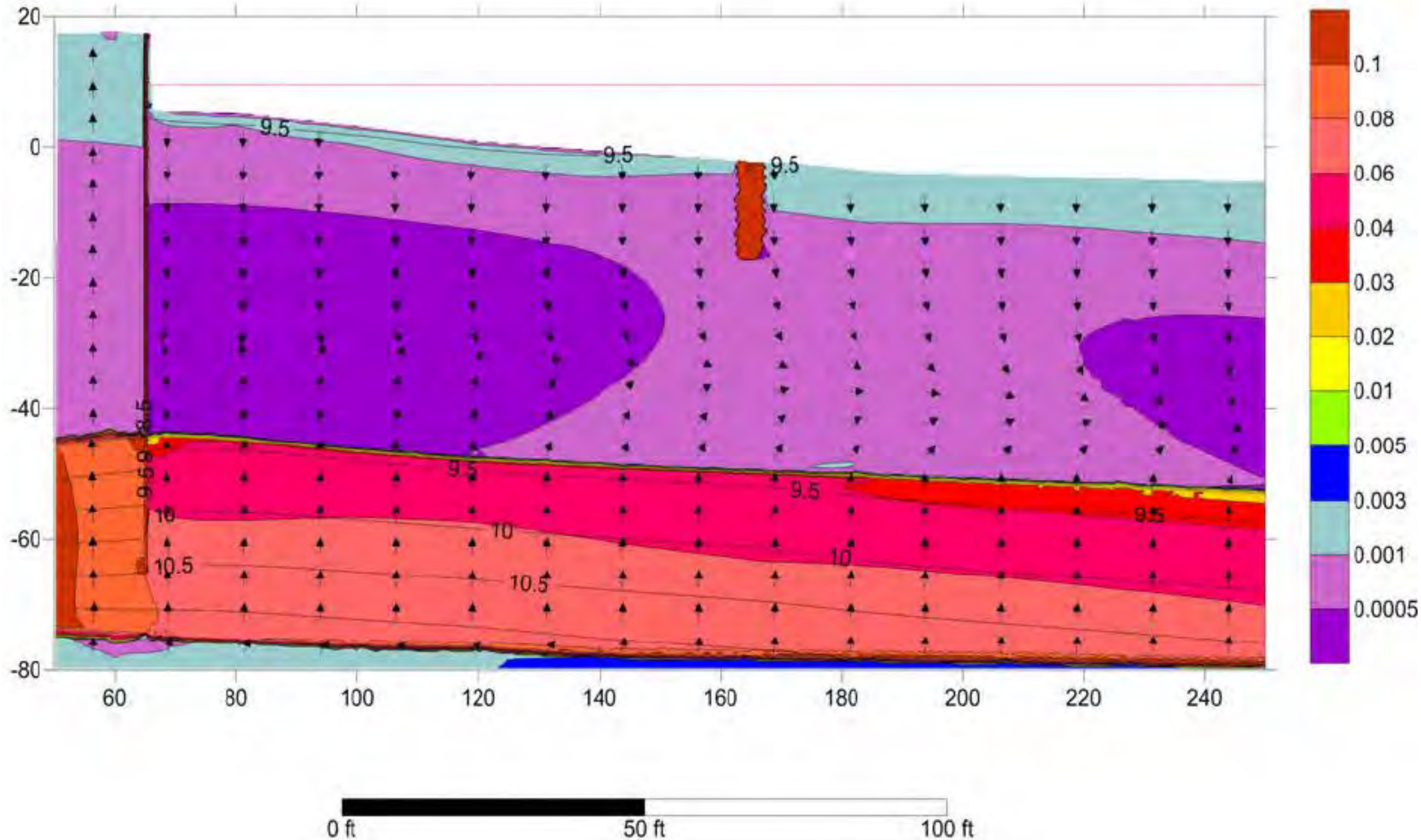


Figure B-15
Vertical Barrier plus Capping Simulation 1300 Hrs
Wyckoff OU-1 Focused Feasibility Study

Simulated Head and Hydraulic Gradient at 1400 hrs on 12/13/2012 - Basecase

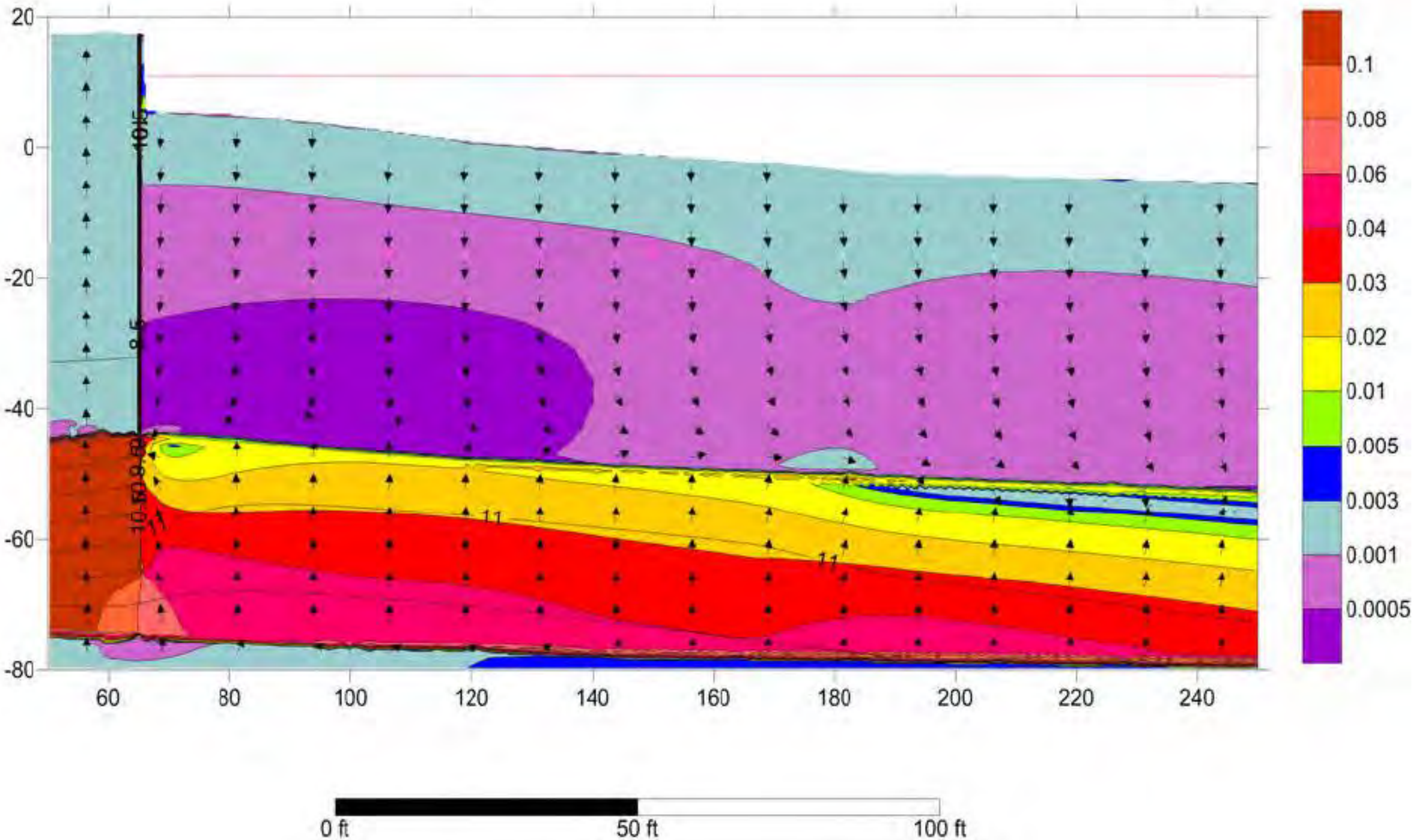


Figure B-16
Basecase Simulation at 1400 Hours
Wyckoff OU-1 Focused Feasibility Study

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Simulated Head and Hydraulic Gradient at 1400 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall

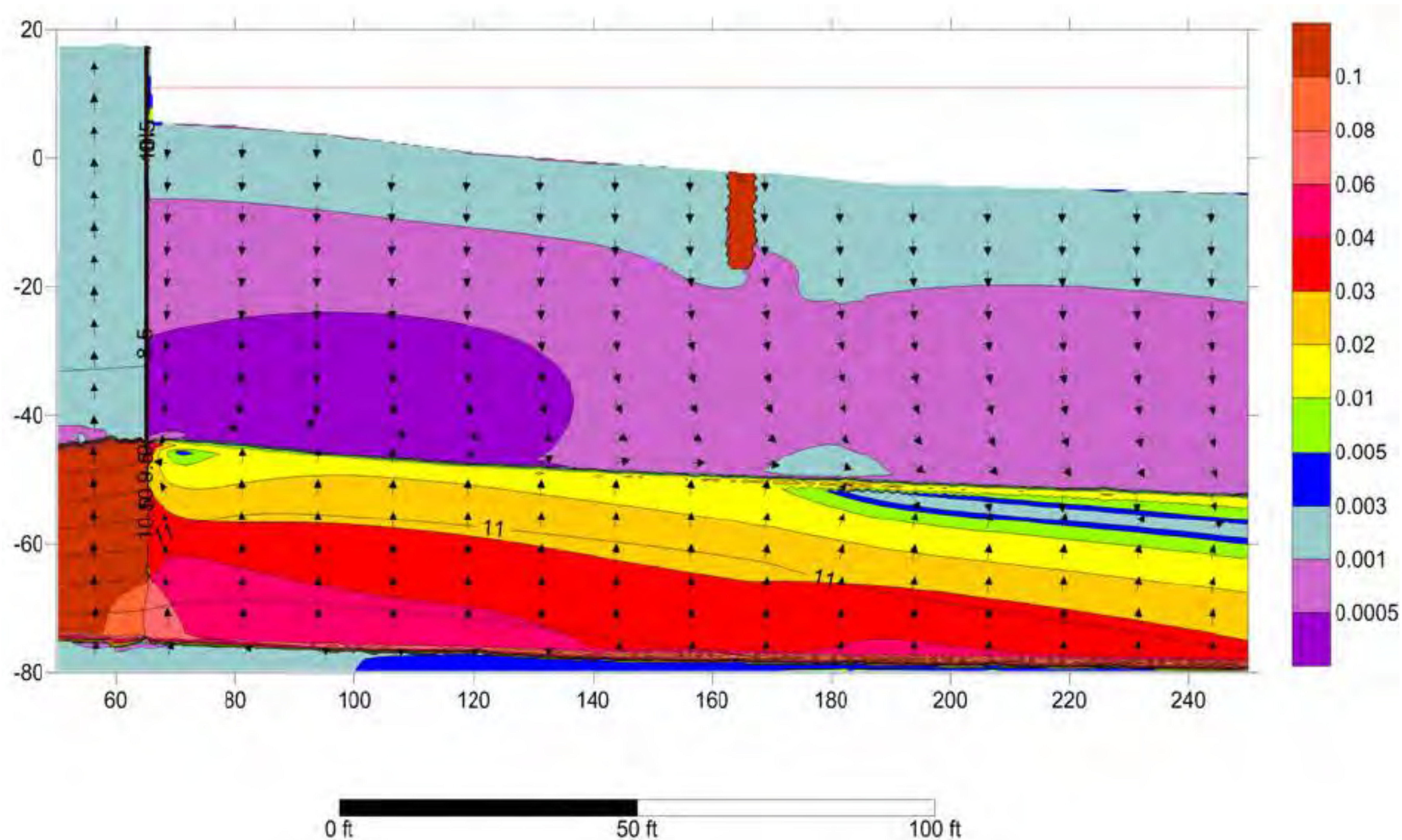


Figure B-17
Vertical Barrier Simulation 1400 Hrs
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 1400 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall – 0.3 ft/day Cap

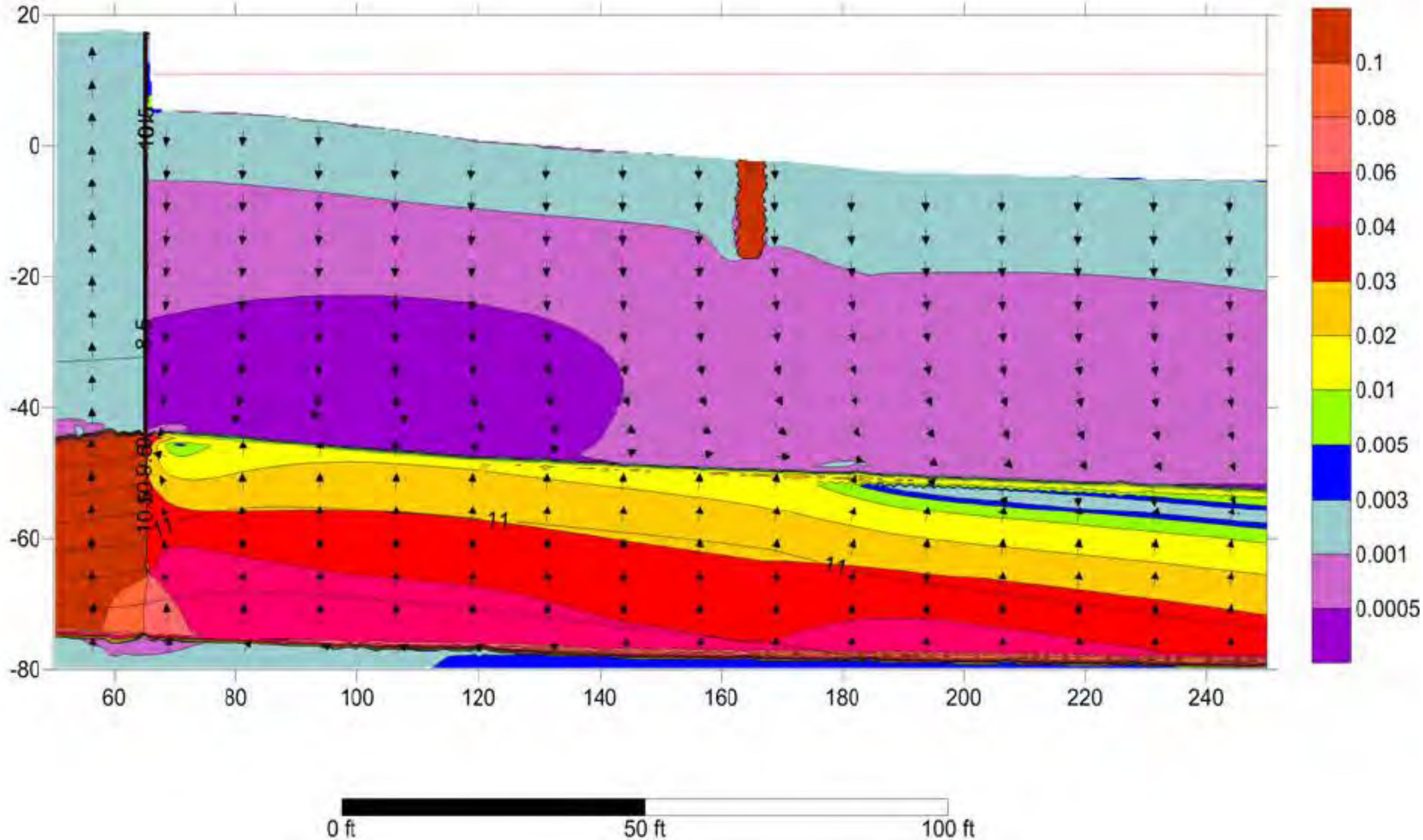


Figure B-18
Vertical Barrier plus Capping Simulation 1400 Hrs
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 1500 hrs on 12/13/2012 - Basecase

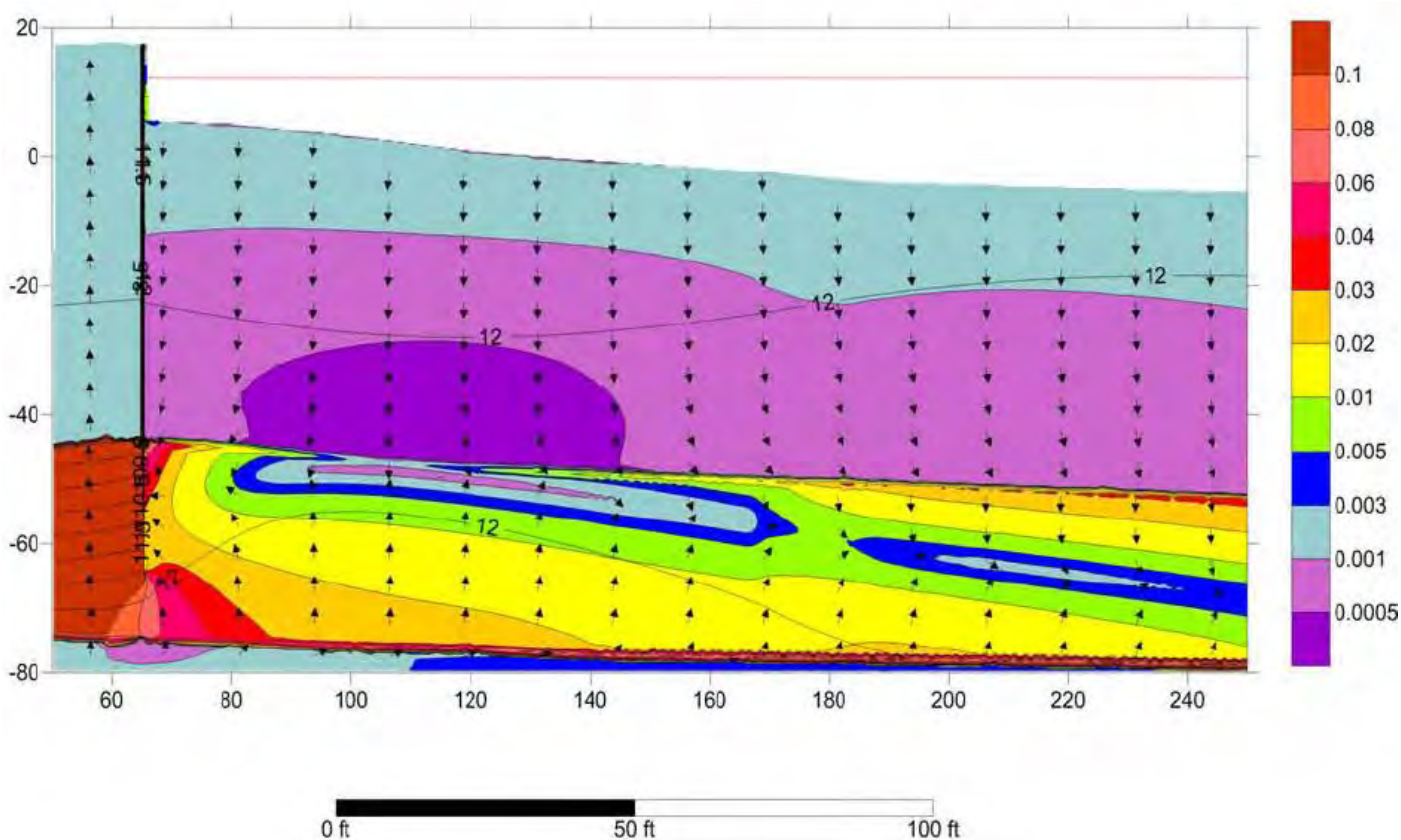


Figure B-19
Basecase Simulation at 1500 Hours
Wyckoff OU-1 Focused Feasibility Study

Simulated Head and Hydraulic Gradient at 1500 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall

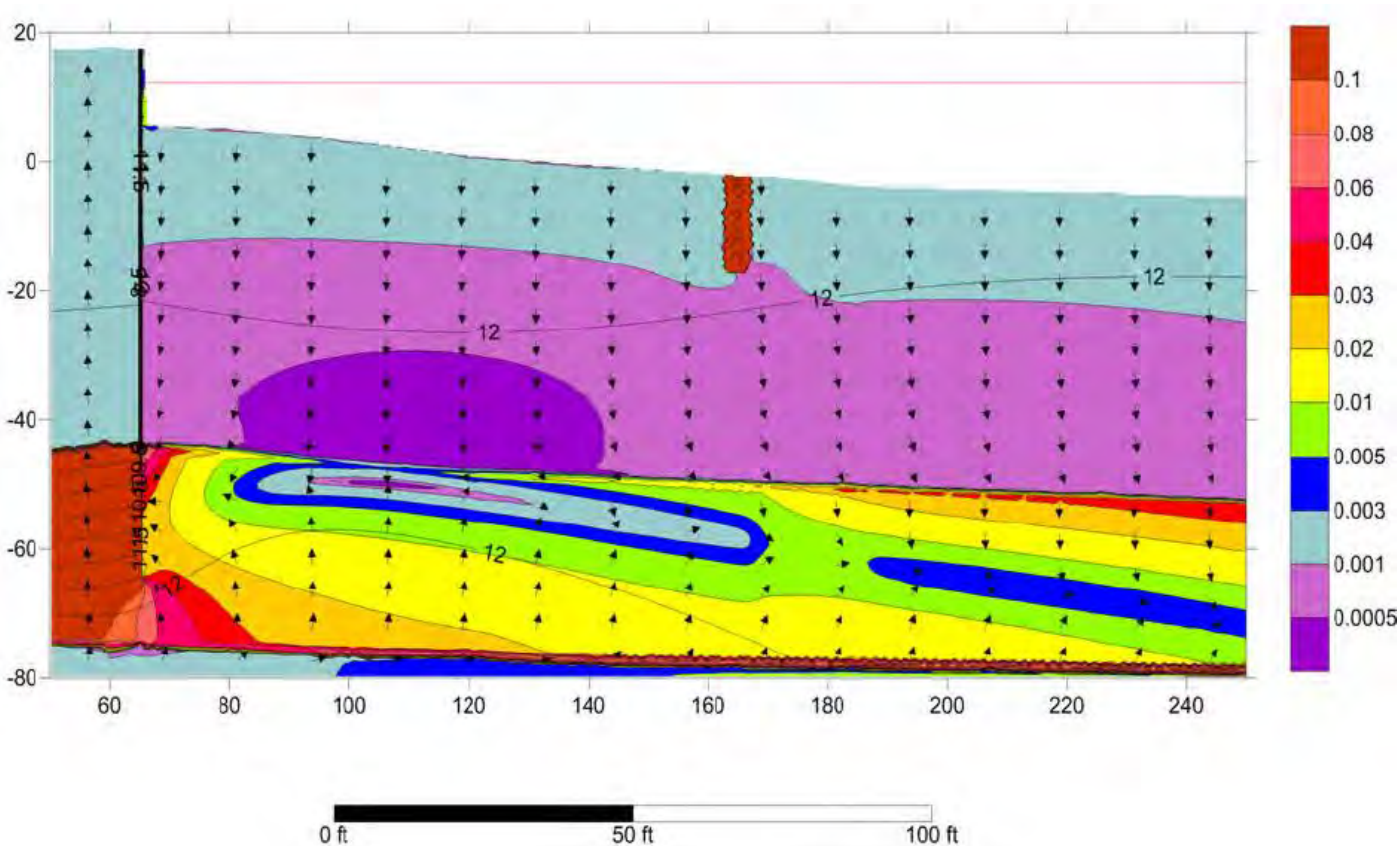


Figure B-20
Vertical Barrier Simulation 1500 Hrs
Wyckoff OU-1 Focused Feasibility Study

Simulated Head and Hydraulic Gradient at 1500 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall – 0.3 ft/day Cap

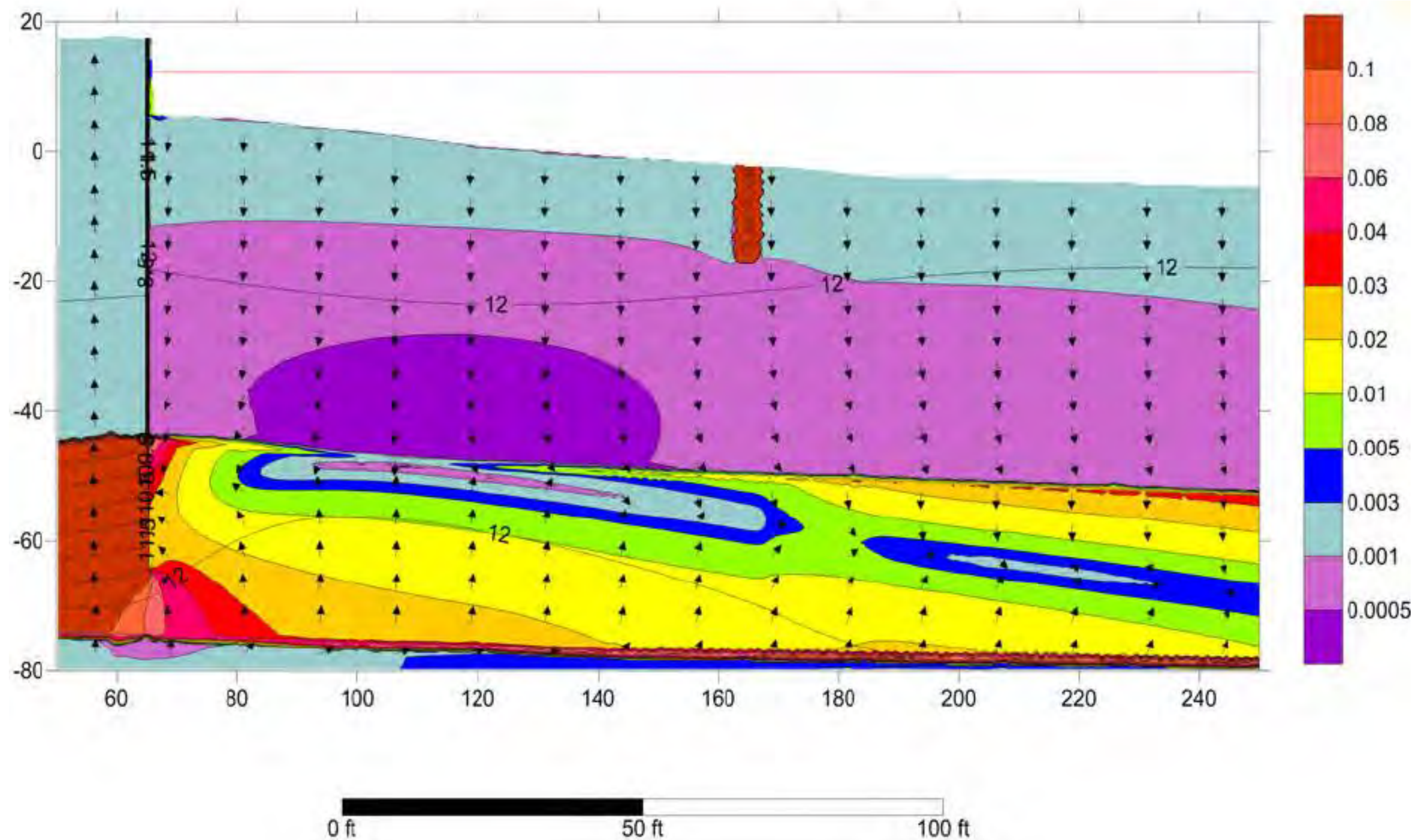


Figure B-21
Vertical Barrier plus Capping Simulation 1500 Hrs
Wyckoff OU-1 Focused Feasibility Study

Simulated Head and Hydraulic Gradient at 1600 hrs on 12/13/2012 - Basecase

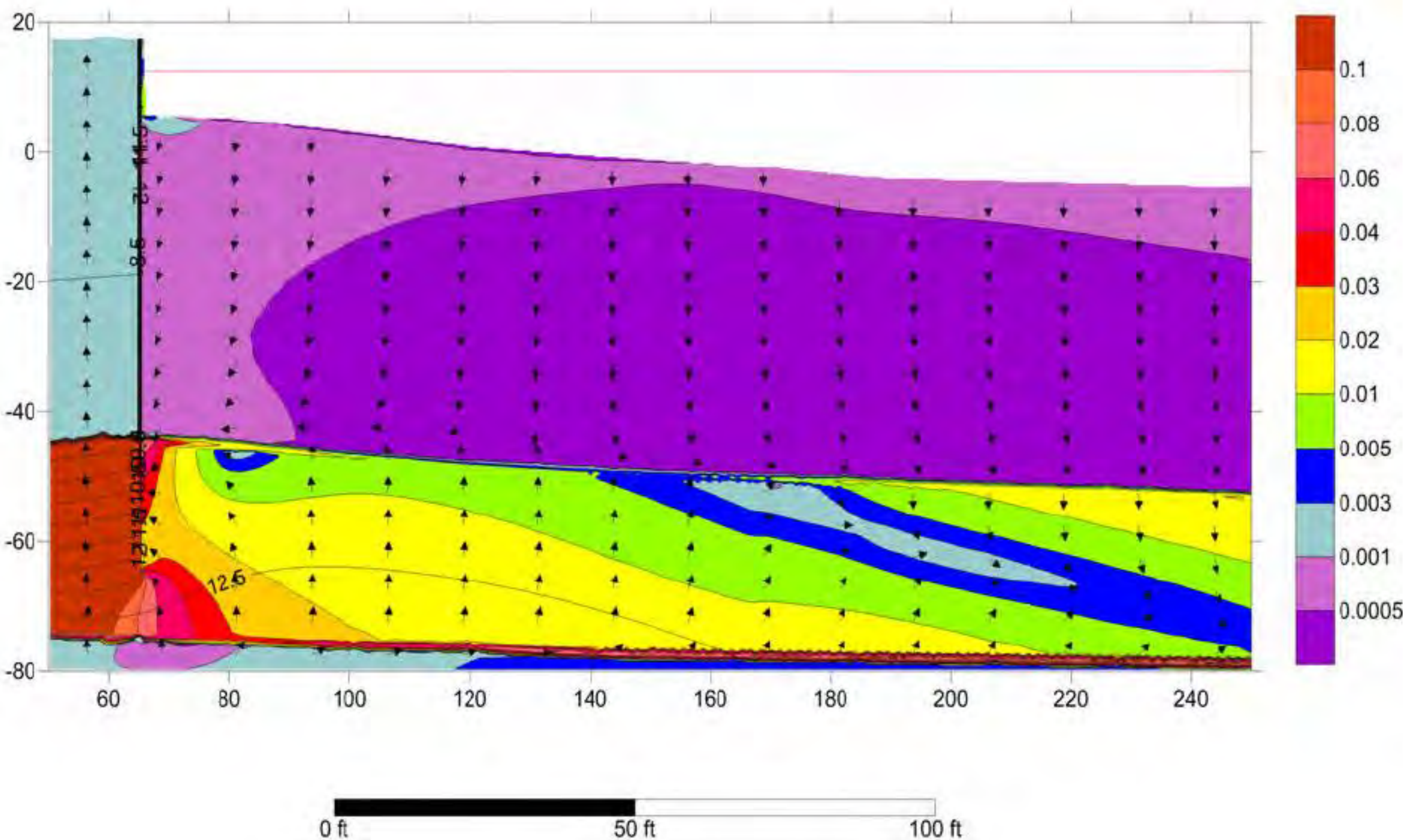


Figure B-22
Basecase Simulation at 1600 Hours
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 1600 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall

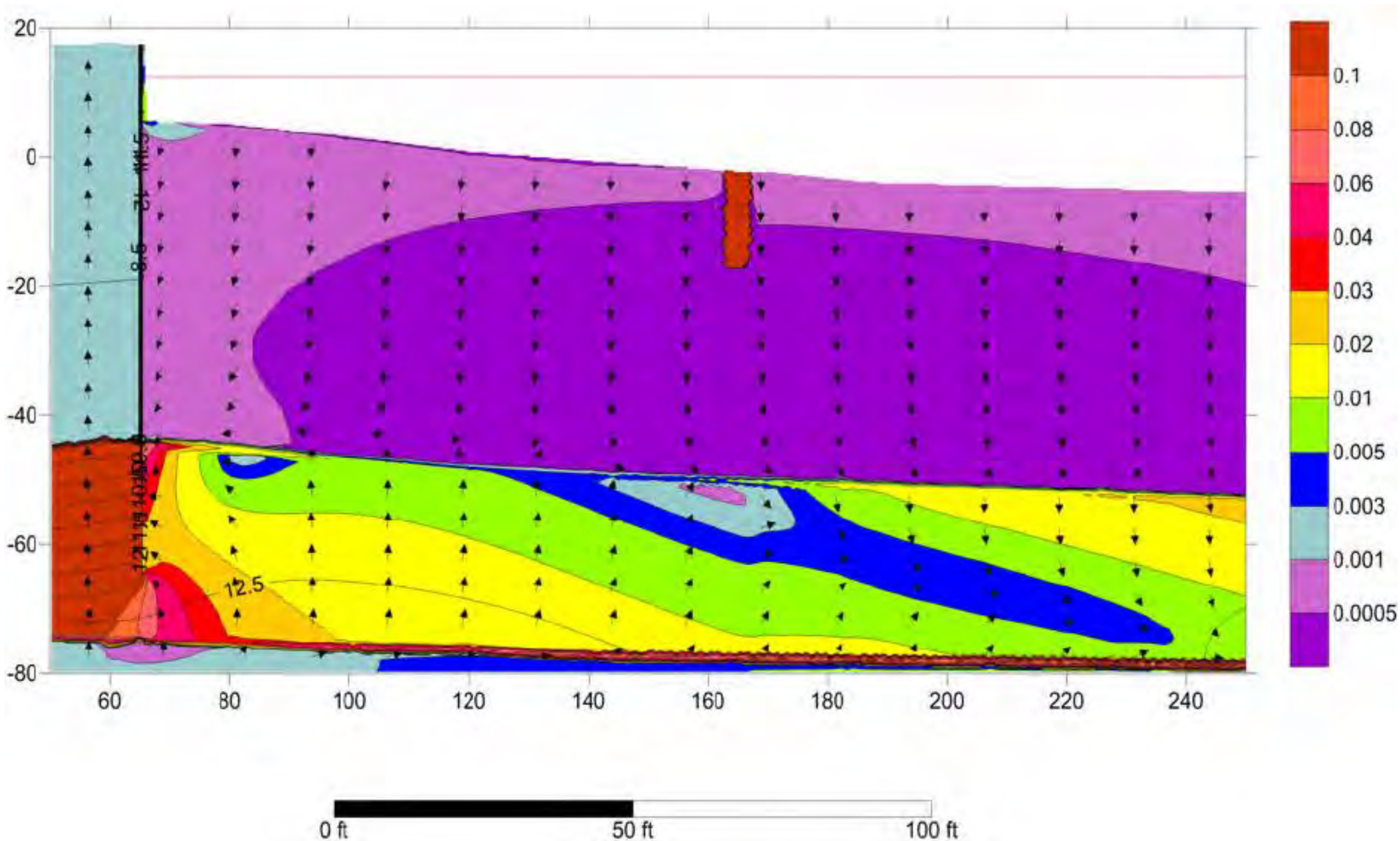


Figure B-23
Vertical Barrier Simulation 1600 Hrs
Wyckoff OU-1 Focused Feasibility Study

Simulated Head and Hydraulic Gradient at 1600 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall – 0.3 ft/day Cap

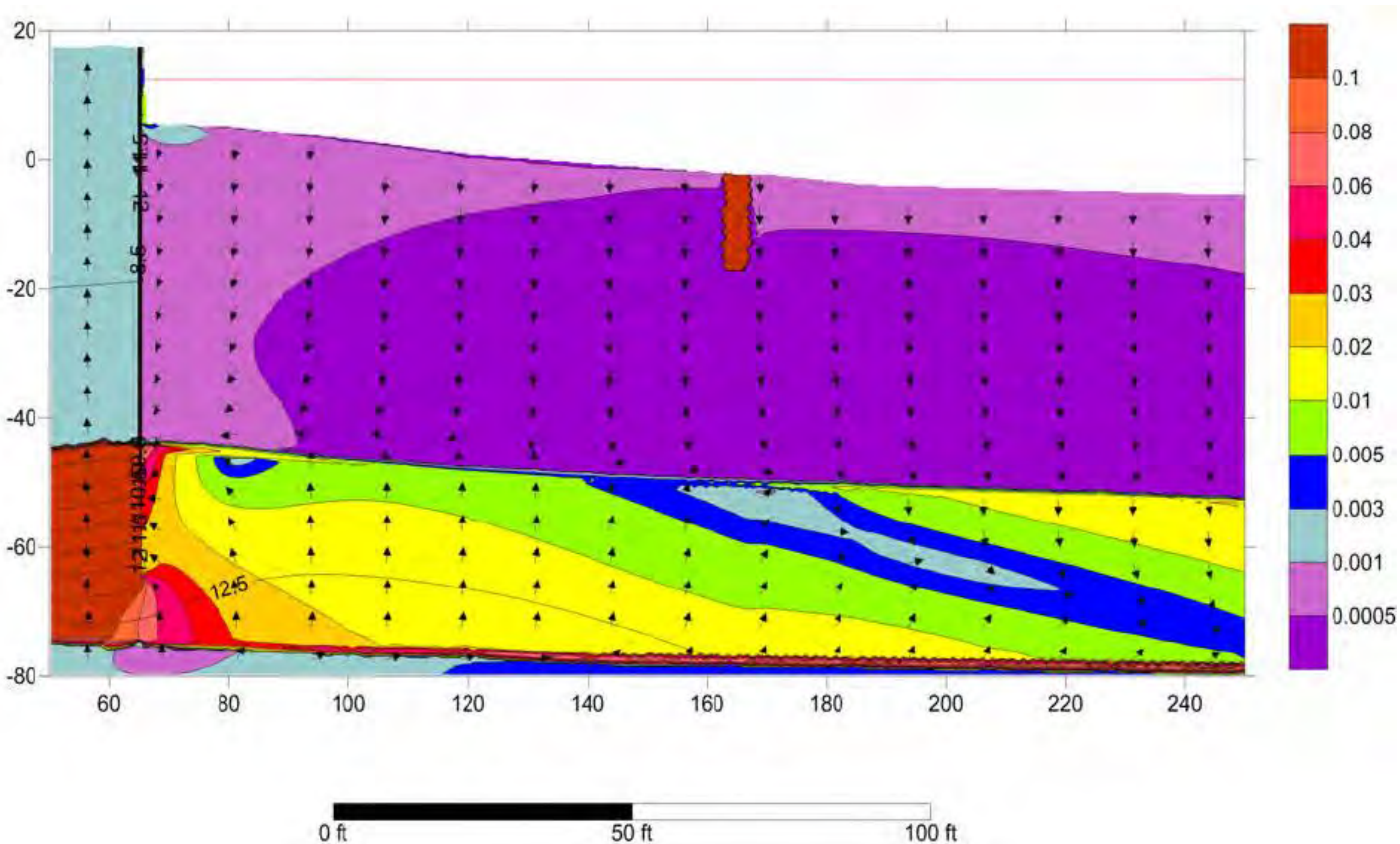


Figure B-24
Vertical Barrier plus Capping Simulation 1600 Hrs
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 1700 hrs on 12/13/2012 - Basecase

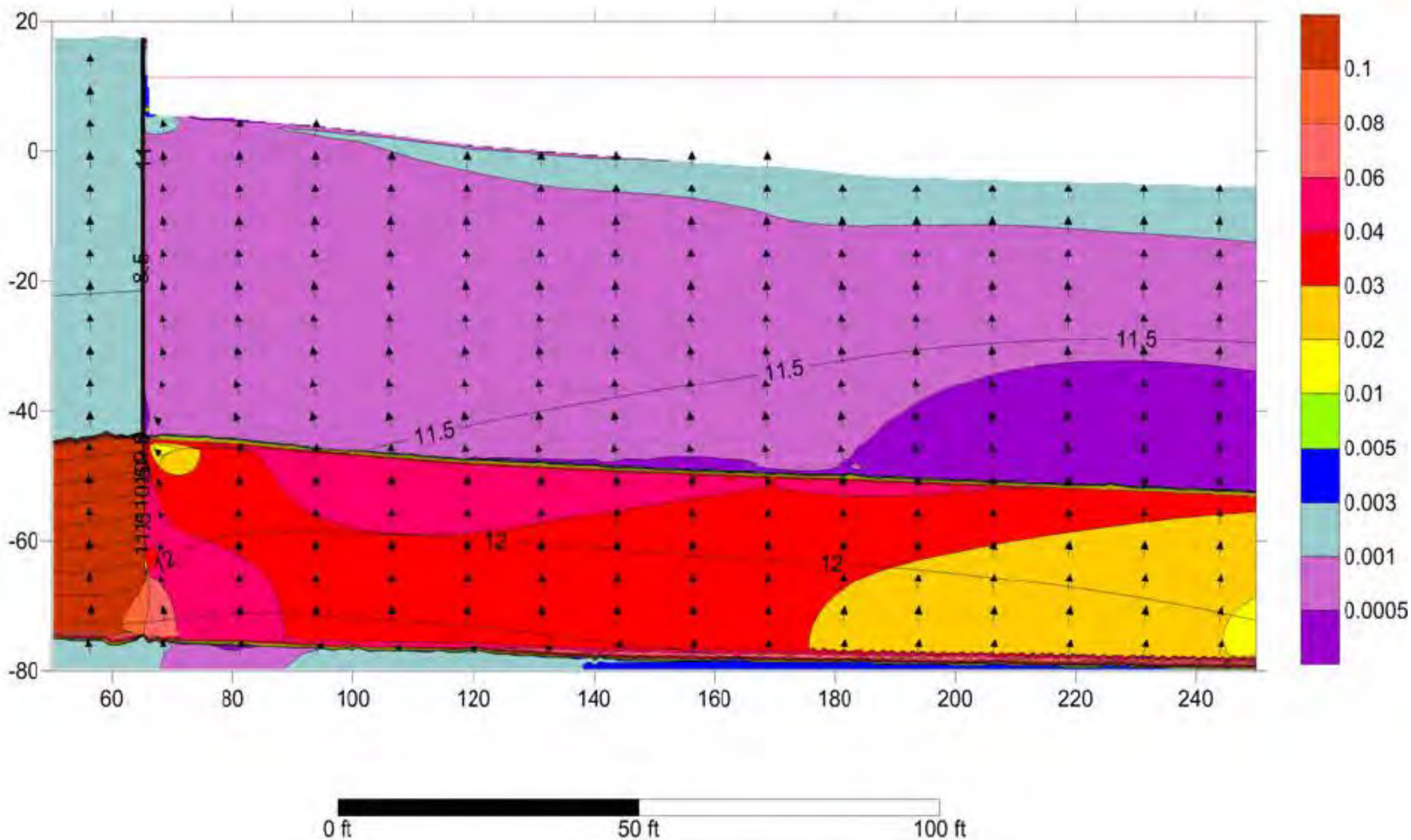


Figure B-25
Basecase Simulation at 1700 Hours
Wyckoff OU-1 Focused Feasibility Study

Simulated Head and Hydraulic Gradient at 1700 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall

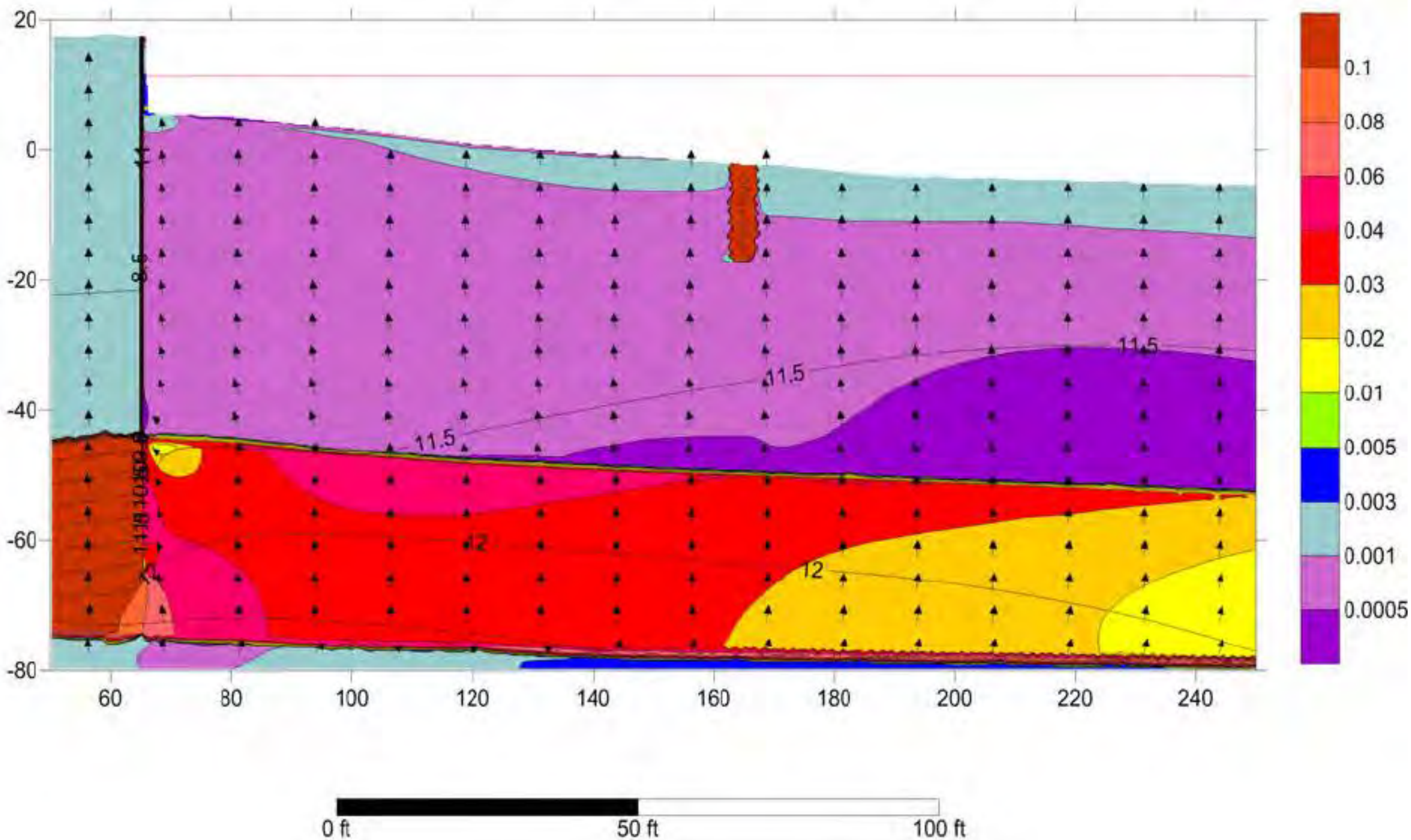


Figure B-26
Vertical Barrier Simulation 1700 Hrs
Wyckoff OU-1 Focused Feasibility Study

Simulated Head and Hydraulic Gradient at 1700 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall – 0.3 ft/day Cap

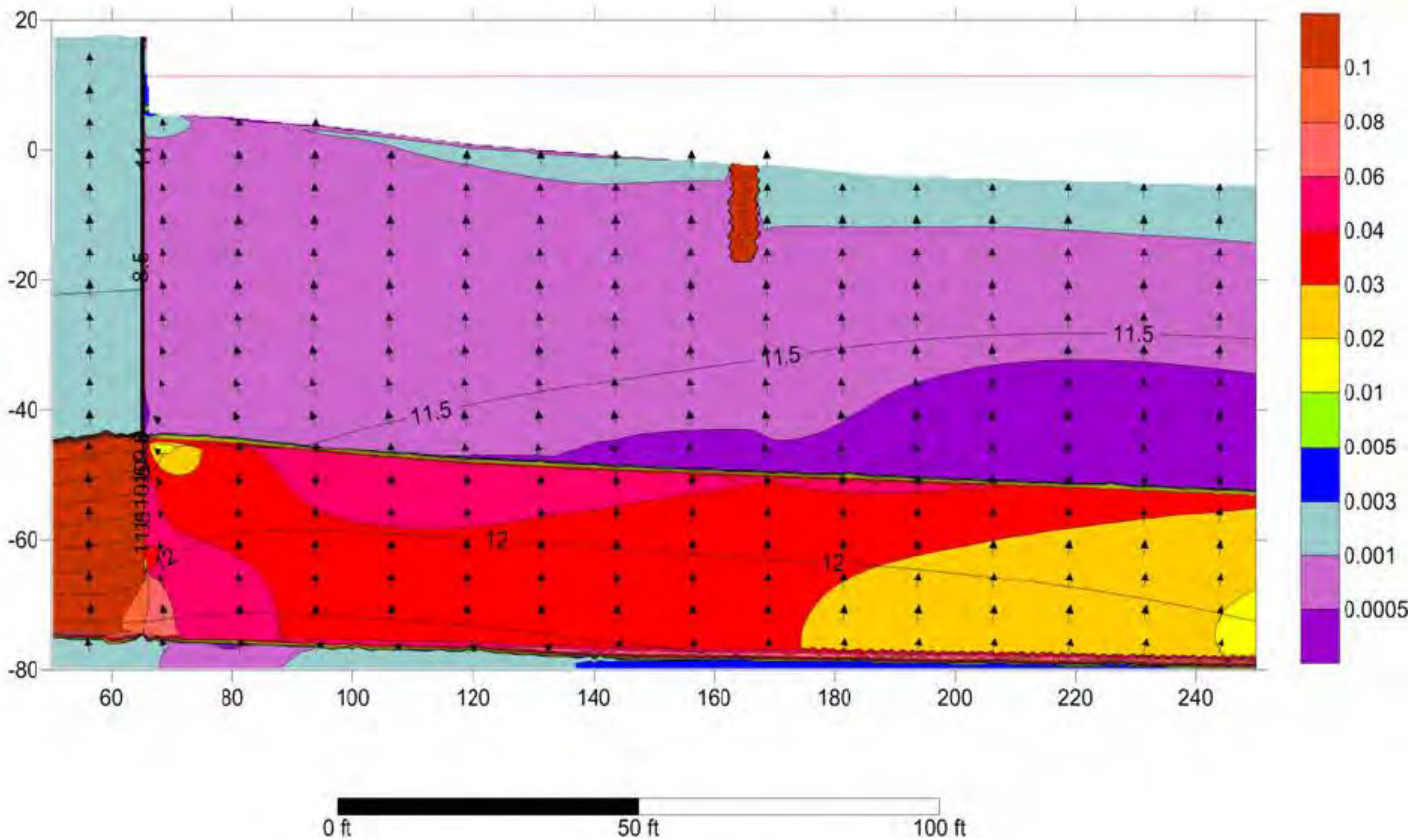


Figure B-27
Vertical Barrier plus Capping Simulation 1700 Hrs
Wyckoff OU-1 Focused Feasibility Study

Simulated Head and Hydraulic Gradient at 1800 hrs on 12/13/2012 - Basecase

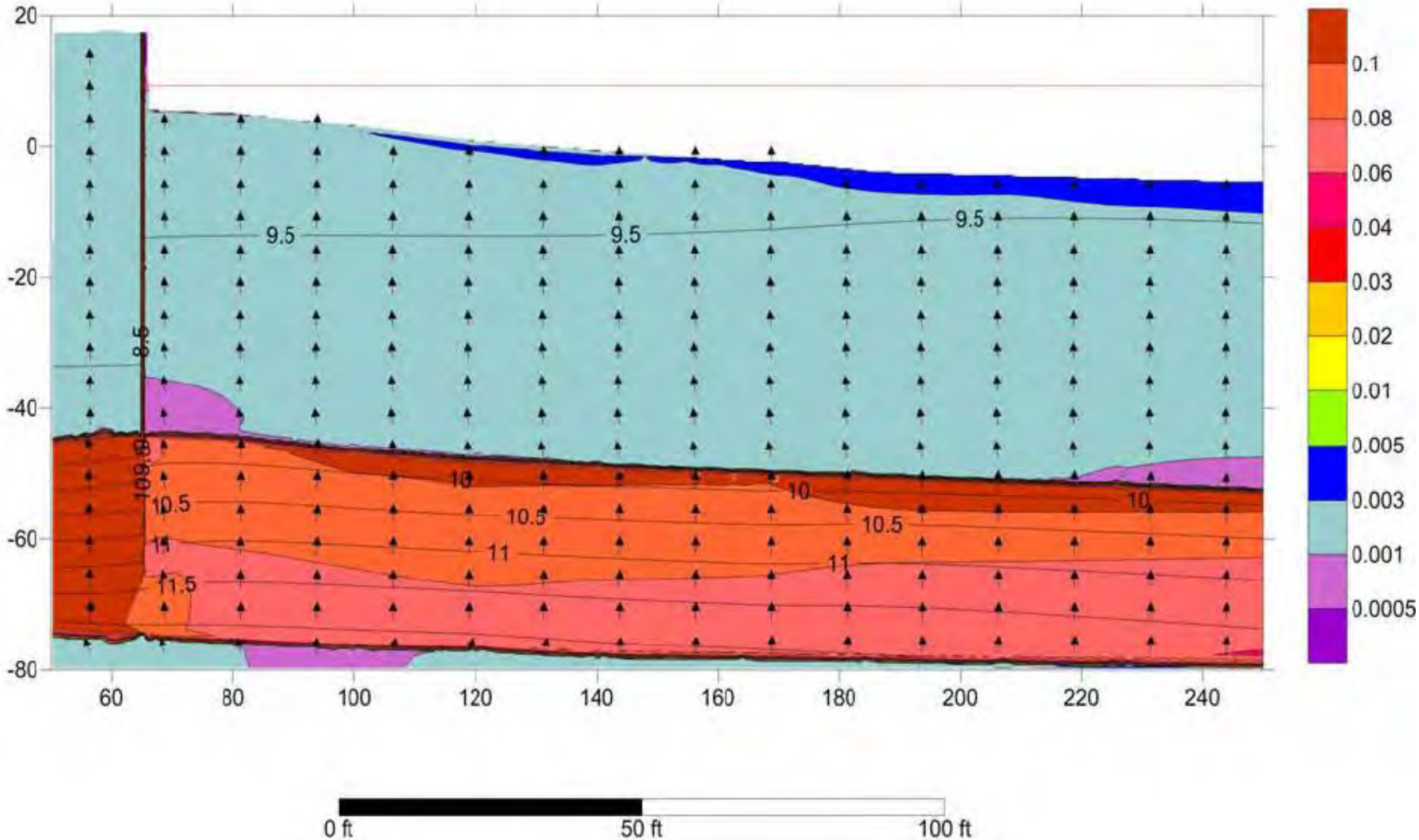


Figure B-28
Basecase Simulation at 1800 Hours
Wyckoff OU-1 Focused Feasibility Study

Simulated Head and Hydraulic Gradient at 1800 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall

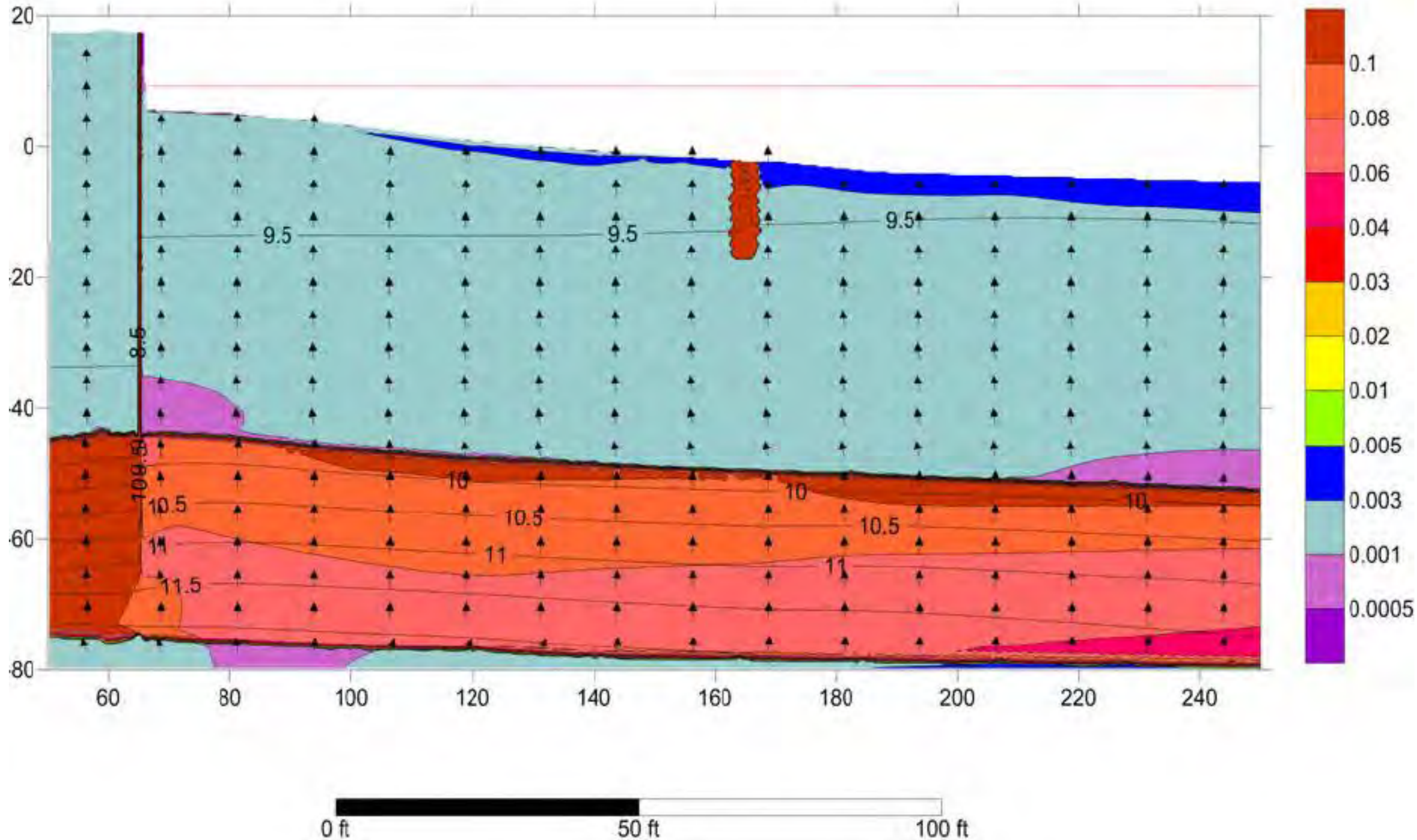


Figure B-29
Vertical Barrier Simulation 1800 Hrs
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 1800 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall – 0.3 ft/day Cap

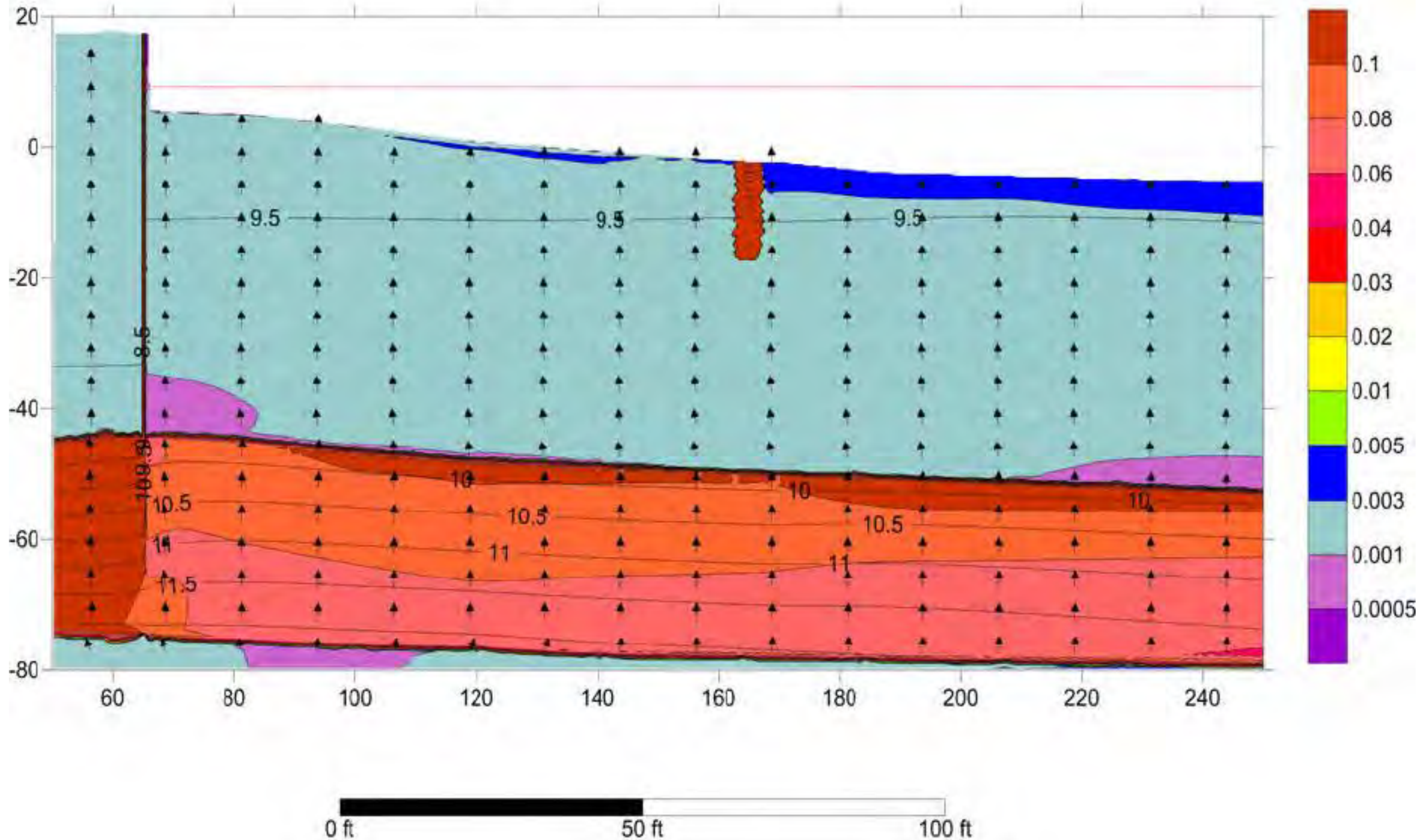


Figure B-30
Vertical Barrier plus Capping Simulation 1800 Hrs
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 1900 hrs on 12/13/2012 - Basecase

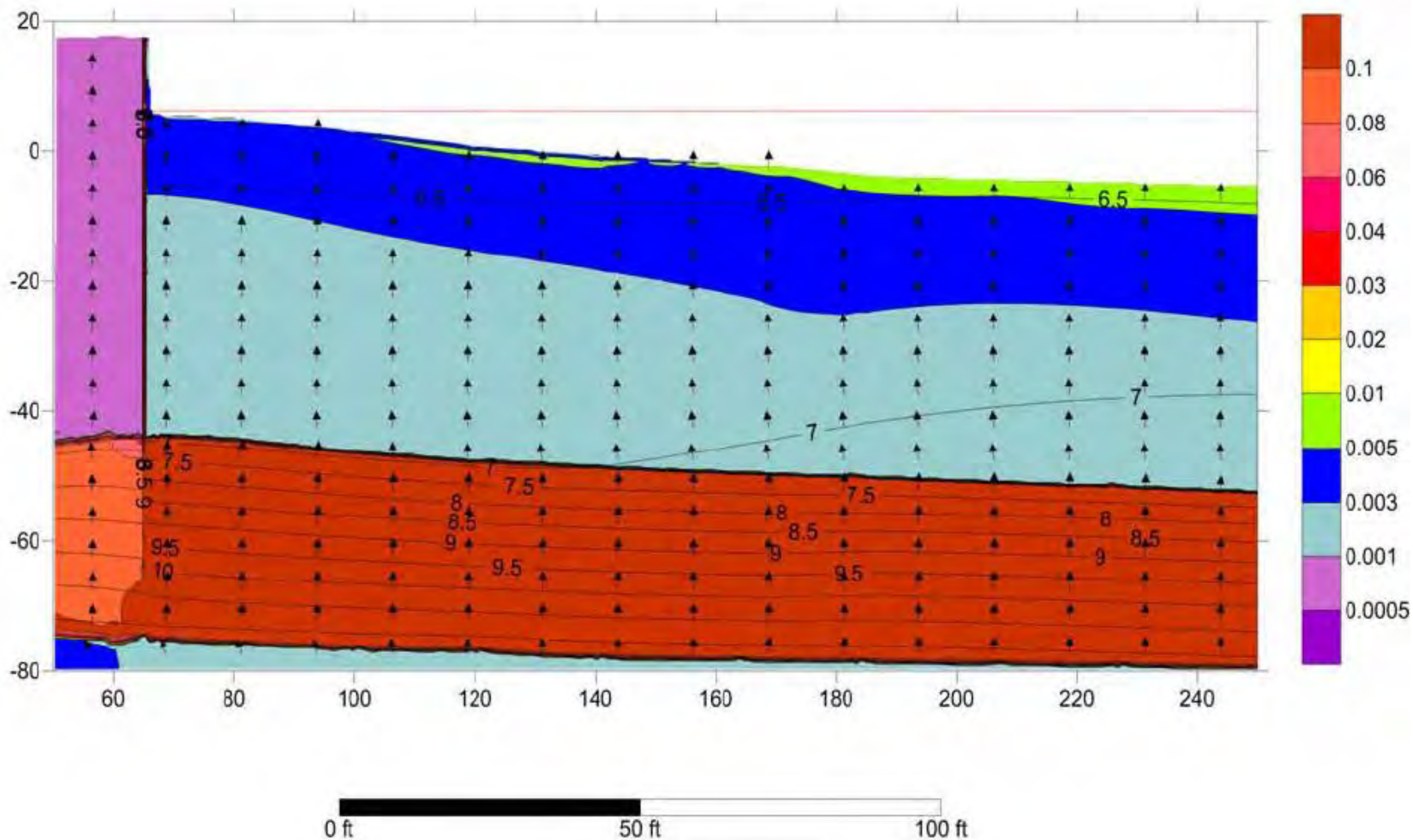
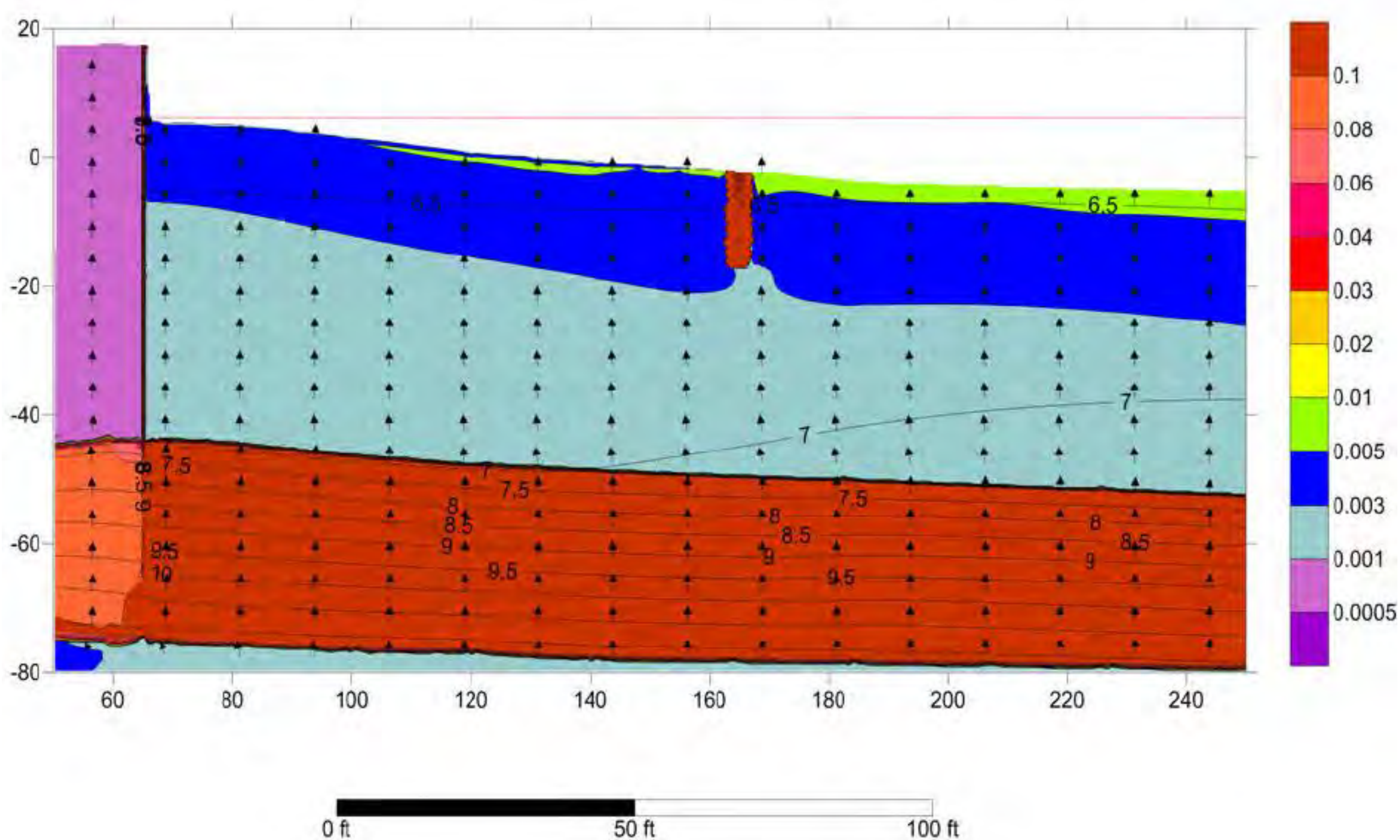


Figure B-31
Basecase Simulation at 1900 Hours
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 1900 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall



FigureB-32
Vertical Barrier Simulation 1900 Hrs
Wyckoff OU-1 Focused Feasibility Study

Simulated Head and Hydraulic Gradient at 1900 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall – 0.3 ft/day Cap

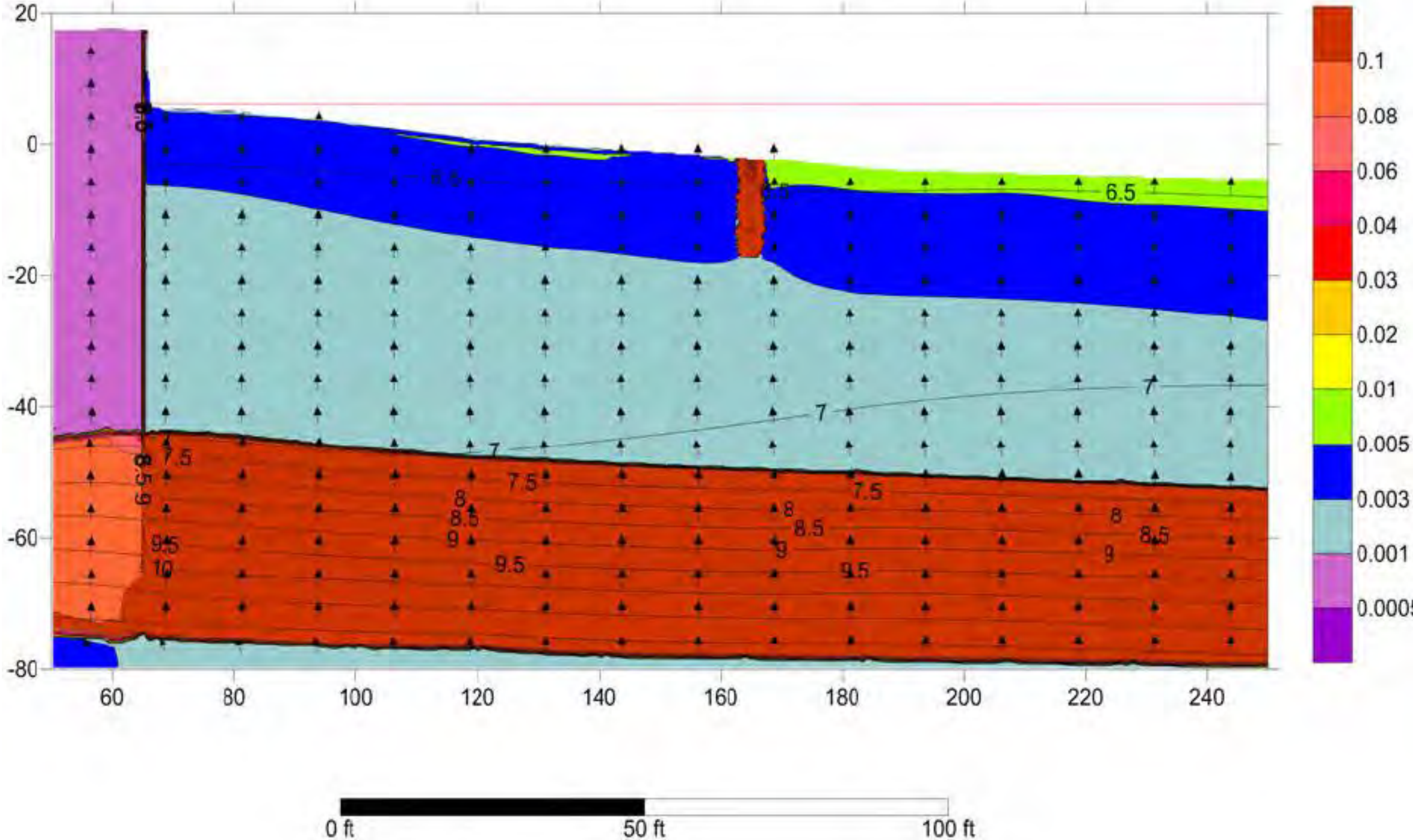


Figure B-33
Vertical Barrier plus Capping Simulation 1900 Hrs
Wyckoff OU-1 Focused Feasibility Study

Simulated Head and Hydraulic Gradient at 2000 hrs on 12/13/2012 - Basecase

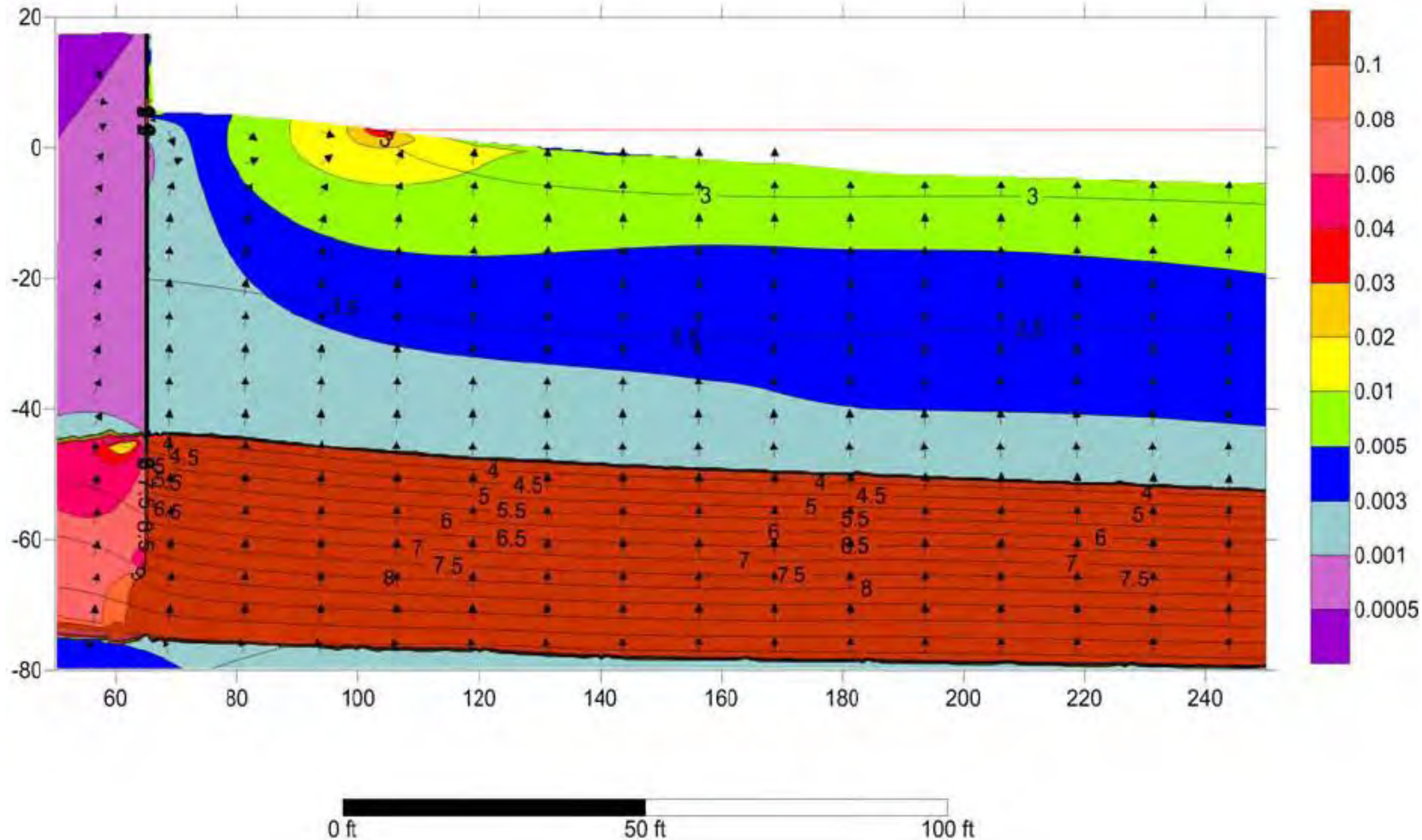


Figure B-34
Basecase Simulation at 2000 Hours
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 2000 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall

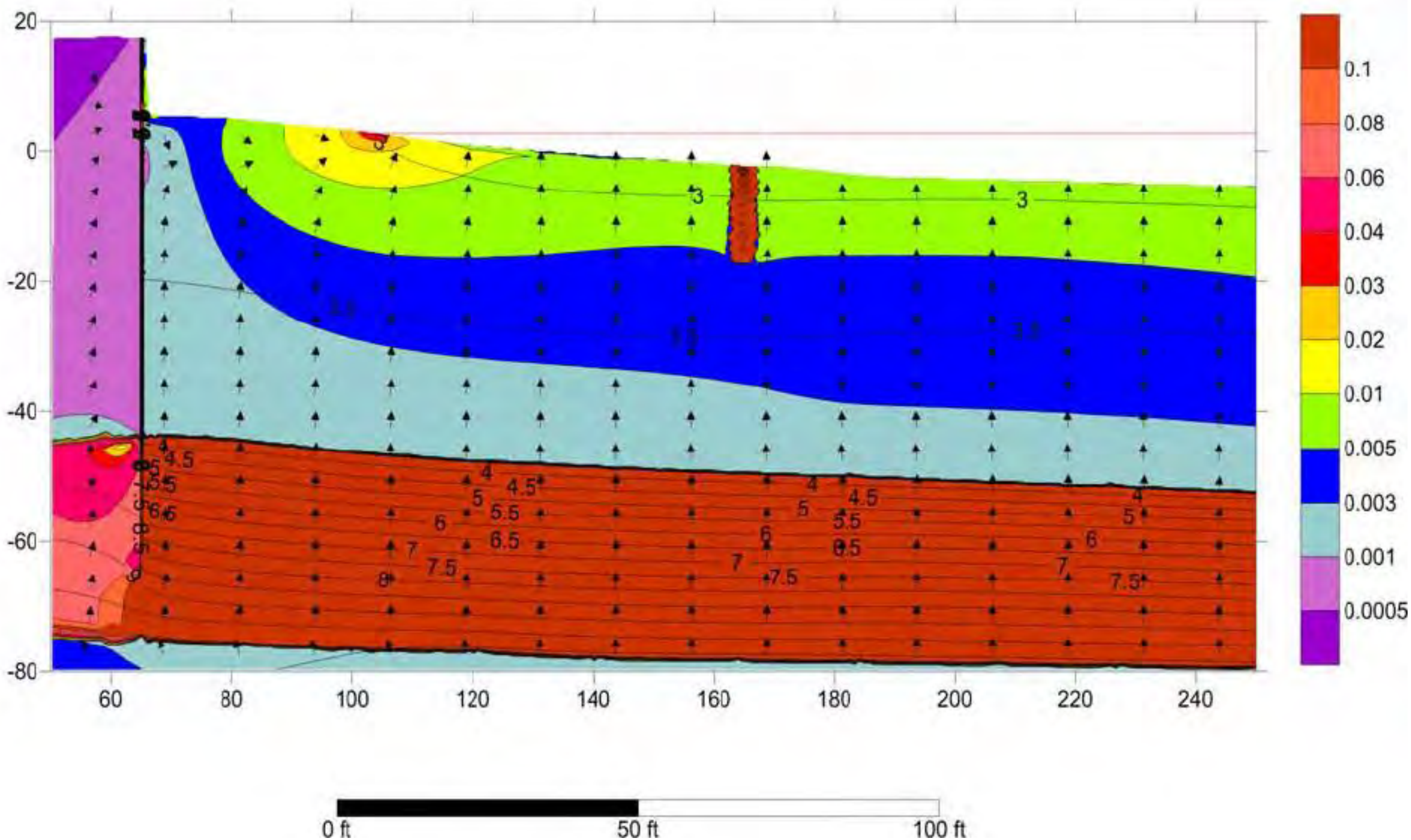


Figure B-35
Vertical Barrier Simulation 2000 Hrs
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 2000 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall – 0.3 ft/day Cap

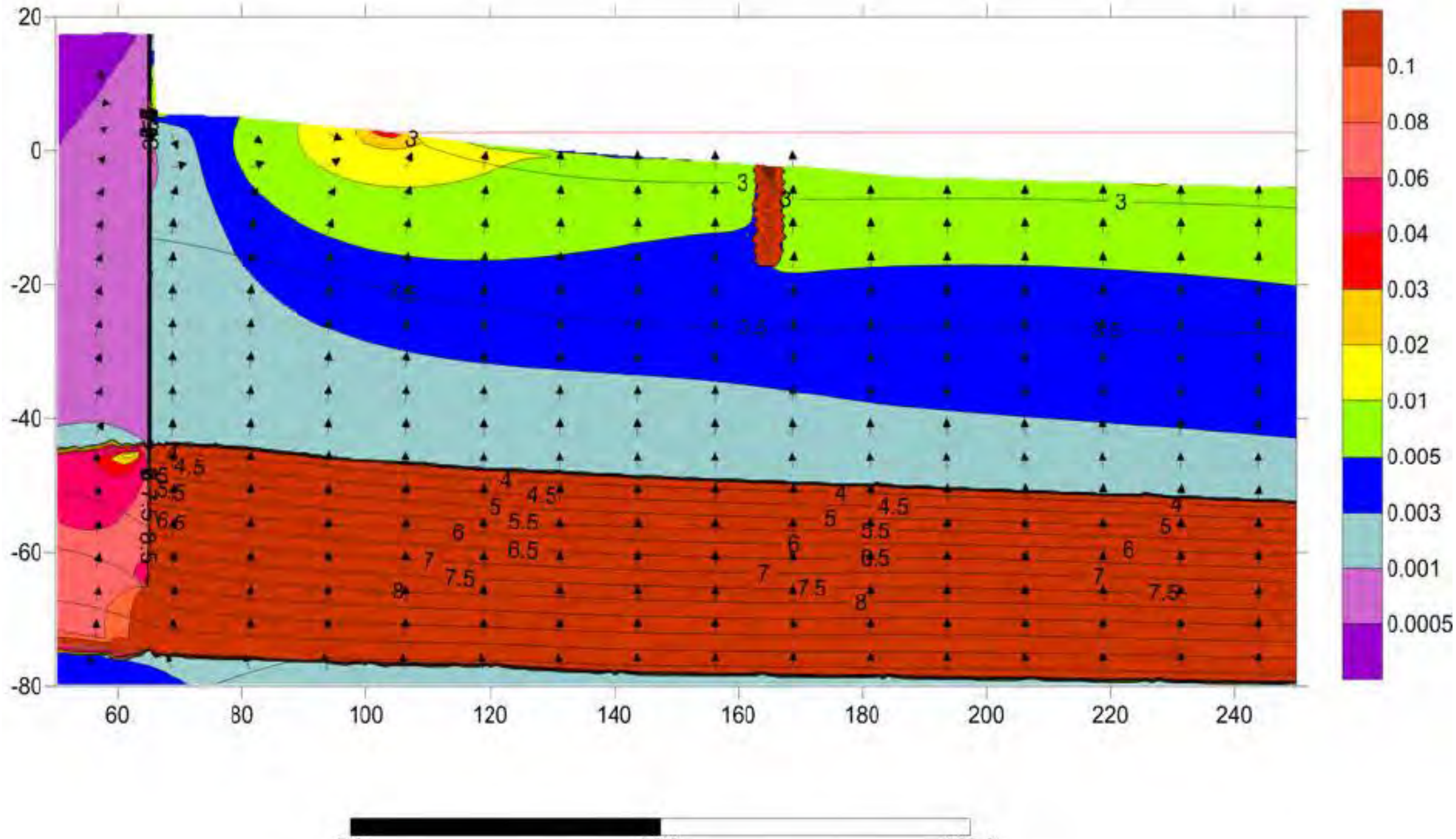


Figure B-36
Vertical Barrier plus Capping Simulation 2000 Hrs
Wyckoff OU-1 Focused Feasibility Study

Simulated Head and Hydraulic Gradient at 2100 hrs on 12/13/2012 - Basecase

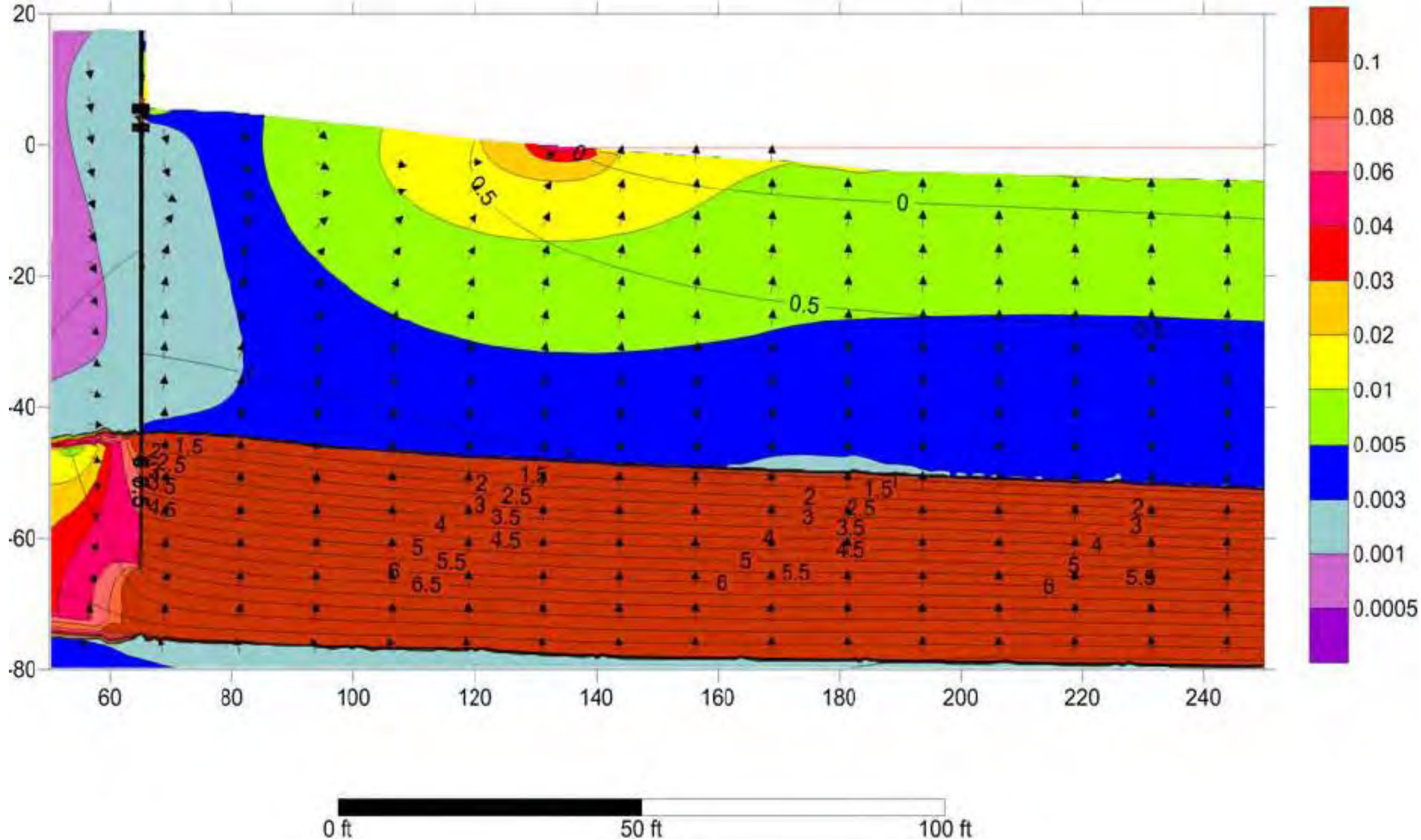


Figure B-37
Basecase Simulation at 2100 Hours
Wyckoff OU-1 Focused Feasibility Study

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Simulated Head and Hydraulic Gradient at 2100 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall

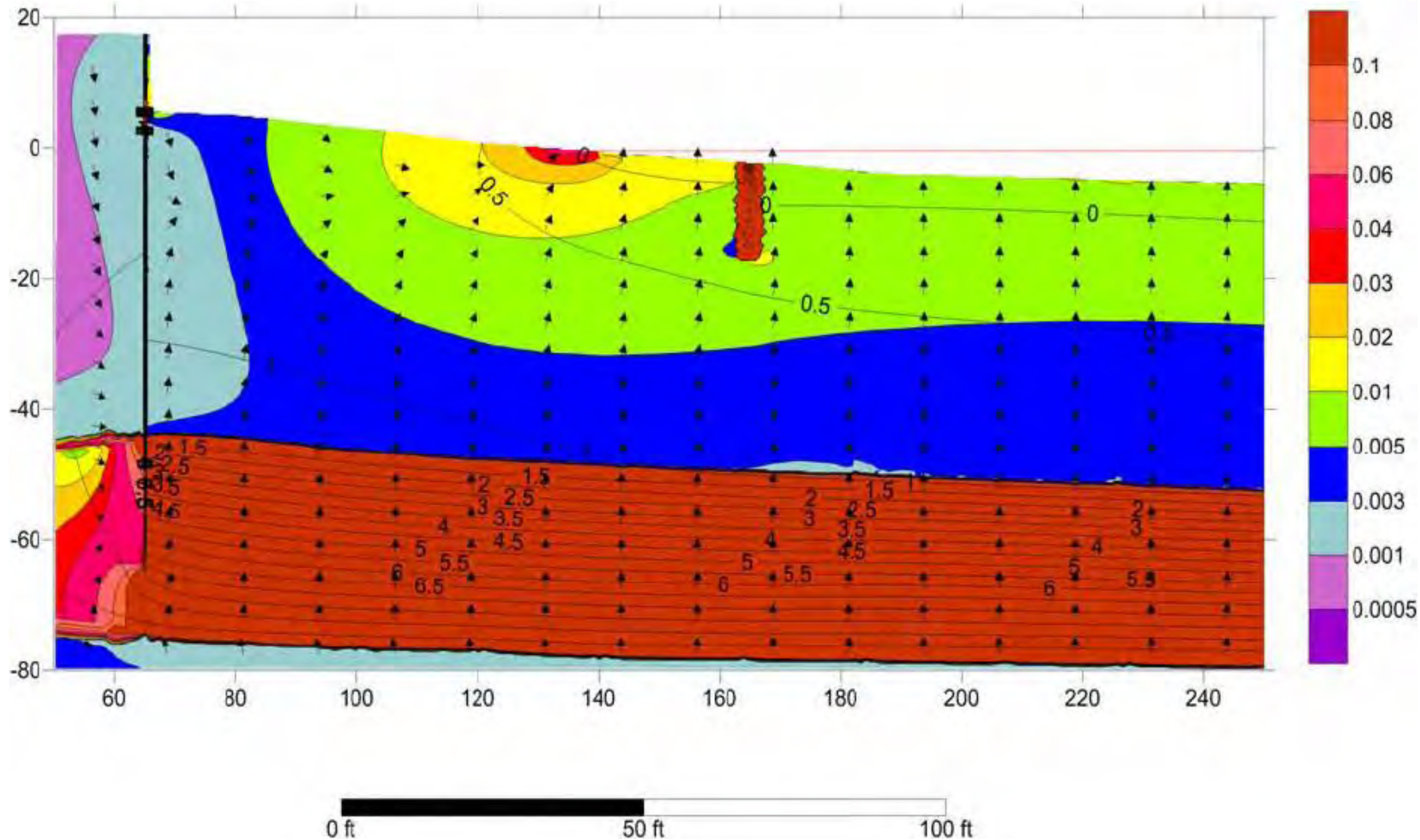

Figure B-38
Vertical Barrier Simulation 2100 Hrs
Wyckoff OU-1 Focused Feasibility Study

Simulated Head and Hydraulic Gradient at 2100 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall – 0.3 ft/day Cap

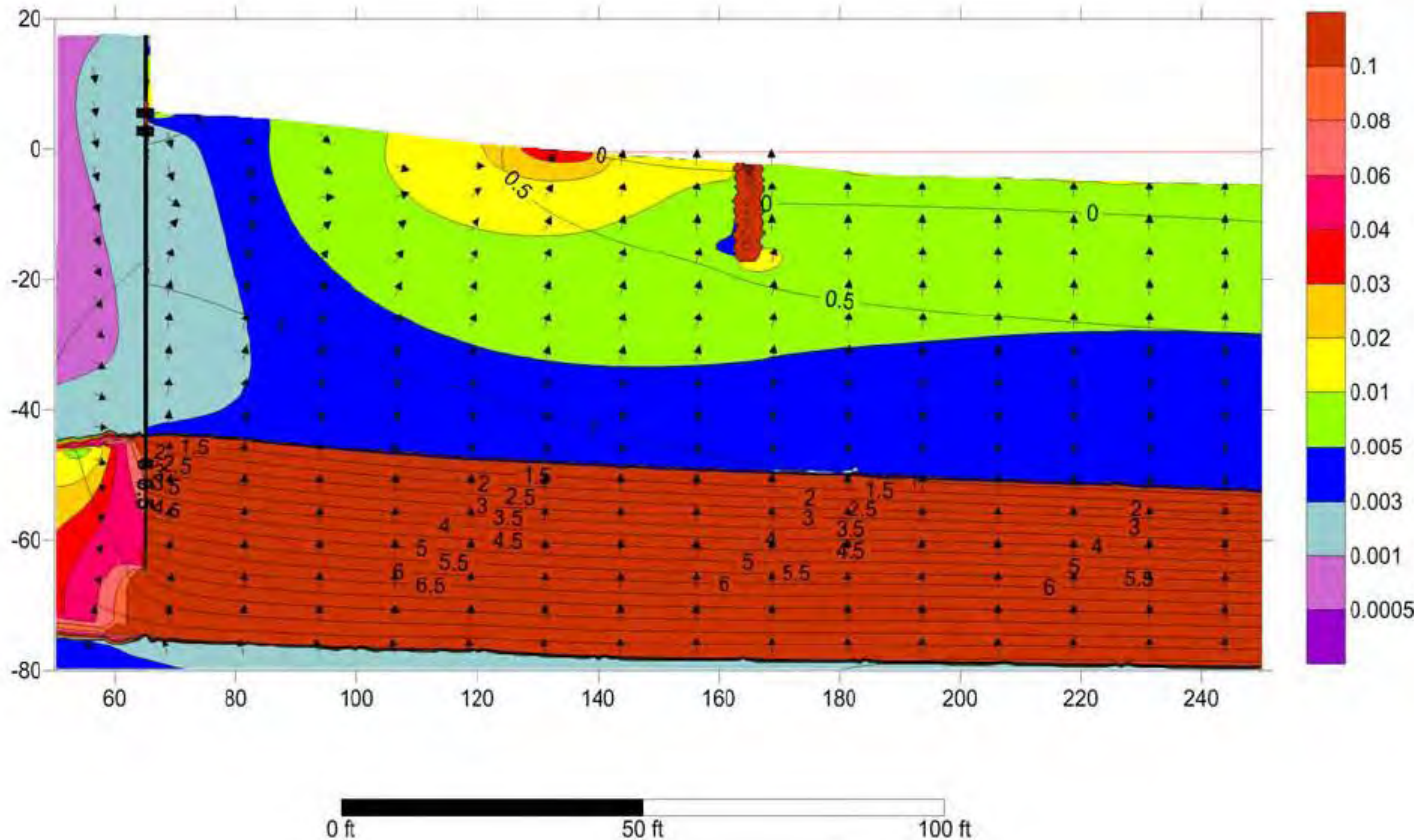

Figure B-39
Vertical Barrier plus Capping Simulation 2100 Hrs
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 2200 hrs on 12/13/2012 - Basecase

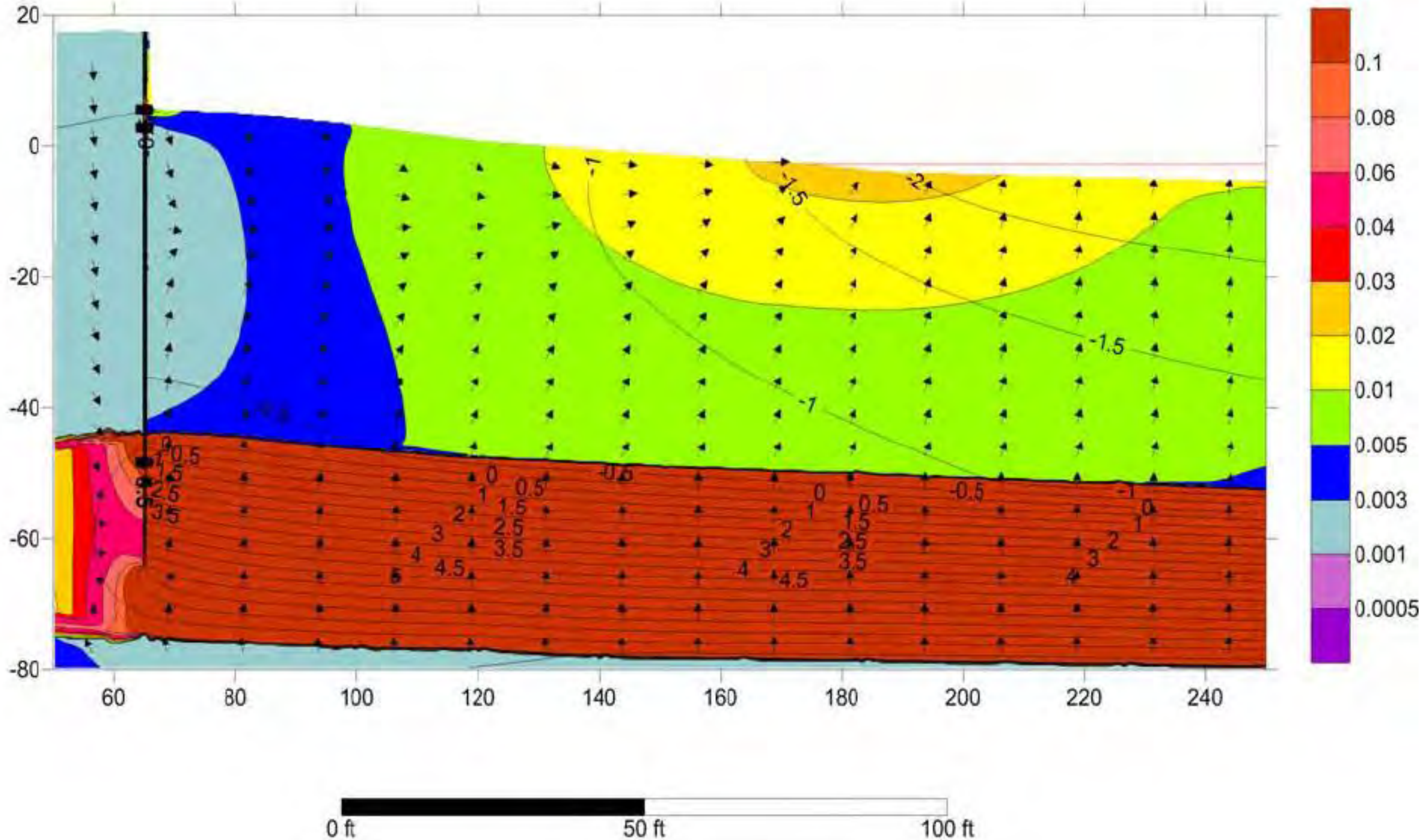

Figure B-40
Basecase Simulation at 2200 Hours
Wyckoff OU-1 Focused Feasibility Study

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Simulated Head and Hydraulic Gradient at 2200 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall

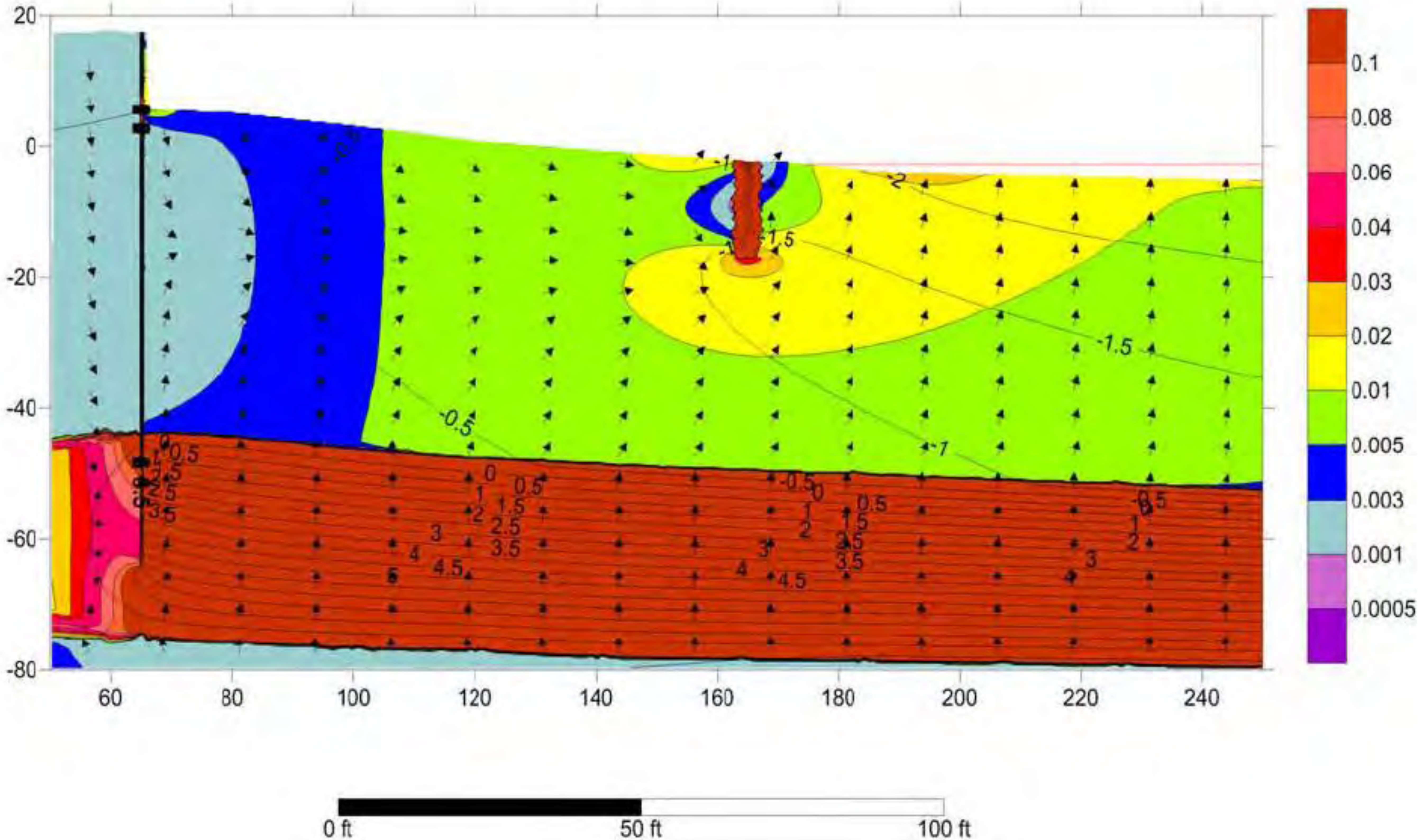

Figure B-41
Vertical Barrier Simulation 2200 Hrs
Wyckoff OU-1 Focused Feasibility Study

Simulated Head and Hydraulic Gradient at 2200 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall – 0.3 ft/day Cap

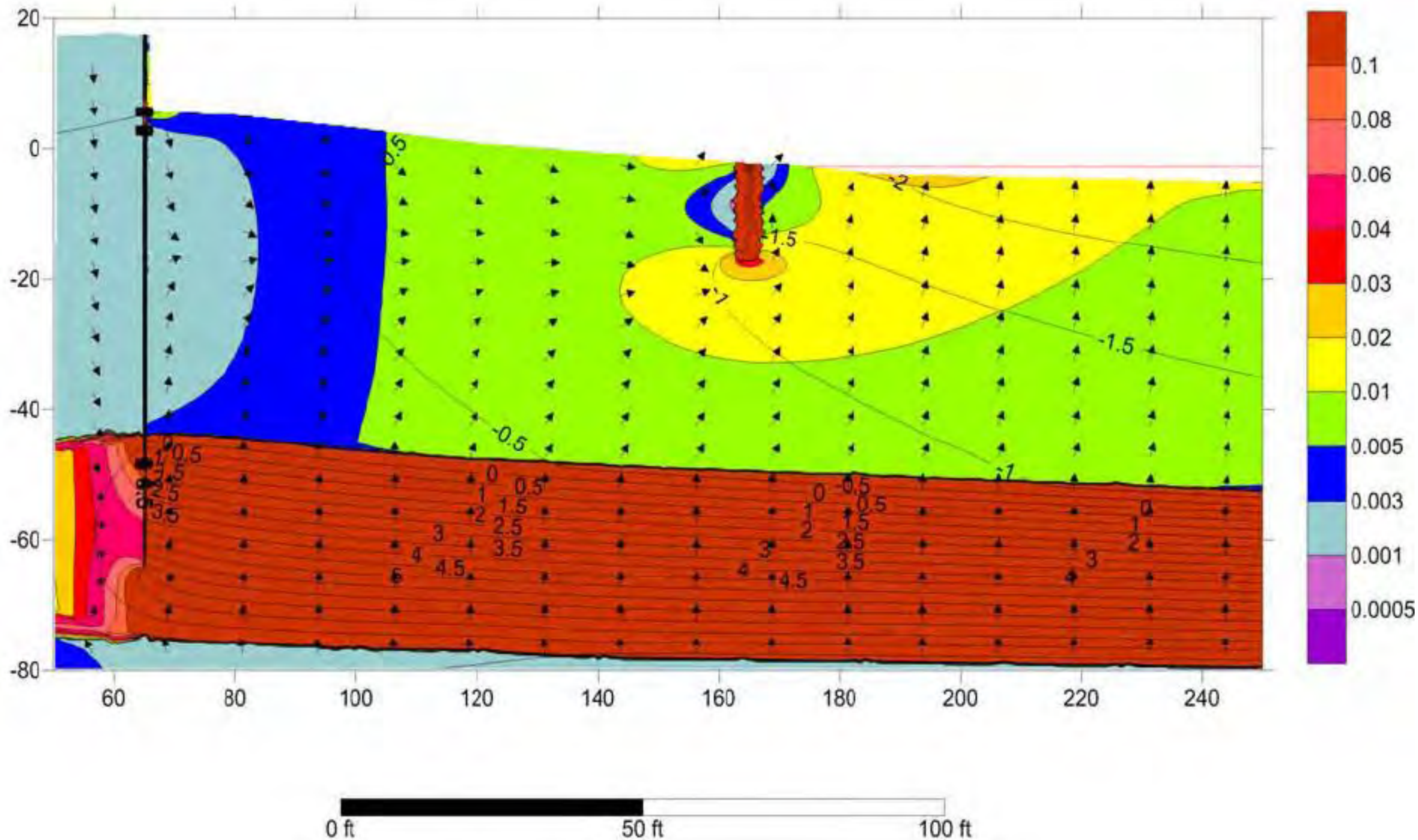

Figure B-42
Vertical Barrier plus Capping Simulation 2200 Hrs
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 2300 hrs on 12/13/2012 - Basecase

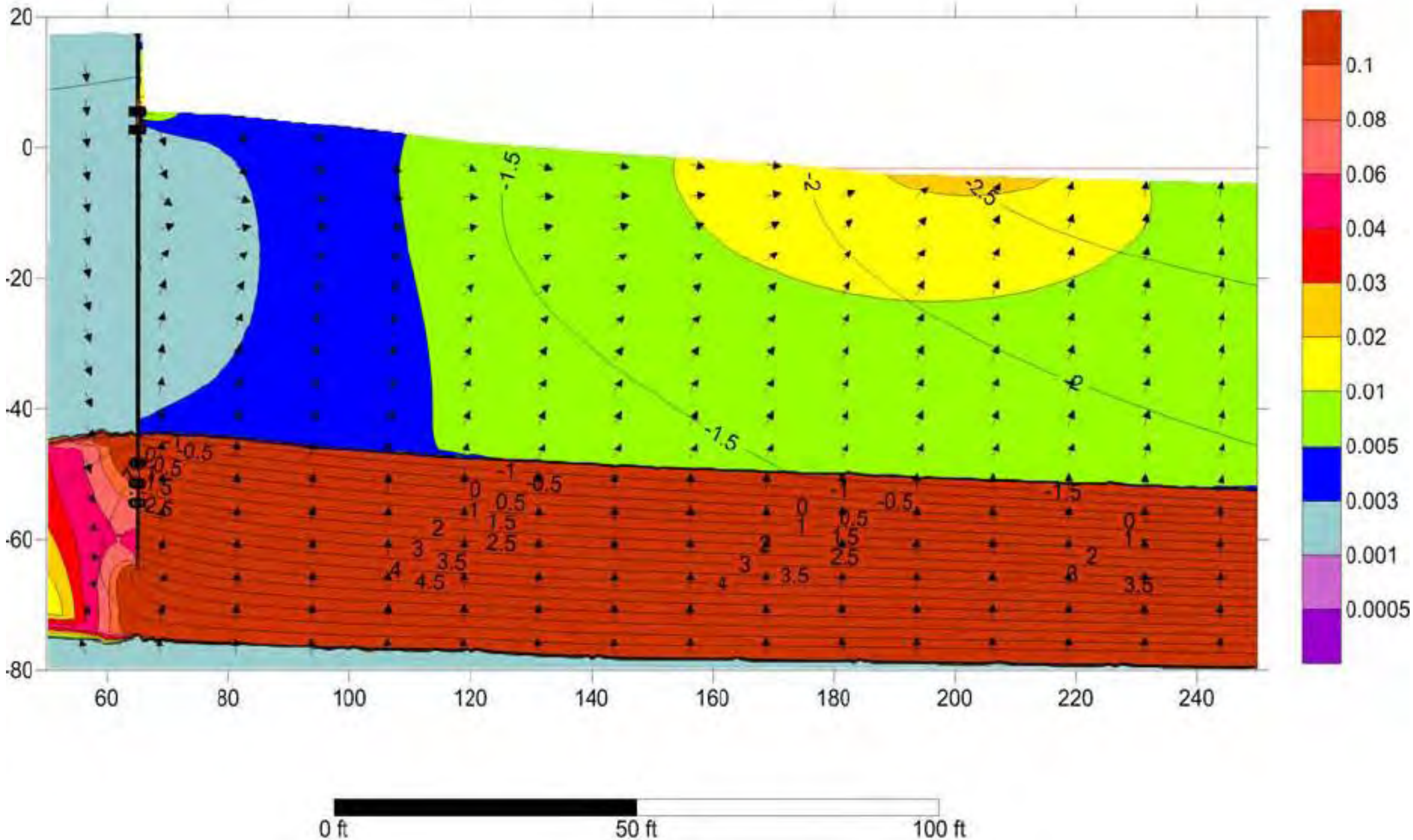

Figure B-43
Basecase Simulation at 2300 Hours
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 2300 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall

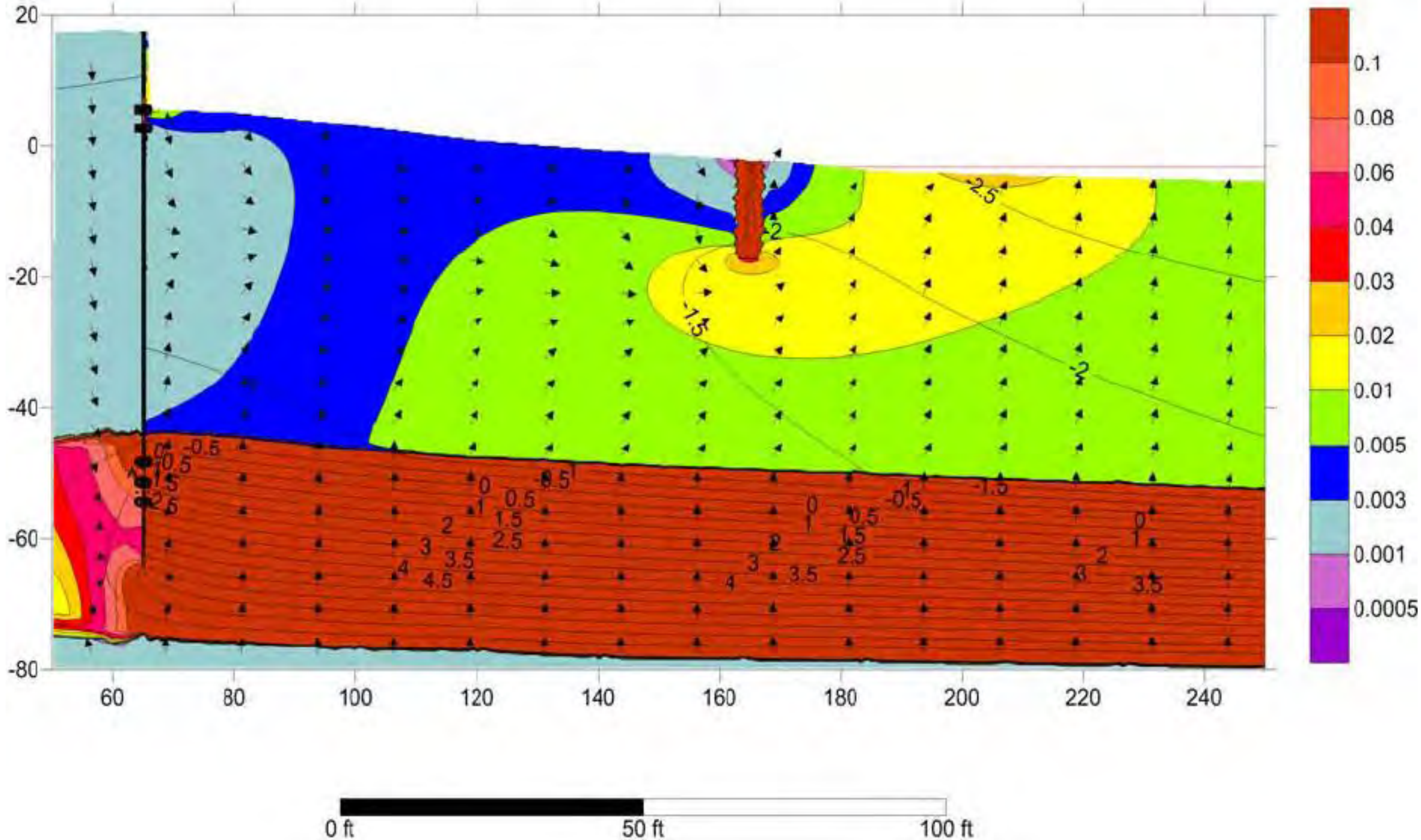

Figure B-44
Vertical Barrier Simulation 2300 Hrs
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 2300 hrs on 12/13/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall – 0.3 ft/day Cap

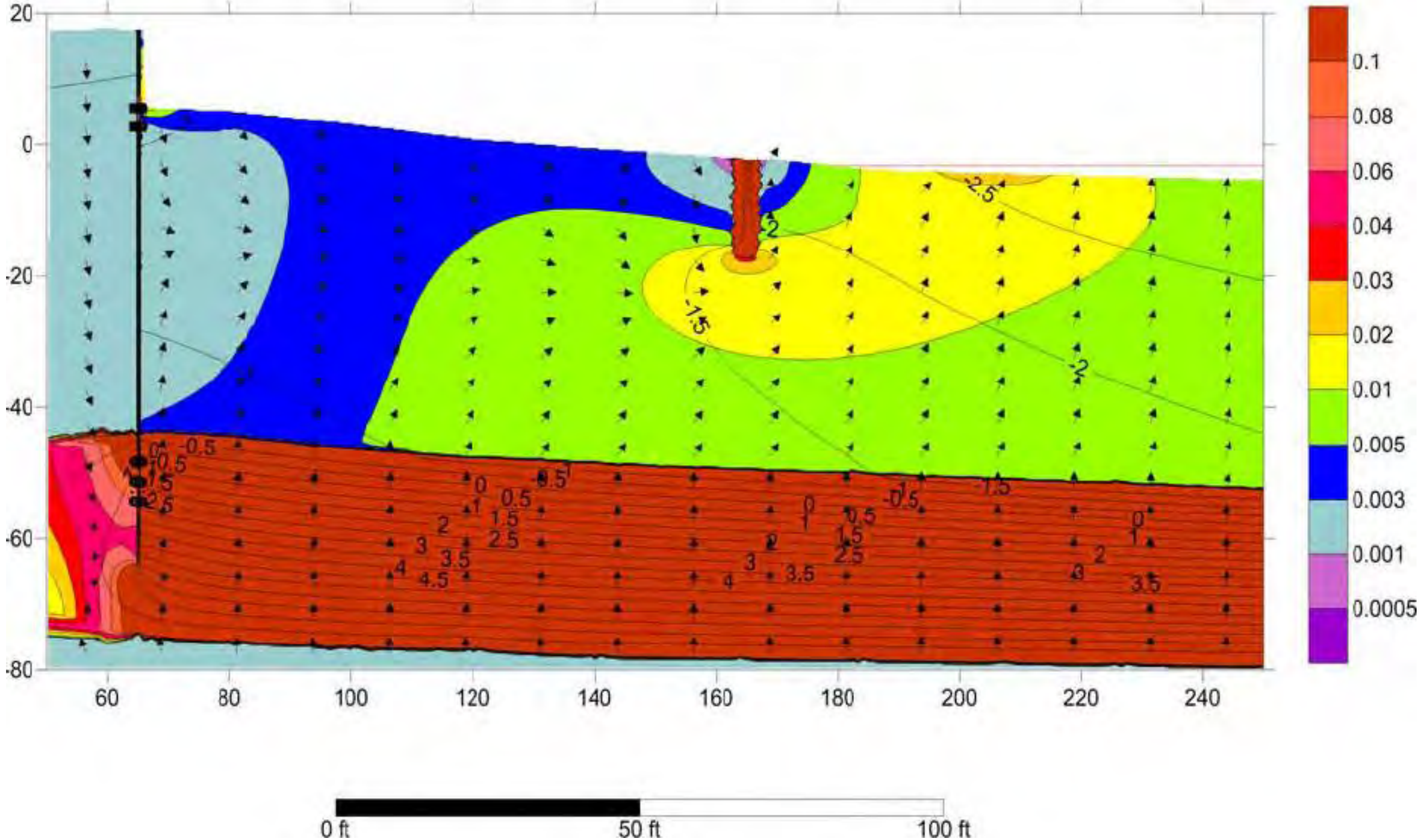

Figure B-45
Vertical Barrier plus Capping Simulation 2300 Hrs
Wyckoff OU-1 Focused Feasibility Study

Simulated Head and Hydraulic Gradient at 000 hrs on 12/14/2012 - Basecase

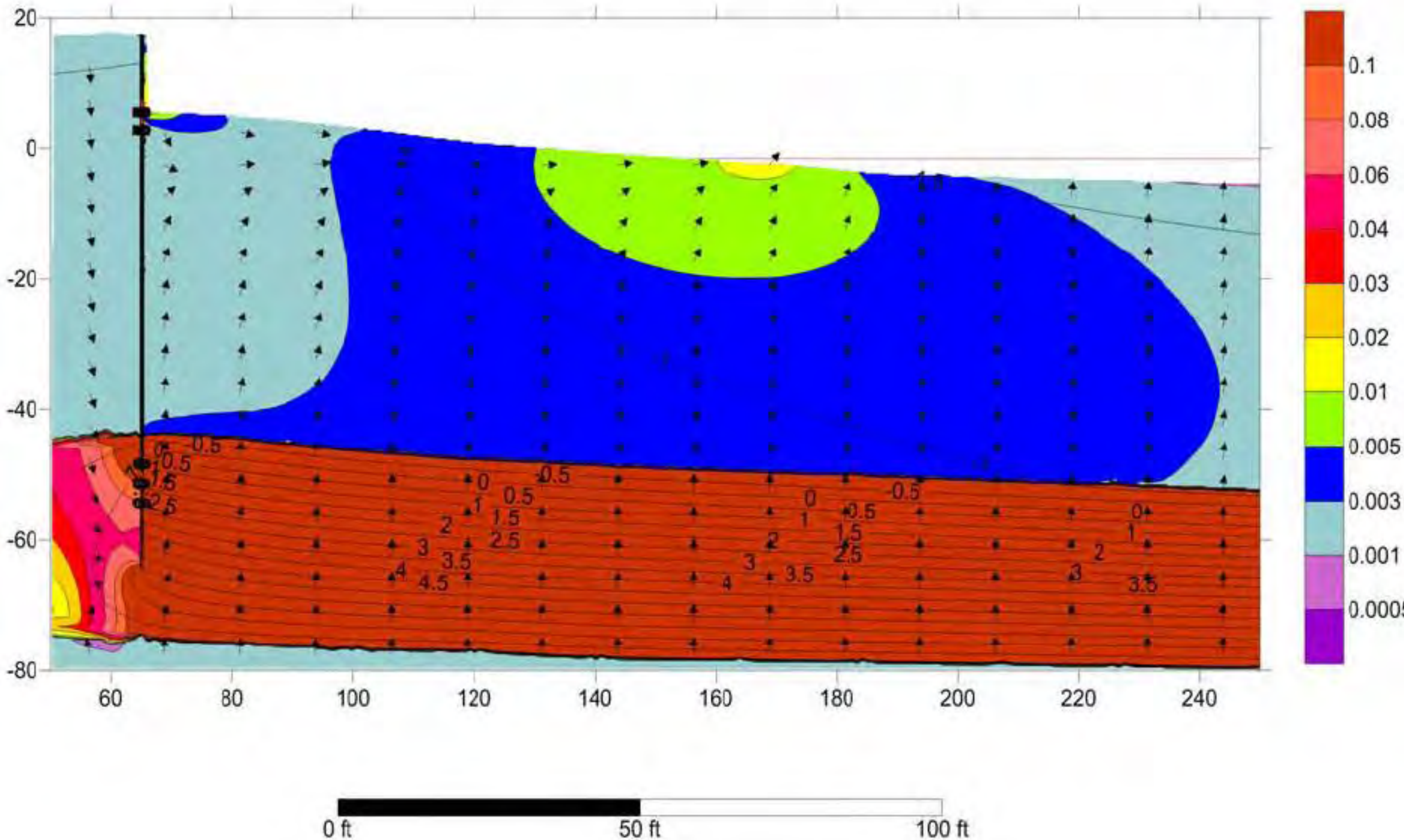

Figure B-46
Basecase Simulation at 000 Hours
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 000 hrs on 12/14/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall

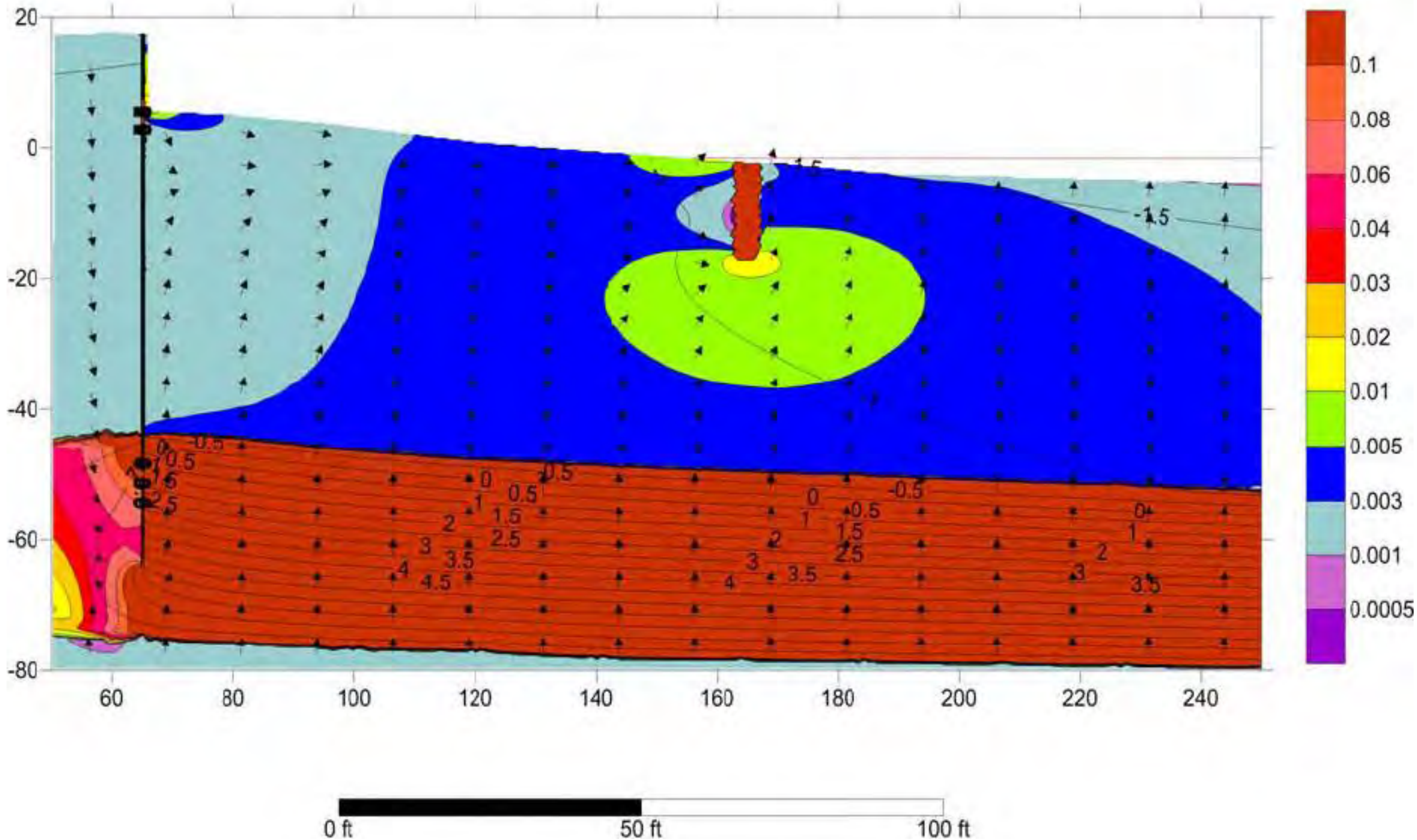

Figure B-47
Vertical Barrier Simulation 000 Hrs
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 000 hrs on 12/14/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall – 0.3 ft/day Cap

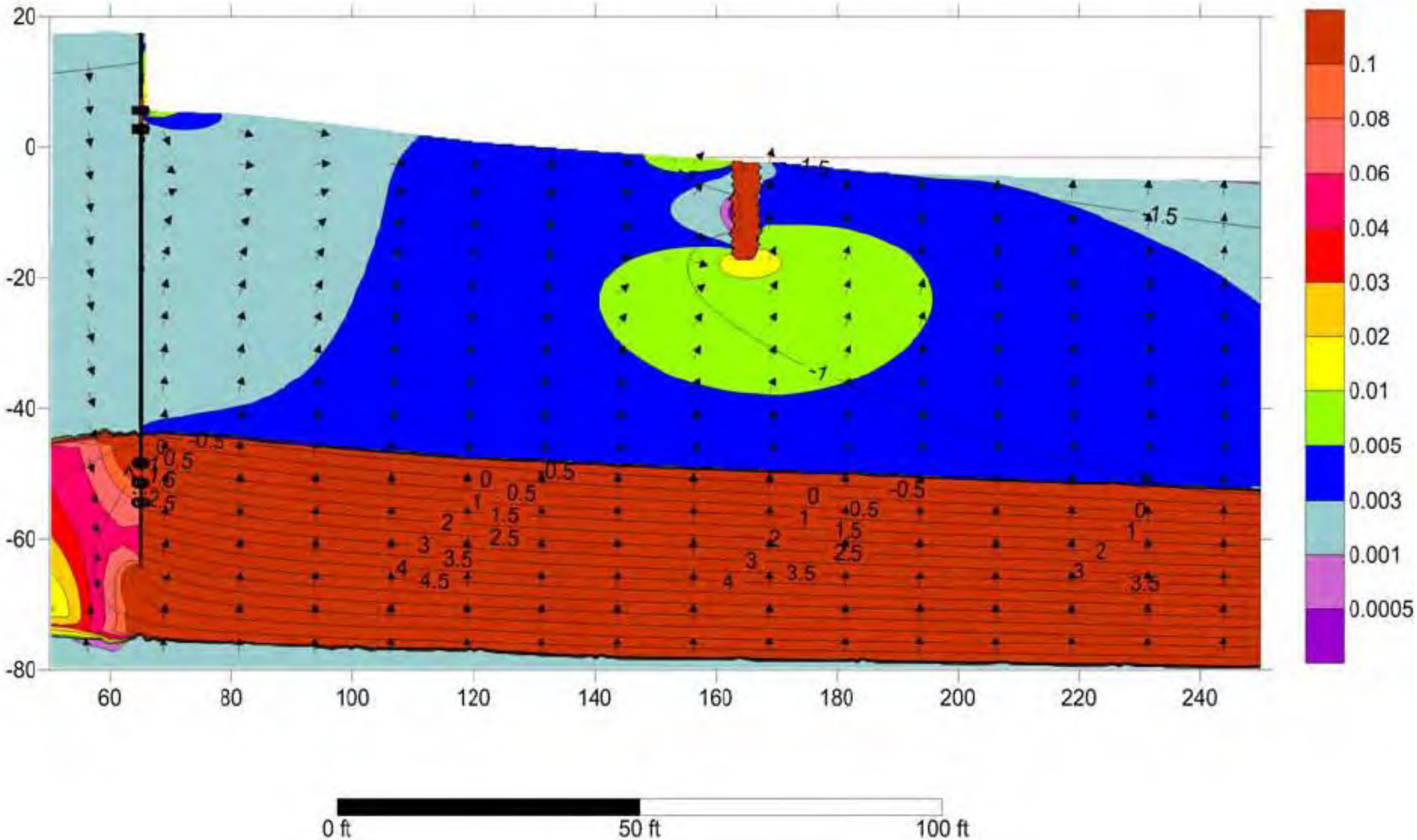

Figure B-48
Vertical Barrier plus Capping Simulation 000 Hrs
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 100 hrs on 12/14/2012 - Basecase

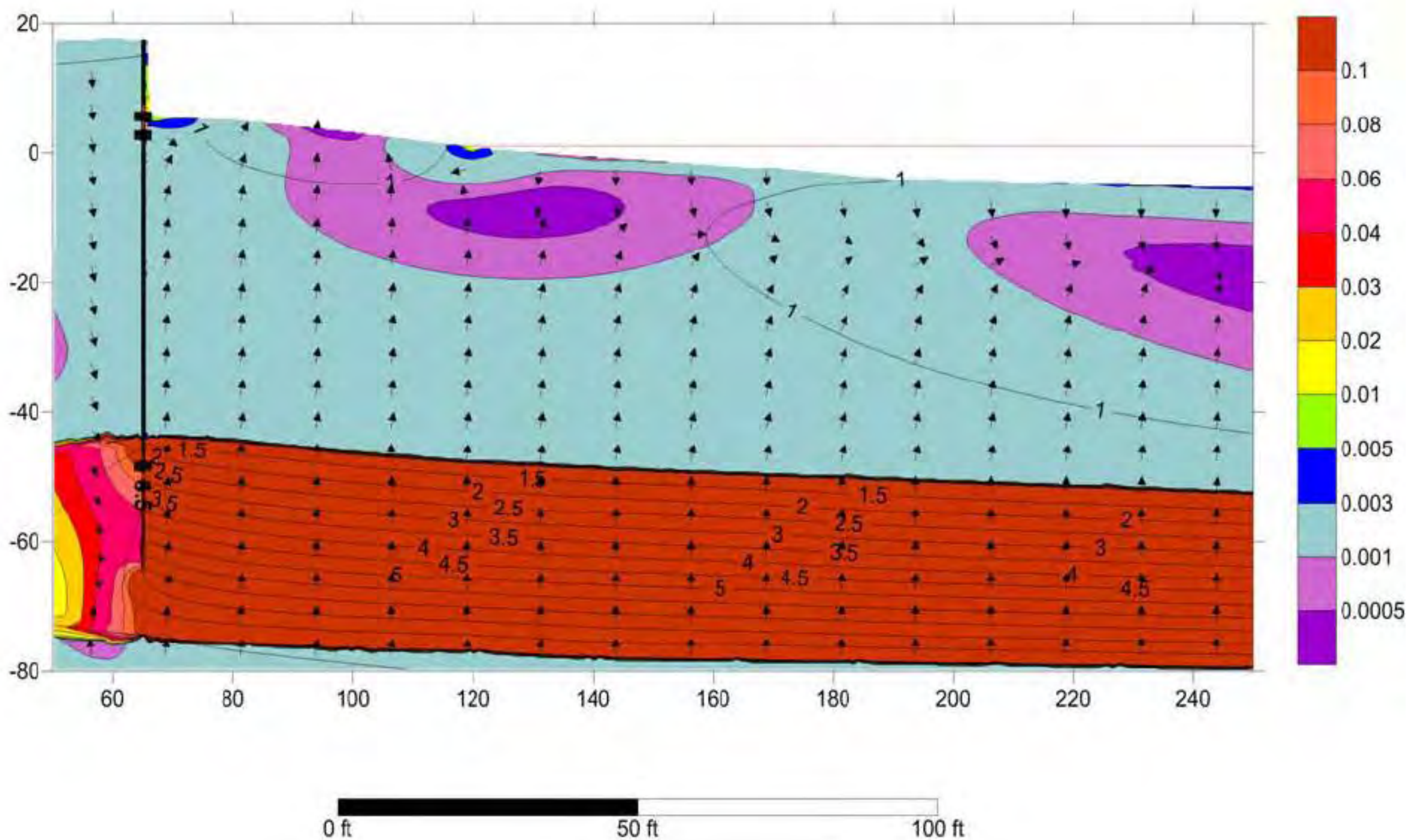

Figure B-49
Basecase Simulation at 100 Hours
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 100 hrs on 12/14/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall

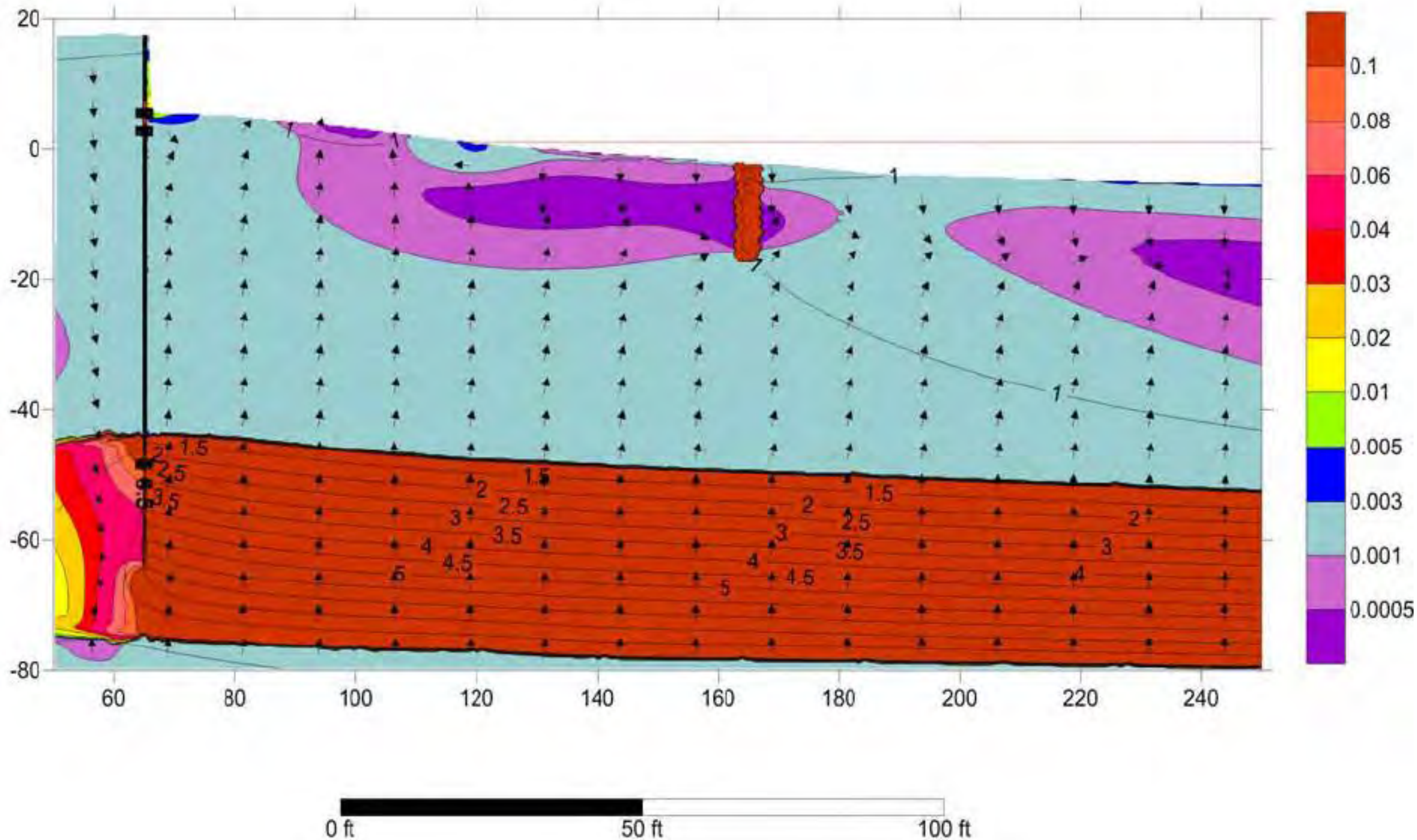

Figure B-50
Vertical Barrier Simulation 100 Hrs
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 100 hrs on 12/14/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall – 0.3 ft/day Cap

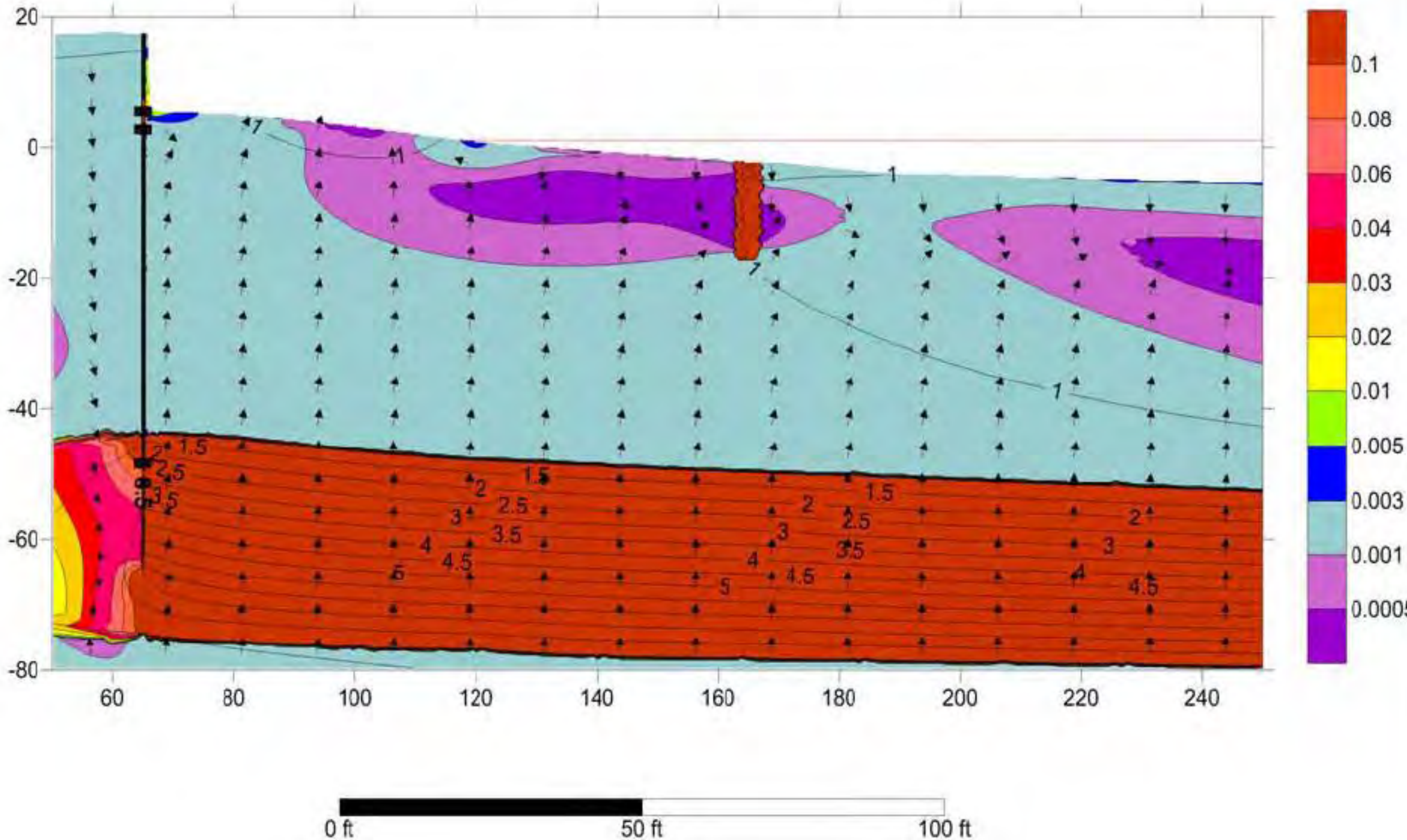

Figure B-51
Vertical Barrier plus Capping Simulation 100 Hrs
Wyckoff OU-1 Focused Feasibility Study

Simulated Head and Hydraulic Gradient at 200 hrs on 12/14/2012 - Basecase

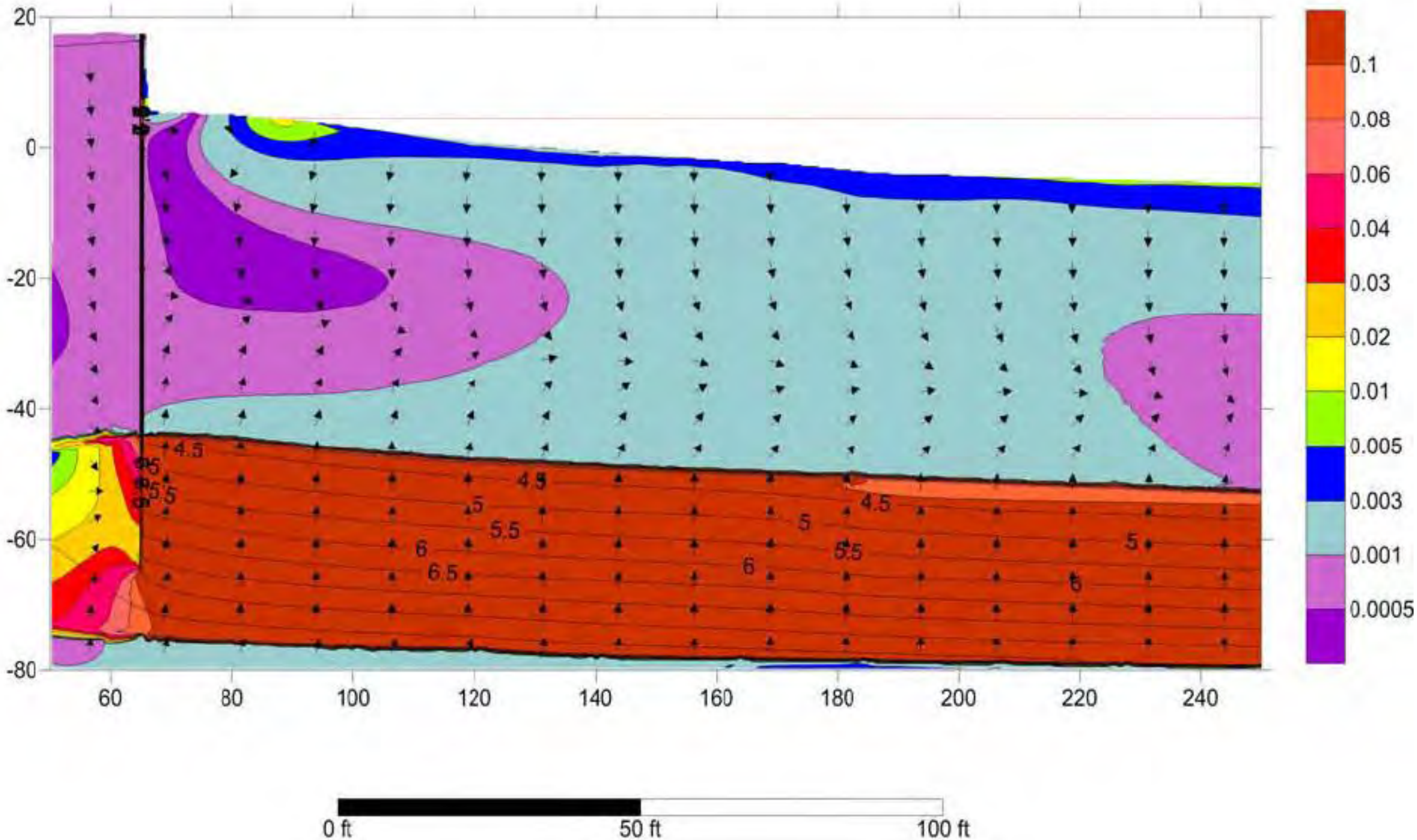

Figure B-52
Basecase Simulation at 200 Hours
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 200 hrs on 12/14/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall

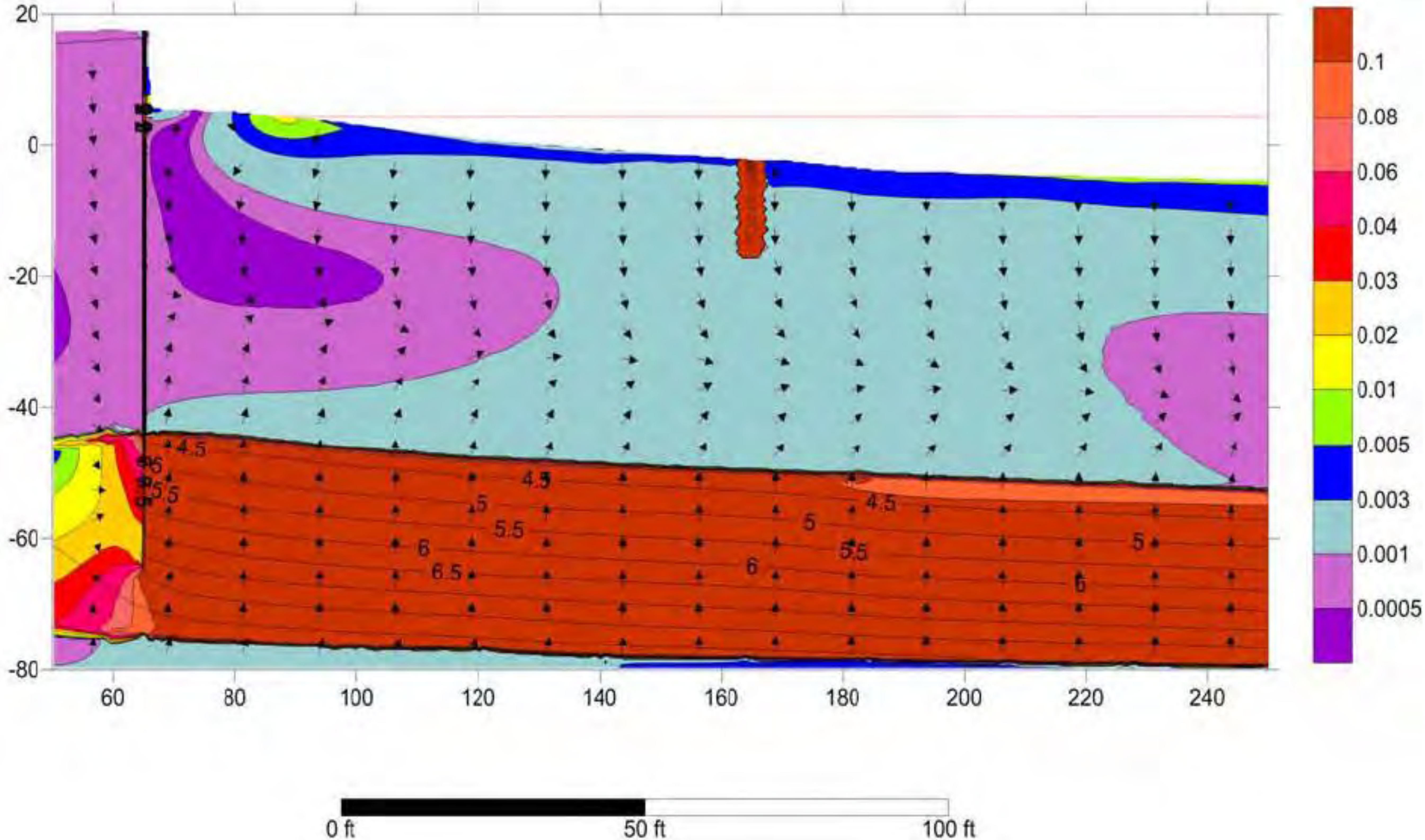

Figure B-53
Vertical Barrier Simulation 200 Hrs
Wyckoff OU-1 Focused Feasibility Study

Simulated Head and Hydraulic Gradient at 200 hrs on 12/14/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall – 0.3 ft/day Cap

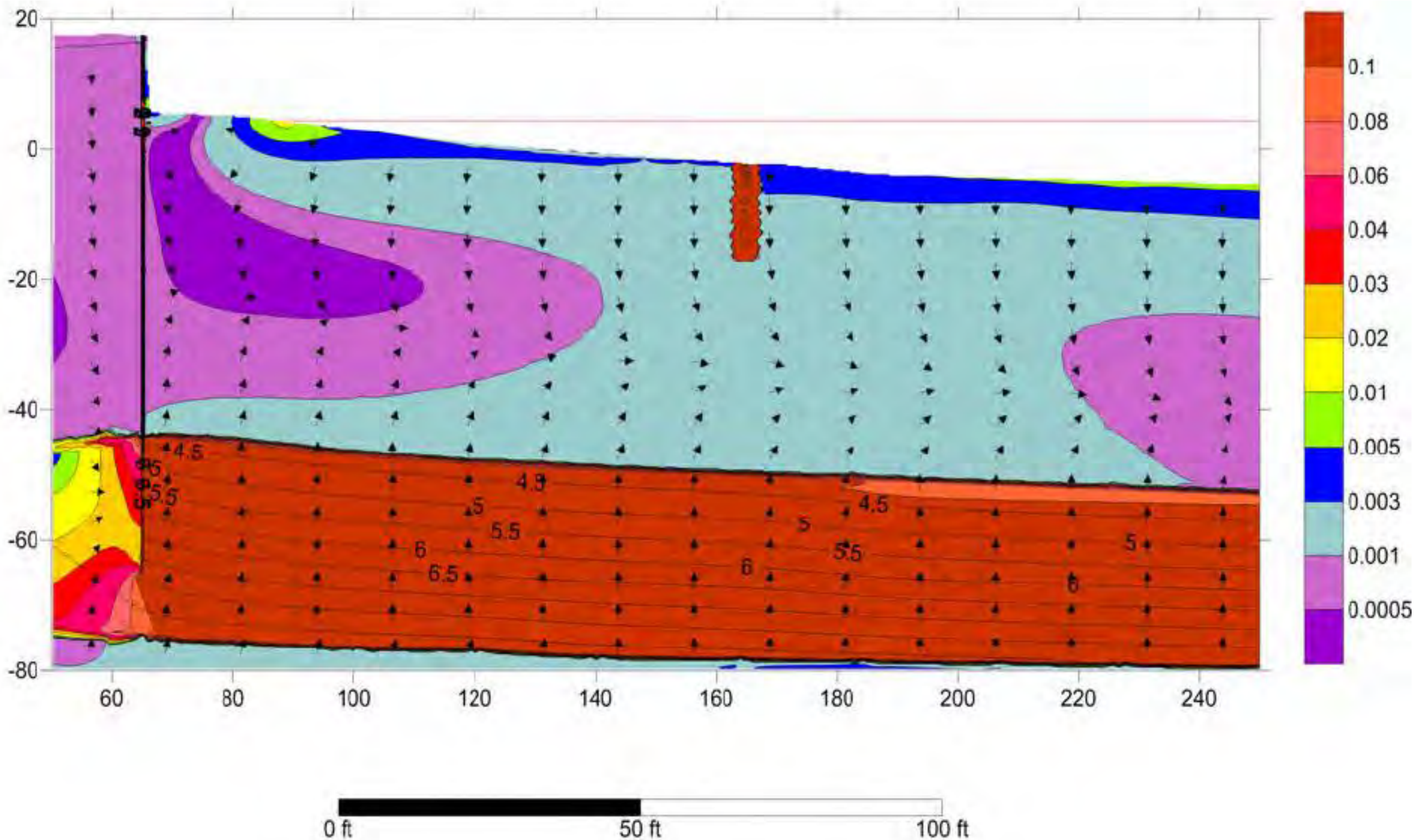

Figure B-54
Vertical Barrier plus Capping Simulation 200 Hrs
Wyckoff OU-1 Focused Feasibility Study

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Simulated Head and Hydraulic Gradient at 300 hrs on 12/14/2012 - Basecase

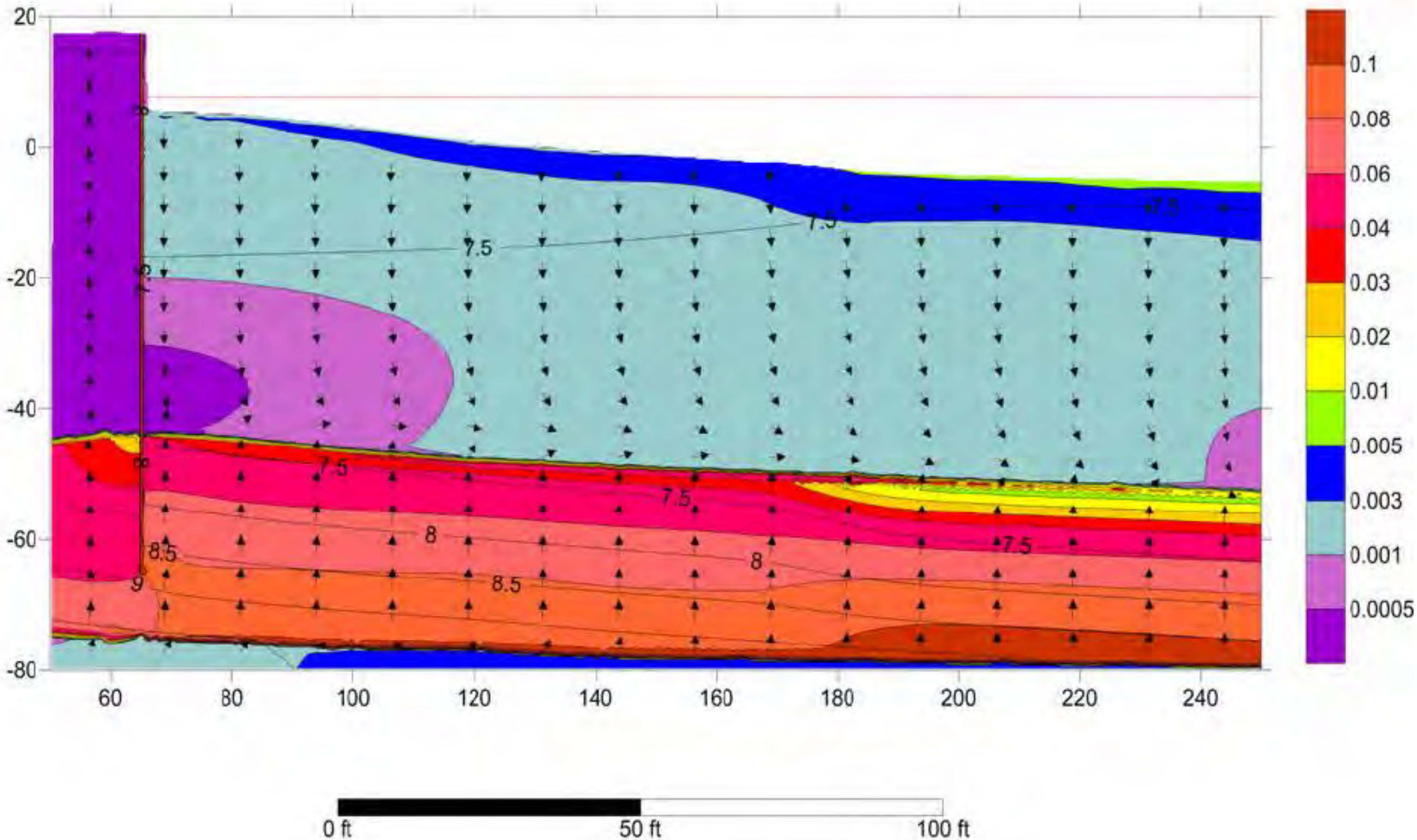

Figure B-55
Basecase Simulation at 300 Hours
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 300 hrs on 12/14/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall

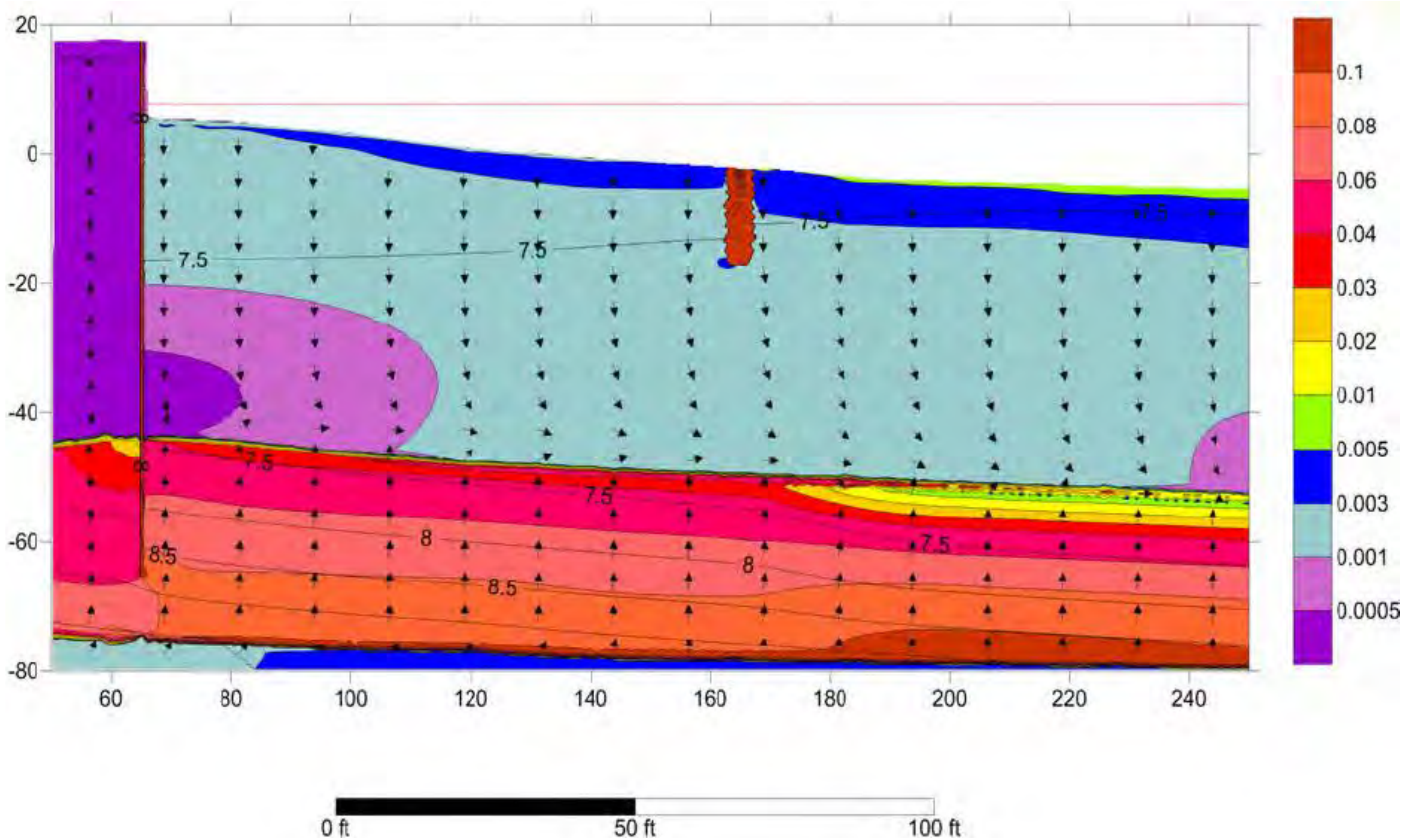

Figure B-56
Vertical Barrier Simulation 300 Hrs
Wyckoff OU-1 Focused Feasibility Study

EPA

Simulated Head and Hydraulic Gradient at 300 hrs on 12/14/2012 – 15 ft Deep Vertical Barrier 100 ft from Sheetpile Wall – 0.3 ft/day Cap

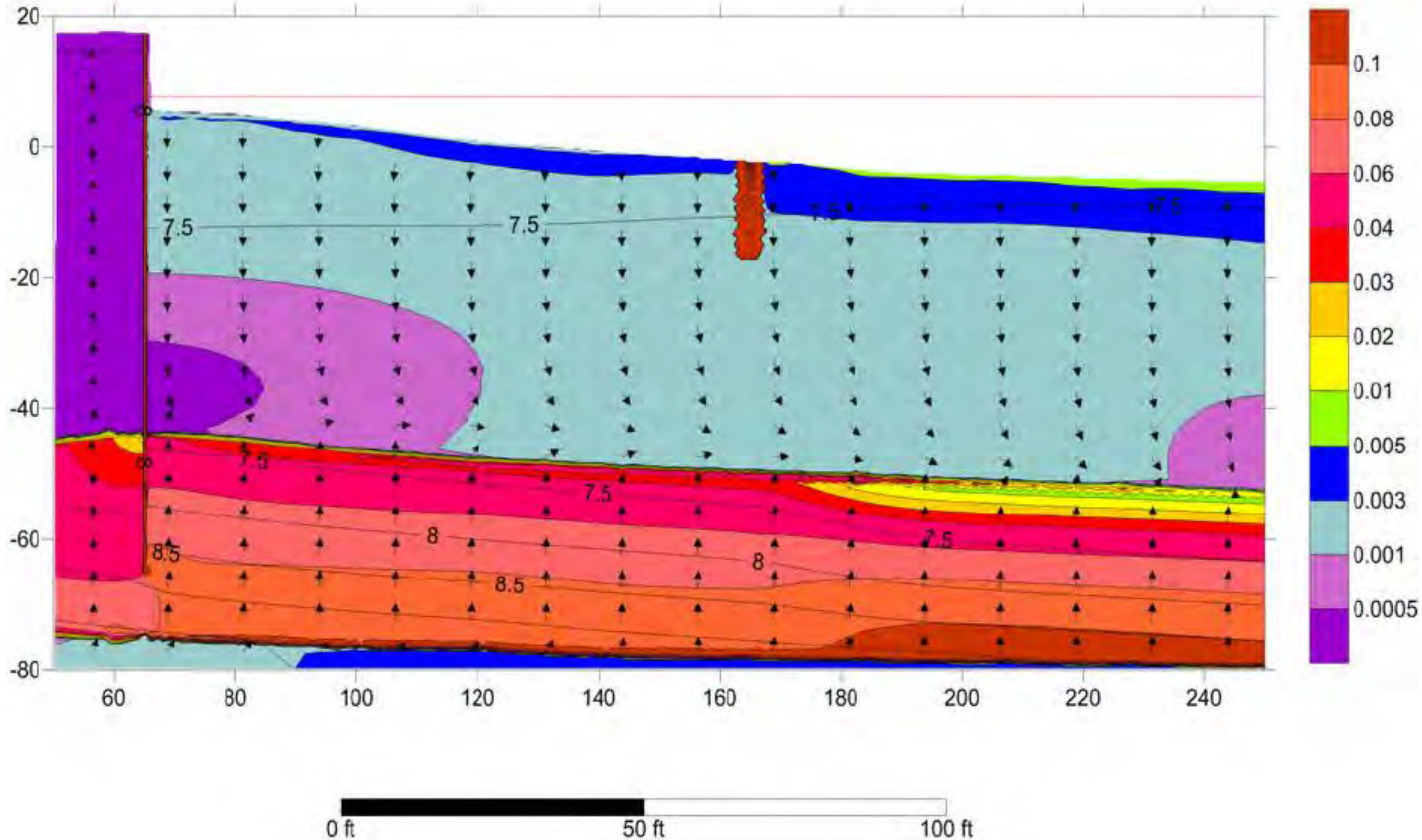

Figure B-57
Vertical Barrier plus Capping Simulation 300 Hrs
Wyckoff OU-1 Focused Feasibility Study

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Appendix C
Analysis of Wave-Driven Sediment Transport at the Wyckoff OU-1 Focused Feasibility Study Project Area, Bainbridge Island, Washington

Analysis of Wave-Driven Sediment Transport at the Wyckoff OU-1 Focused Feasibility Study Project Area, Bainbridge Island, Washington

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PREPARED BY: Adele Buttolph/PDX

DATE: May 22, 2013

PROJECT NUMBER: 427757.FS.01

1. Introduction

This Technical Memorandum provides a baseline analysis of wave-driven sediment transport at the OU-1 Focused Feasibility Study (FFS) Project Area of the East Harbor Operable Unit (OU-1), Wyckoff Eagle Harbor Superfund Site. The FFS Project Area is located on Bainbridge Island, Washington (Figure 1). This sediment transport analysis presents information on coastal conditions and processes to support the conceptual site model for FFS Project Area. The objectives of this analysis are to:

- Evaluate sediment transport from wave breaking and wave-induced currents
- Identify potential erosion and accretion areas
- Corroborate the understanding of the coastal regime and related process assumptions

The calculation approach, results of modeling, and conclusions drawn from the analysis address the morphologic stability of emergent tidal and shallow subtidal areas.

2. FFS Project Area Description

The FFS Project Area is 10.8 acres and includes intertidal portions of the OU-1/East Harbor area (Figure 1). The project area extends between about elevations 0 to -1 foot Mean Lower Low Water (MLLW) at the seaward edge to about 6 to 15 feet MLLW toward the upper beach and the sheet pile wall that forms the boundary between the FFS Project Area with the Wyckoff uplands. The sheet pile wall was installed between 1999 and 2001 and provides containment for NAPL released in the upland during historical operations.

The general marine setting of the FFS Project Area consists of beach and tideflat environments along the North Shoal and East Beach as identified on Figure 2. These areas are described as follows:

North Shoal. The North Shoal consists of the intertidal area on the north shore of the former Wyckoff facility. It is bounded to the west by the transition to capped areas of the West Beach, and to the east by the transition to the East Beach.

East Beach. The East Beach consists of the intertidal area on the eastern side of the former Wyckoff facility. It merges to the north with the North Shoal and extends south to just beyond the former Wyckoff facility boundary.

3. USACE 2012 Sediment Stability and Mobility Analyses

Work for the current coastal analysis builds on sediment stability and mobility modeling conducted by the US Army Corps of Engineers (USACE) as part of the Final 2011 Year 17 Monitoring Report for the East Harbor Operable Unit, Wyckoff/Eagle Harbor Superfund FFS Project Area (USACE 2012). The 2012 USACE monitoring report included a Sediment Stability Report (Appendix C), and an Operations, Maintenance, and Monitoring Plan Sediment Mobility Analysis (Appendix D). The USACE work consisted of bathymetric/topographic surveys, and circulation and wave modeling conducted to evaluate sediment transport potential over a relatively broad scale in

Eagle Harbor. The current sediment transport analysis for the OU-1 FFS adapts and refines modeling elements on a more detailed scale. This includes evaluation of effects of breaking waves and longshore transport to better establish baseline coastal conditions for the FFS Project Area.

Physical stability of sediments at the FFS Project Area was investigated using bathymetric and topographic surveys conducted by the USACE as documented in their 2012 Sediment Stability Report (USACE 2012 Appendix C). Surveys were conducted over time and differences between survey elevations were computed to assess sediment stability. Although the North Shoal and East Beach sections were determined to be stable, uncertainties in the survey data were similar in value to the changes computed. Each survey had an accuracy of ±1 feet in water depths less than less than40 feet. The potential “worst case” cumulative error when comparing two data sets could be as much as 2 feet. This uncertainty was compounded by the combining of surveys from more than one year into a single data set. Calculated changes (both erosion and accretion) appear to be primarily in the range of 2 feet. Therefore, changes in elevation are about the same as the potential error in the measurements. Thus, tolerance and accuracy considerations may affect the representativeness of the surveys at this scale. .

Processes controlling sediment mobility and transport include waves, currents, and vessels. USACE conducted a study for the overall Wyckoff/Eagle Harbor site to determine the roles of vessels, tidal currents, and wave orbital velocities on sediment transport (USACE 2012 Appendix D). USACE applied the Coastal Modeling System (CMS)-Flow model (Buttolph et al. 2006) to compute tidal currents, and applied the CMS-Wave model (Lin et al. 2008) to calculate wave fields from which orbital velocities were determined. CMS-Flow is a two-dimensional circulation and sediment transport model that calculates water level, currents, sediment transport, and morphology change. CMS-Wave is a steady state spectral wave generation, propagation, and transformation model. CMS models have been developed for engineering applications and contain features targeted for a wide range of coastal project needs. The two models were run separately so that the specific roles of tidal currents and wave orbital velocities could be evaluated for sediment mobility potential The analysis was conducted by computing stresses and sediment mobility potential in a post-processing mode rather than including sediment transport calculations from within the modeling system. The study found that, of the three factors investigated, vessels provide the dominant forcing for potential sediment mobility within Eagle Harbor, including North Shoal and East Beach.

On many shorelines and coasts, waves are the dominant driving force for sediment transport along the coast. As waves propagate into shallow water, the processes of wave transformation and breaking creates conditions for sediment mobilization. These processes also generate wave-induced longshore currents. Wave properties and angle of wave attack to the shoreline control the strength of the longshore current. During periods of sufficiently large waves, sediment is mobilized within the surf zone and transported by the longshore current.

The Wyckoff/Eagle Harbor sediment stability analysis conducted by the USACE did not specifically include wave-driven longshore transport, as it was not necessary for the purposes of that study. By extending the modeling effort to include evaluation of wave-driven longshore current on sediment transport, the present analysis further evaluates the analysis of coastal processes affecting the FFS Project Area. The current analysis includes determination of whether the existing material is stable or prone to erosion.

FFS Project Area Coastal Analysis Approach

The current coastal analysis for the FFS Project Area describes modeling conducted to investigate the following:

- Role of wave breaking and wave-driven sediment transport as controls on erosion and accretion
- Morphologic stability at the FFS Project Area
- Transport patterns including transport of material into the FFS Project Area from the south

The approach taken to evaluate morphologic stability and wave-driven longshore transport along the North Shoal and East Beach was to conduct coupled circulation, wave, and sediment transport modeling over spring tidal conditions during 100-yr wind forcing. Coupling the models provides calculation of currents generated by breaking waves over the entire tide range, thereby providing information on wave-driven transport for areas in the nearshore zone and beach areas.

Although the modeling was conducted using the best information available, it should be considered a reconnaissance-level effort owing to the limits of current bathymetric survey accuracy, coverage, and spatial density which were not sufficient to calibrate the sediment transport model.

Numerical Modeling

The following summary documents the circulation, wave, and sediment transport modeling conducted for this study.

Numerical modeling was conducted by applying the CMS-Flow and CMS-Wave models. CMS-Flow and CMS-Wave can be operated in a coupled mode that provides for interactions between the two models resulting in a more complete representation of processes than running each model separately. For example, CMS-Flow provides time-varying total water depth (resulting from tidal elevation and morphology change if sediment transport is invoked) and current fields to CMS-Wave allowing for waves to respond to both water depth and currents. CMS-Wave provides wave properties to CMS-Flow allowing for calculation of wave-driven currents, wave-driven sediment transport, wave-induced mixing, and wave-driven setup. For the subject study, the 64-bit parallel implicit version of CMS-Flow (CMS-Flow v4r14-64p) was applied which contains CMS-Wave embedded within it. All grid development, model setup, production runs, and post-processing was conducted within the Surfacewater Model System (SMS) version 11. Documentation on the SMS can be found at the following web site: http://www.xmswiki.com/xms/SMS:SMS.

The initial step was to refine the CMS grids developed by the USACE by increasing resolution in the North Shoal and East Beach areas. The CMS-Flow model developed by the USACE took advantage of a relatively new feature in the model called telescoping grid. This feature allows for grid development containing fewer cells than a traditional spatially-variable grid thereby reducing computation time. Presently, the SMS system does not include the capability to edit telescoping grids, therefore requiring development of a new CMS-Flow grid for this study. A new telescoping grid was developed with high resolution in the FFS Project Area. However, testing of the coupled CMS-Flow and CMS-Wave system using the telescoping CMS-Flow grid resulted in an unstable grid configuration from a modeling perspective. Therefore, a non-telescoping CMS-Flow grid was developed and applied to the study. The non-telescoping grid did not exhibit the stability problems that were experienced with the telescoping grid.

Bathymetry for the models was obtained from two sources. Data from bathymetric surveys conducted by the USACE were applied for the Wyckoff FFS Project Area. Bathymetry for Puget Sound was obtained from an online digital database developed by the University of Washington (Finlayson 2005). The two datasets were combined and mapped to the model grids. USACE survey data was applied in a priority mode with the Puget Sound data mapped to all areas not covered by the survey data. The vertical datum applied in the models is mean sea level in units of meters. Grids were referenced to Washington North State Plane (FIPS 4601) in units of meters.

CMS-Flow and CMS-Wave grids were defined over identical domains. Figure 3 shows the model domain and bathymetry. Bathymetry within Eagle Harbor is shown in Figure 4. The CMS-Flow grid was developed first with greatest resolution specified at the FFS Project Area. To calculate sediment transport and morphology change in the nearshore area and on the beach, resolution in the range of 5 to 12 m was specified. Detail of the CMS-Flow grid spacing in the FFS Project Area is shown in Figure 5.

CMS-Wave was refined further in the study to provide a more detailed representation of the sheet piling along the North Shore and East Beach areas of the grid. This refinement was conducted by splitting cells that overlay the sheet pile to reduce their size and to provide an improved representation of the vertical wall. Figure 6 shows detail of the CMS-Wave grid resolution at the FFS Project Area. Minimum cell size in the CMS-Wave grid is 2.4 m.

Modeling of sediment transport requires specification of grain size over the model domain. Median grain size (d50) for the FFS Project Area was obtained from grain size information provided in the 2011 OU-1FFS Project Area monitoring report (USACE 2012) and mapped to the CMS-Flow grid. Figure 7 shows the sediment sample locations and median grain size of samples applied in the modeling. Outside of the FFS Project Area, an approximated representative median grain size of 0.2 mm was specified. This median grain size was selected based on the grain size analysis contained in the USACE 2012 report which showed that a large percentage of material that was collected fell into the sand sized particle class. Because sufficient survey and grain size data are not available to calibrate the sediment transport model, default sediment transport parameters values were applied. Default values are expected give reasonable results, although results can be improved by calibration with higher-resolution survey data.

Boundary conditions for CMS-Flow were specified at two boundaries in the northern portion of the grid corresponding to Port Townsend and Everett. Measured water-surface elevation values obtained from NOAA gauges at Port Townsend (gauge 9444900) and Everett (gauge 9447659) were applied as tidal forcing. Locations of the Port Townsend and Everett gauges are shown in Figure 8. Overlapping data availability at the Port Townsend and Everett gauges was limited. Verified 6-minute water-level values at the Port Townsend gauge were available from January 1, 1996 through December 31, 2012 (gauge is presently operating). Verified 6-minute water levels values at the Everett gauge were available for November 3, 1995 through February 20, 1996. Based on the data availability for the two gauges, CMS-Flow validation was conducted for the full month of January 1996 and production simulations were specified to start on January 18, 1996 so that the spring tide range was simulated.

Wave-driven sediment transport is most intense during storms. Forcing for the wave model was specified to be a subset of the 100-year 2-minute winds applied to force the wave modeling conducted by the USACE in their analysis (Table 1**Error! Reference source not found.**). Winds selected for this analysis ranged in direction from 60 to 180 degrees azimuth. Direction convention for winds used in this analysis is 0 degrees denoting wind from the north and directions increasing clockwise. The USACE analysis also included wind from more easterly to northerly directions. In this analysis, winds from these directions were not included because the FFS Project Area location is sheltered from waves propagating from north to south in the main body of Puget Sound.

TABLE 1
Wind Speed and Direction Applied to Wave Model

Wind Speed (m/s)	Wind Direction[1] (degrees)
8.2	60
7.7	90
9.8	120
17.0	150
26.2	180

[1] Directions are wind "from" 0 degrees (north) and increasing clockwise.

Five production simulations were conducted with each applying one wind velocity from Table 1 to force CMS-Wave. CMS-Flow and CMS-Wave were coupled at 1-hour intervals which provided for smooth transitioning of wave and transport properties over the tide range. Simulation duration was specified to be 96 hours with 24 hours of ramp to full forcing. The hydrodynamic time step and model output were set to 15 minute intervals. Sediment transport was computed by application of the non-equilibrium transport formulation which has been demonstrated to perform well for coastal applications (Sanchez and Wu 2011; Wu et al. 2013).

The five simulations were identical except for the wind velocity applied. For each simulation, wind velocity applied to the wave model was held constant over the duration of the simulation. It should be noted that the wind velocities applied in the modeling effort are 2-minute 100-year extreme values and would not occur in nature over the duration of the simulations. To estimate the degree of conservatism for the range of wind speeds applied, the ratios of the 2-minute wind speeds to estimated hourly wind speeds, following the 1984 Shore Protection Manual approach, are 1.12 for the minimum wind speed applied (7.7 m/sec) and 1.24 for the maximum wind speed applied (26.2 m/sec). This specification of winds in the modeling effort was conducted to allow for response of waves and sediment transport over a range of tide levels and to provide sufficient time within the model to allow for enough morphology change to take place that patterns of erosion and accretion at the FFS Project Area, if developed, would have strong signatures. Morphology change calculated by the simulations would be large compared to an actual storm event because of the persistent and constant extreme wind forcing applied in the model. During actual storms, winds come from a range of directions and vary over time. Therefore, morphology change results from the modeling are considered conservative.

4. CMS-Flow Model Validation

CMS-Flow was validated for water-surface elevation at NOAA Seattle gauge 9447130 (Figure 8**Error! Reference source not found.**) for the month of January 1996. A comparison of NOAA measured and CMS-Flow calculated water levels for the validation period is shown in Figure 9**Error! Reference source not found.**. CMS-Flow water levels match measured water levels with error in maximum and minimum water levels ranging from 0 to 1 percent.

5. Results

Results of the sediment transport analysis modeling include time-series fields of wave properties, water level, currents, sediment transport, and morphology change. Plots of selected results are provided to illustrate processes that are most significant for the North Shoal and East Beach. Figures 10 through 14 show wave height and direction (top panel), current speed and direction (middle panel), and sediment concentration and direction (bottom panel) for input wind directions of 180, 150, 120, 90, and 60 degrees, respectively. Each figure was developed from fields at peak high tide when the currents, waves, and sediment transport have greatest coverage over the beach and nearshore areas of the FFS Project Area. Note that contour ranges for each field type are constant for the five figures with wave height range of 0 to 2.5 m, current speed range of 0 to 0.5 m/sec, and sediment concentration range of 0 to 0.6 kg/m^3. Constant contour ranges for each property allows for comparison of fields for the range of wind forcing. The sediment transport model computes both bed load and suspended load. Model output of sediment concentration is total load (both bed and suspended loads).

Waves are highest for winds originating from the south owing to the fetch length and greatest wind strength (26.2 m/sec). Modeled wave heights east of the FFS Project Area exceeded 2.6 m. Heights of waves reaching the FFS Project Area decrease with wind directions rotating from south, to northeast, through east). This decrease in height with wind direction owes to combination of fetch, wind strength, and sheltering of waves from the northeast.

Well-developed longshore currents are generated along the shoreline for wind directions of 180, 150, and 120 degrees. These currents develop south of the FFS Project Area and flow northward into the area. There is a weakening of the longshore current in the central to north parts of the East Beach, and then strengthening and broadening of the current on the northeast part of North Shoal. These wave-driven currents range in strength from near zero along East Beach to approaching 0.5 m/sec in the northeast part of North Shoal. For winds originating from 90 and 60 degrees, the longshore current is weak to non-existent.

Plots of sediment transport indicate that material is mobilized for each of the wind and wave conditions simulated, but less material is mobilized for simulations with winds originating from 90 and 60 degrees, as compared to winds from 180, 150, and 120 degrees.

Transport of the material is a function of transport rates shown by the vectors in the sediment transport plots. Because of the magnitude of the transport rates, the vectors showing the range of transport rates is somewhat complex to interpret. Current speeds can be viewed as a surrogate for transport rate such that stronger transport will take place in the same areas as stronger currents. In areas where material is introduced into the water column but transport rates are weak, material will be redeposited near its original location. In areas where the transport rate is stronger, material will continue to migrate in the direction of transport. For the simulations with winds from the south and southeast, material will be mobilized by the waves and carried parallel to the shoreline and across the North Shoal by the wave-driven current. Material will enter the FFS Project Area carried by wave-driven currents from the south.

Morphology change plots for each simulation are shown in Figure 15. For these figures, the contours range is specified such that with negative values denoting accretion (shown in yellow/orange) and positive values denoting erosion (shown in blue). Simulations with winds from 180 and 150 degrees show the greatest morphology change at localized areas in the vicinity of the boundary between the North Shoal and East Beach. These locations are near the outer boundary of the FFS Project Area and are beyond the limits of non-aqueous phase liquid (NAPL) occurrence indicated by site investigation activities. The inferred NAPL extent in the OU-1 FFS Project is described in the 2012 Field Investigation Technical Memorandum (CH2M HILL 2013).

Morphology change for the simulation with wind from 120 degrees shows a similar pattern to the simulations for 180 and 150 degrees, but with reduced change. The remaining two simulations with winds from 90 and 60 degrees effectively show no change.

Patterns of morphology change for the 180 and 150-degrees wind direction simulations show areas of localized erosion and accretion in the general area near the outer boundary of the FFS Project Area where the North Shoal and East Beach meet. The simulations were forced by constant 100-year extreme winds over 72-plus hours of simulation time which far exceeds the forcing that would take place under natural conditions. An estimate of the rate of morphology change under these extreme conditions is obtained by computing the change in depth by the number of simulations hours. From this approach, we obtain an estimated rate of morphology change of less than 0.005 m/hr under 100-year extreme wind conditions for the areas of greatest change within the FFS Project Area. This estimated rate of morphology change is considered to be at or near a maximum rate and would only occur for short duration during extreme events. Remaining areas of the FFS Project Area will exhibit lower rates of morphology change.

Evaluation of the modeling results indicates that even under extreme conditions the beach and nearshore areas of the FFS Project Area exhibit little to no change in morphology. Material is mobilized and transported by waves and wave-driven currents, primarily during periods when waves from southeast to south directions are present. This transport is directed from south to north along the shoreline starting south of the FFS Project Area and extending to the northern end of East Beach where it then approximately follows the curvature of the shoreline along North Shoal. Sediment is supplied from south of the FFS Project Area and appears to replace material lost from the FFS Project Area that may be occurring from transport.

Modeling of wave-driven transport processes in this analysis is expected to reasonably represent the interactions between forcings and response. However, it should be noted that without calibration of the sediment transport model uncertainties are present in the results. Although it is not possible to quantify the uncertainties, previous experience with the CMS system indicates that results should reasonably represent current sediment transport conditions and associated coastal processes.

6. Conclusions

Coupling of the CMS-Flow and CMS-Wave models provides additional information on currents and sediment transport processes compared to stand-alone application of each model. Specifically, the processes of wave-driven currents, initiation of sediment into the water column by wave breaking and dissipation, and longshore sediment transport were investigated in this study. This analysis fills a gap in knowledge of wave-driven processes at the FFS Project Area:

- The processes of wave transformation, breaking, and wave-driven current initiate mobilization of sediment from the seafloor bottom. This mobilization can take place under weak or strong wave forcing, although entrained concentrations are greater when larger waves are present.
- Wave-driven longshore current drives sediment transport northward along East Beach and follows the approximate shoreline curvature of the North Shoal. Longshore transport also carries material into the FFS Project Area from the south.
- Sediment transport investigated in this analysis originate from wave-induced currents and wave breaking processes. The USACE sediment mobility study found that tidal currents at the FFS Project Area are not sufficient to move material.

- Waves generated by winds from the south to southeast directions exert the dominant control on longshore currents and transport owing to stronger winds from southerly directions, greater fetch length, orientation of the FFS Project Area relative to these directions, and exposure of the shoreline to waves arriving from the south and southeast. The FFS Project Area is relatively sheltered from waves arriving from the north and as a result, these waves have little effect on the FFS Project Area.
- Predicted rates of morphology change at the FFS Project Area are relatively low even under 100-year extreme wind and wave forcing. Under normal conditions associated with more typical wind and wave conditions, morphology change is likely insignificant. Because of uncertainty in the present model from lack of calibration, some uncertainty is also associated with the rates of morphology change.
- Results do not indicate significant erosion promoted by wave breaking.
- High-resolution bathymetric surveys conducted before and after a storm season would provide calibration data for the sediment transport model. Calibration would further reduce uncertainty in model results.

7. References

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Figure 1
Focused Feasibility Study Project Area and Vicinity Map
Wyckoff OU-1 Focused Feasibility Study

EPA

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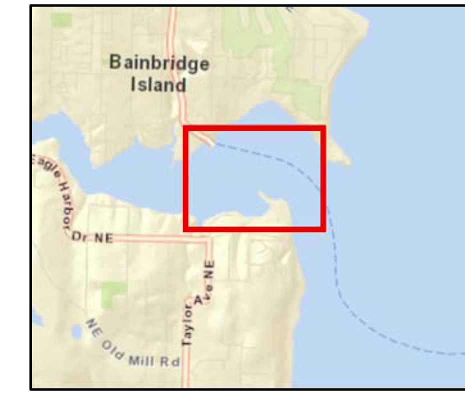

Focused Feasibility Study Project Area

Historical Features
(Locations are approximate)

Approximate Boundary Between East Harbor and West Harbor Operable Units

Structure Footprints

1994 Phase I Cap Boundary

2001 Phase II Cap Boundary

2002 Phase III Cap Boundary

2008 Exposure Barrier System

N

0 135 270 540 Feet

Figure 2

Focused Feasibility Study Project Area

Wyckoff OU-1 Focused Feasibility Study

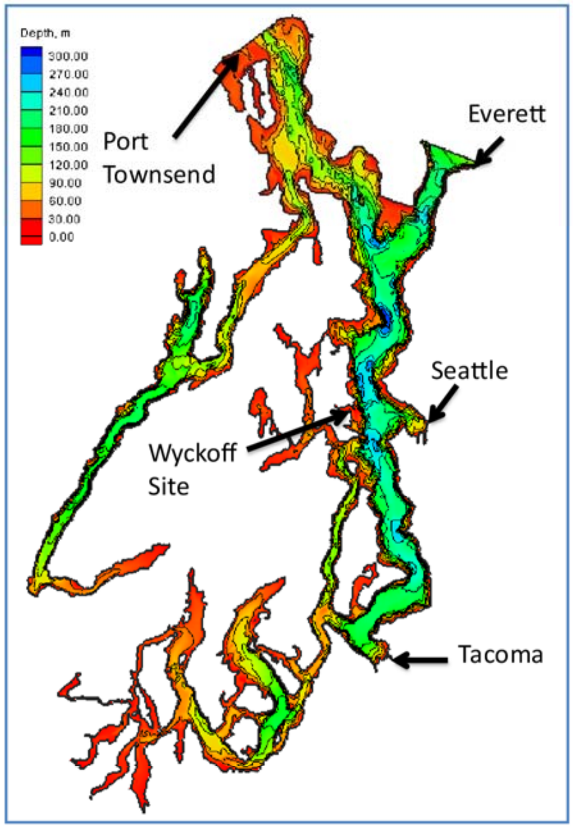

Figure 3
CMS Model Domain and Bathymetry
Wyckoff OU-1 Focused Feasibility Study

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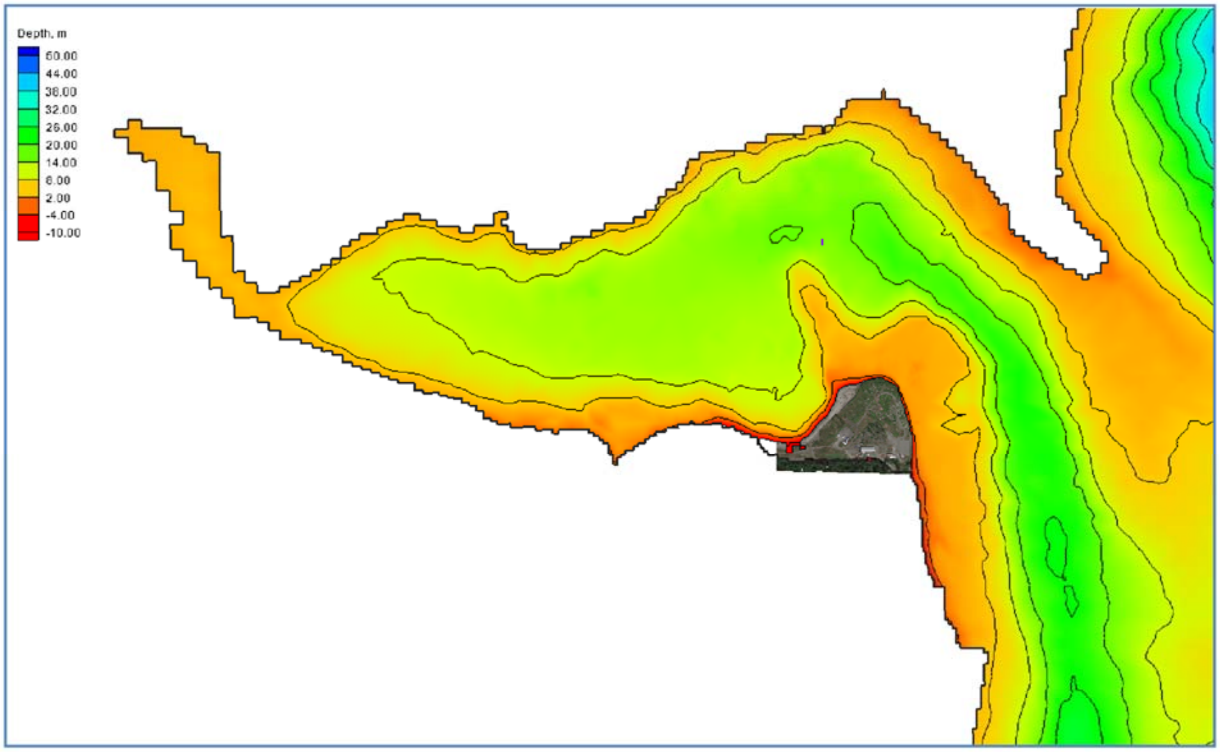

Figure 4
CMS Model Bathymetry for Eagle Harbor
Wyckoff OU-1 Focused Feasibility Study

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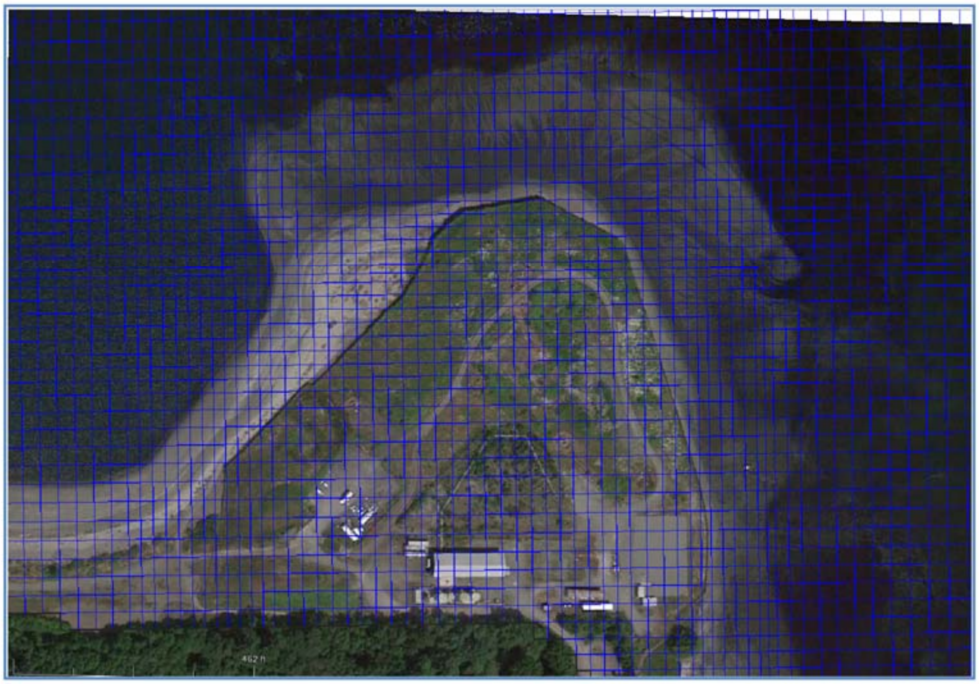

Figure 5
Detail of CMS-Flow Grid Resolution at Project Site
Wyckoff OU-1 Focused Feasibility Study

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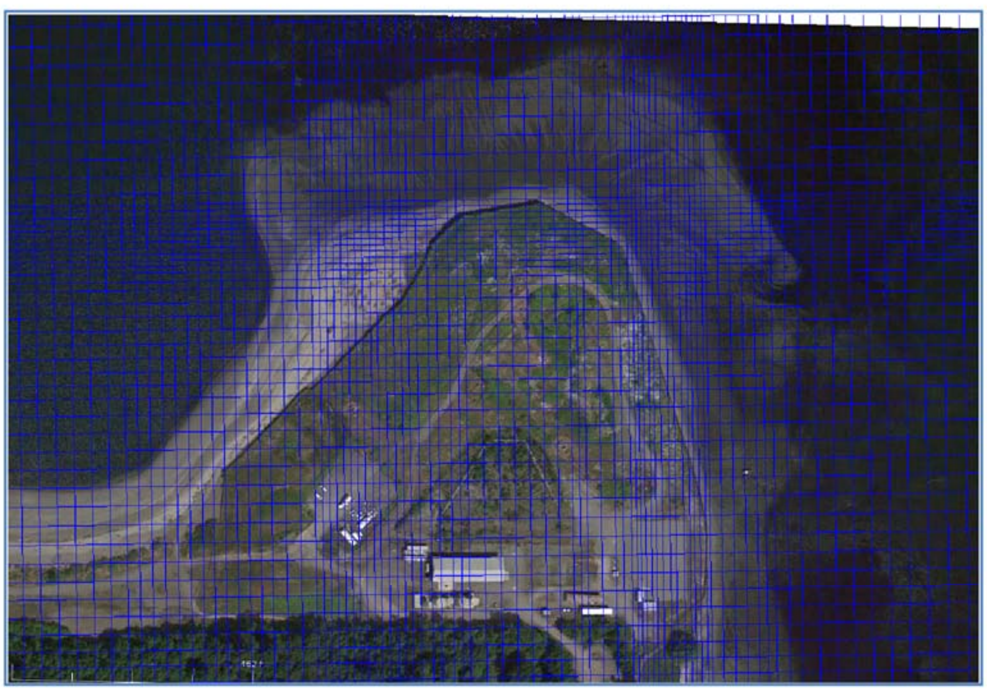

Figure 6
Detail of CMS-Wave Grid Resolution at Project Site
Wyckoff OU-1 Focused Feasibility Study

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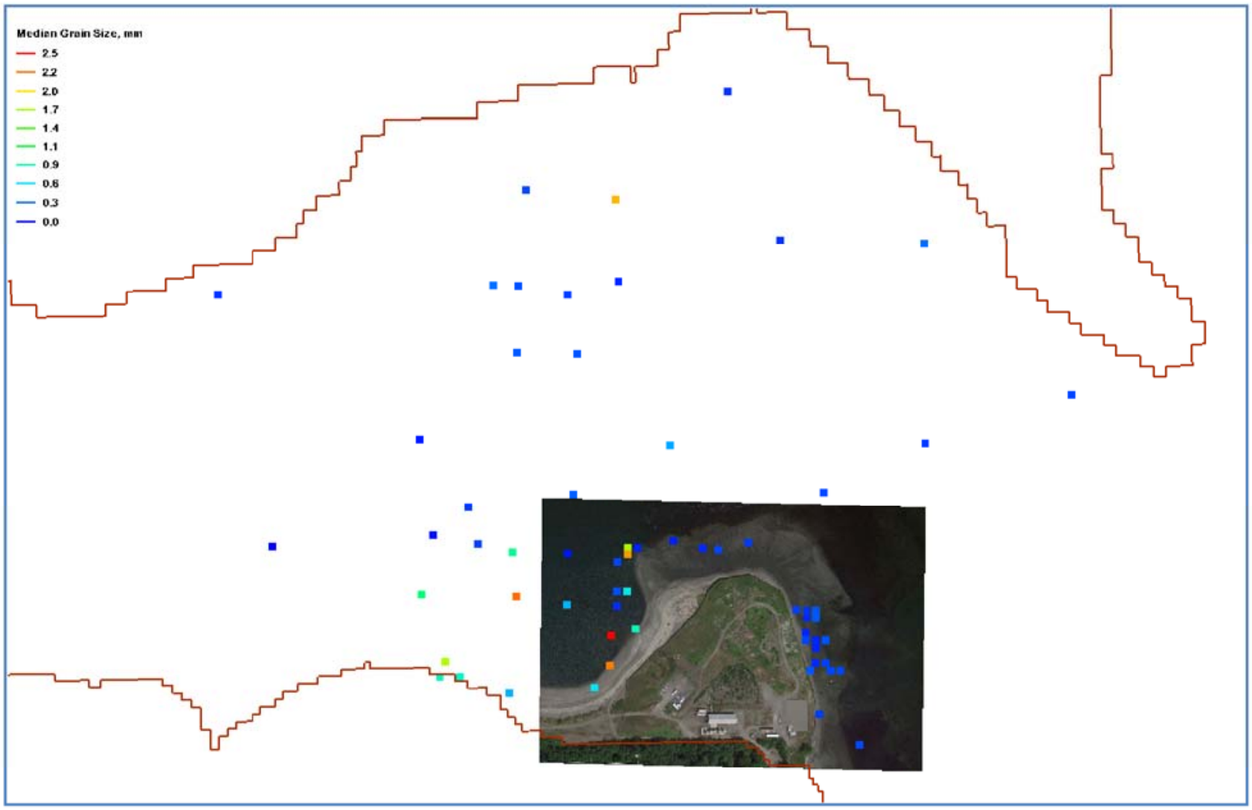

Figure 7
Sediment Sample Locations and Median Grain Size Applied in Model
Wyckoff OU-1 Focused Feasibility Study

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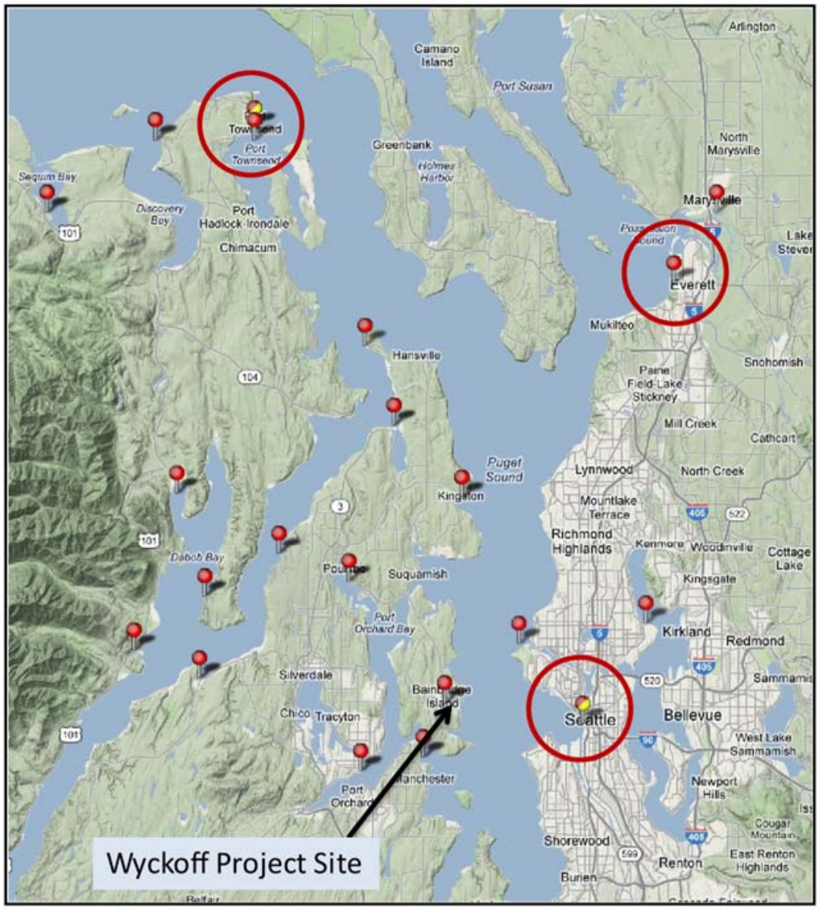

Figure 8
Locations of NOAA Water-Level Gauges (Circled in Red) Applied in this Study
Wyckoff OU-1 Focused Feasibility Study

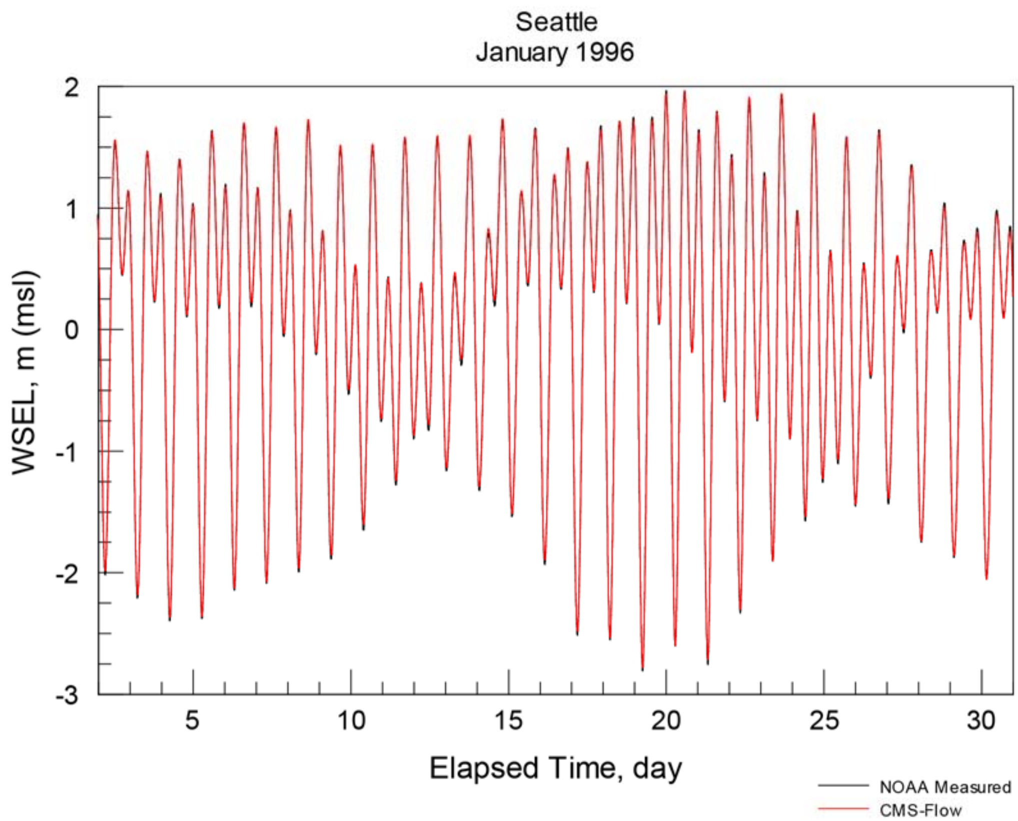

Figure 9
Comparison of Measured and Calculated Water Level at Seattle, WA for January 1996
Wyckoff OU-1 Focused Feasibility Study

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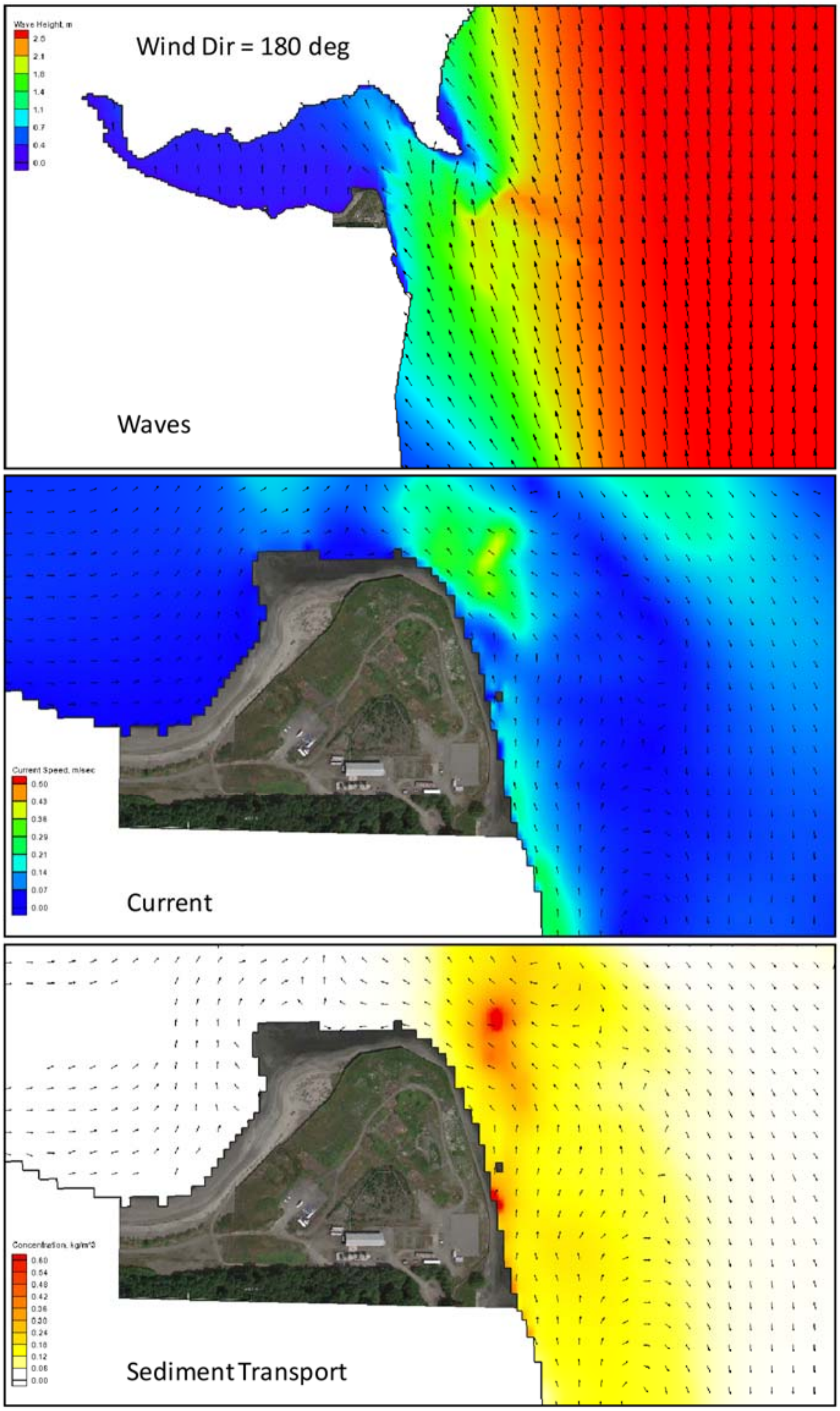

Figure 10
Waves, Currents, and Sediment Transport at Peak High Tide for Wind Direction = 180 deg
Wyckoff OU-1 Focused Feasibility Study

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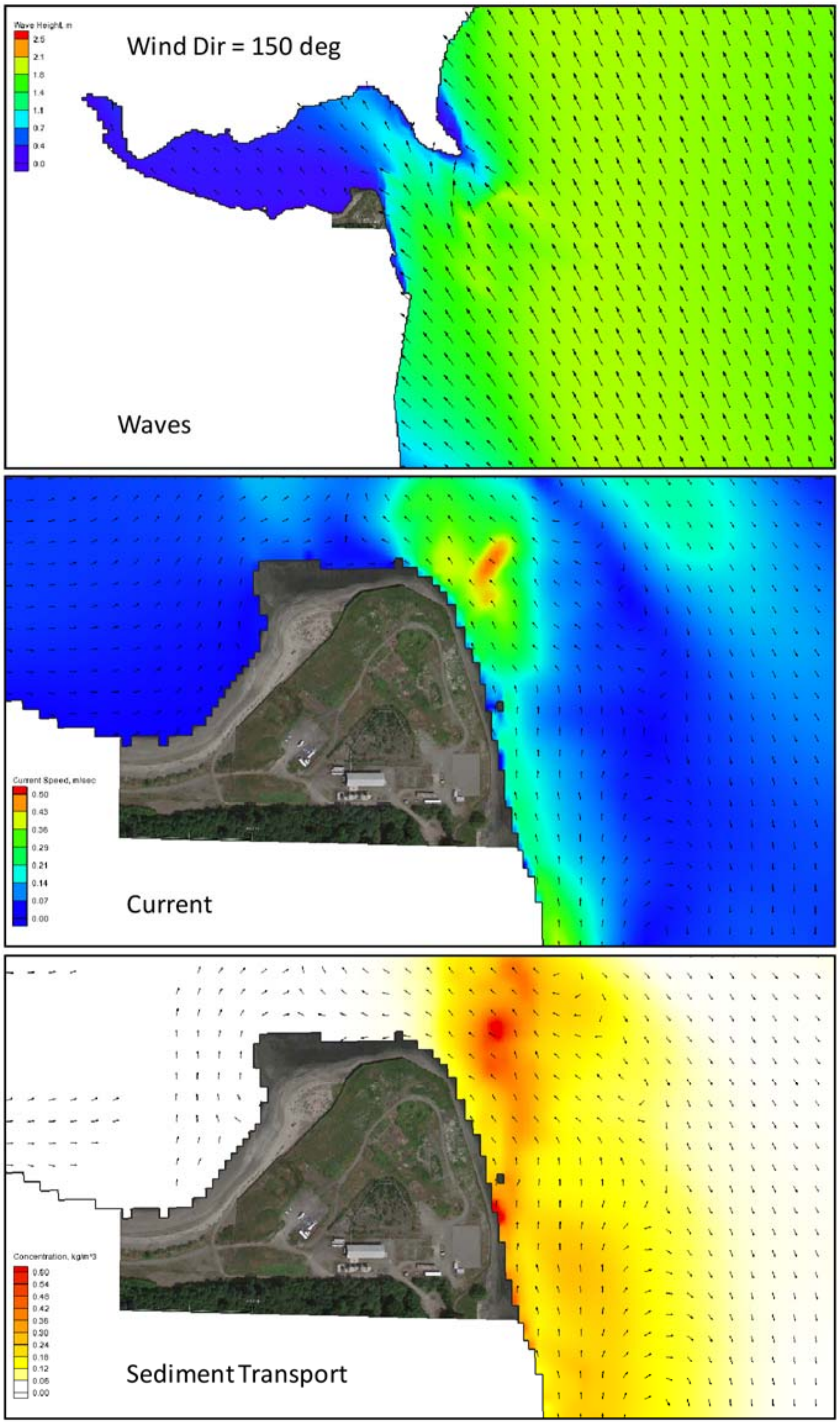

Figure 11
Waves, Currents, and Sediment Transport at Peak High Tide for Wind Direction = 150 deg
Wyckoff OU-1 Focused Feasibility Study

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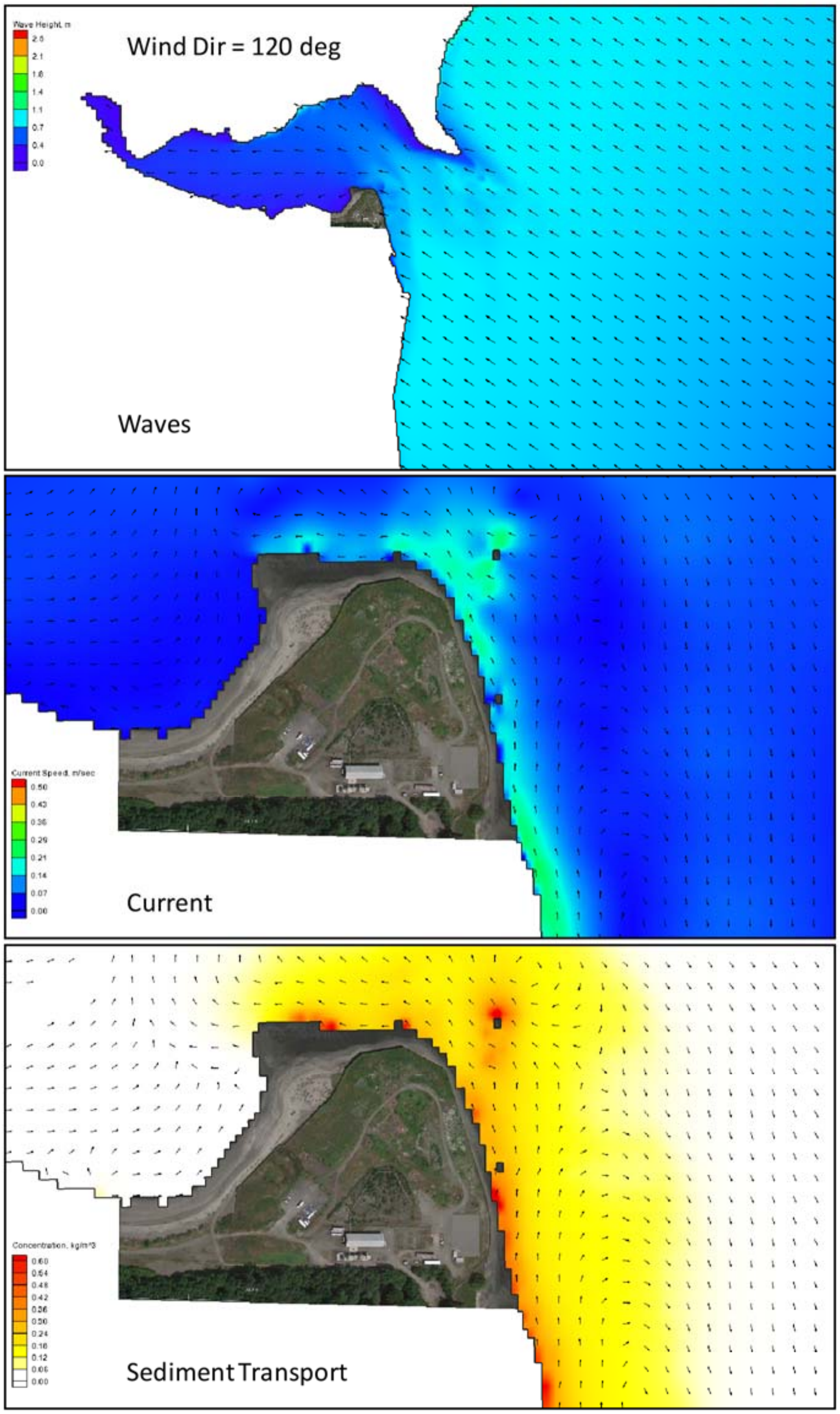

Figure 12
Waves, Currents, and Sediment Transport at Peak High Tide for Wind Direction = 120 deg
Wyckoff OU-1 Focused Feasibility Study

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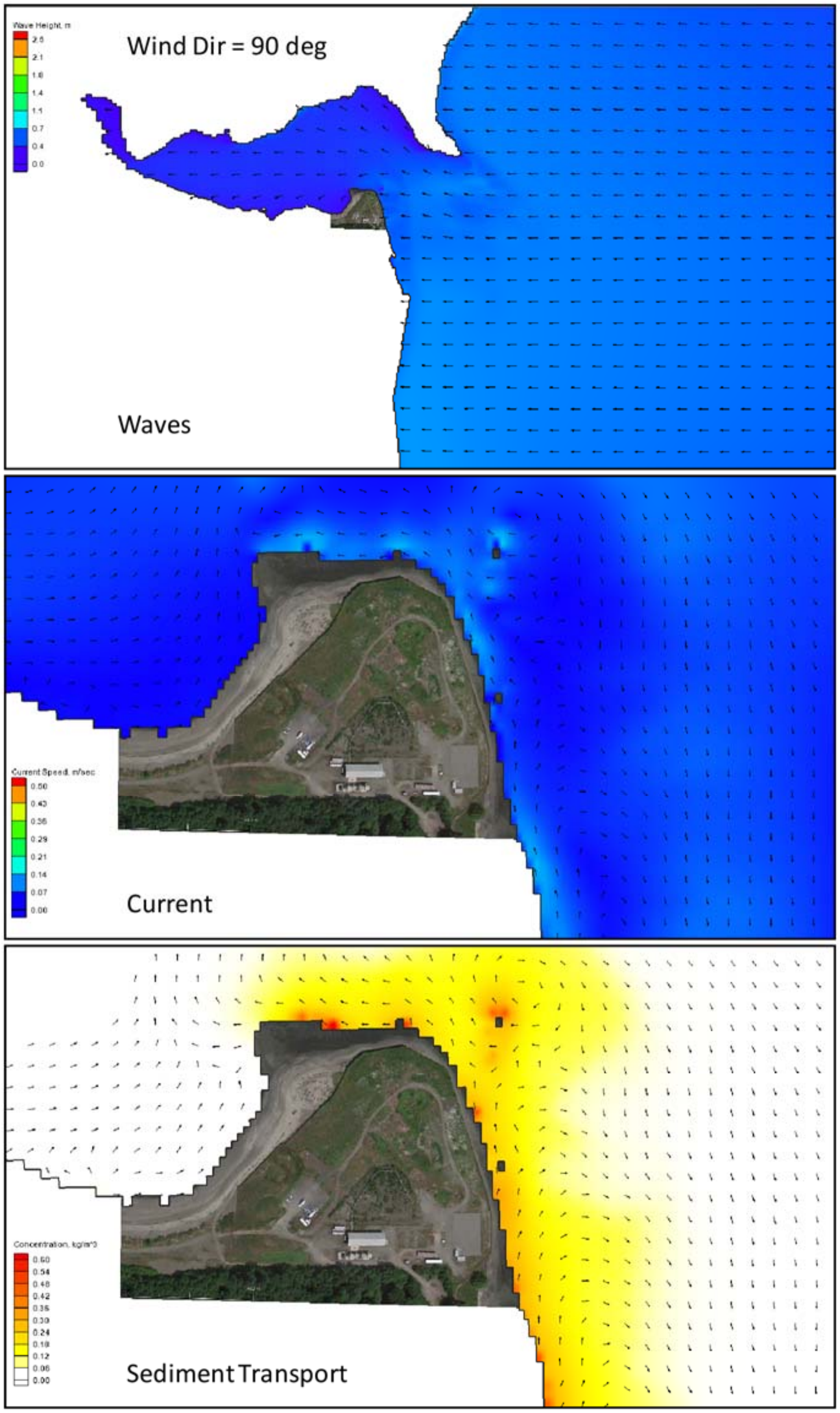

Figure 13
Waves, Currents, and Sediment Transport at Peak High Tide for Wind Direction = 90 deg
Wyckoff OU-1 Focused Feasibility Study

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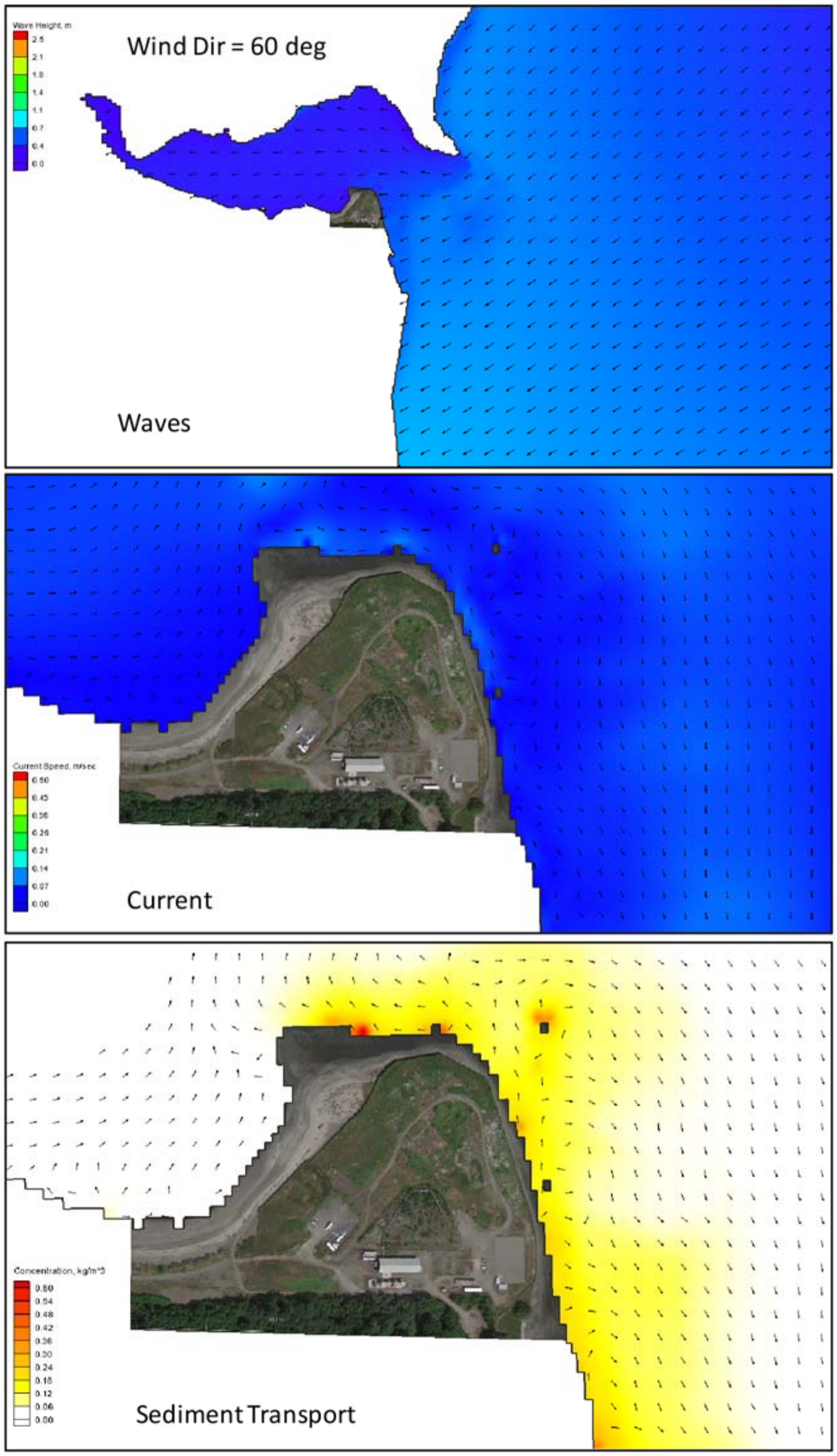

Figure 14
Waves, Currents, and Sediment Transport at Peak High Tide for Wind Direction = 60 deg
Wyckoff OU-1 Focused Feasibility Study

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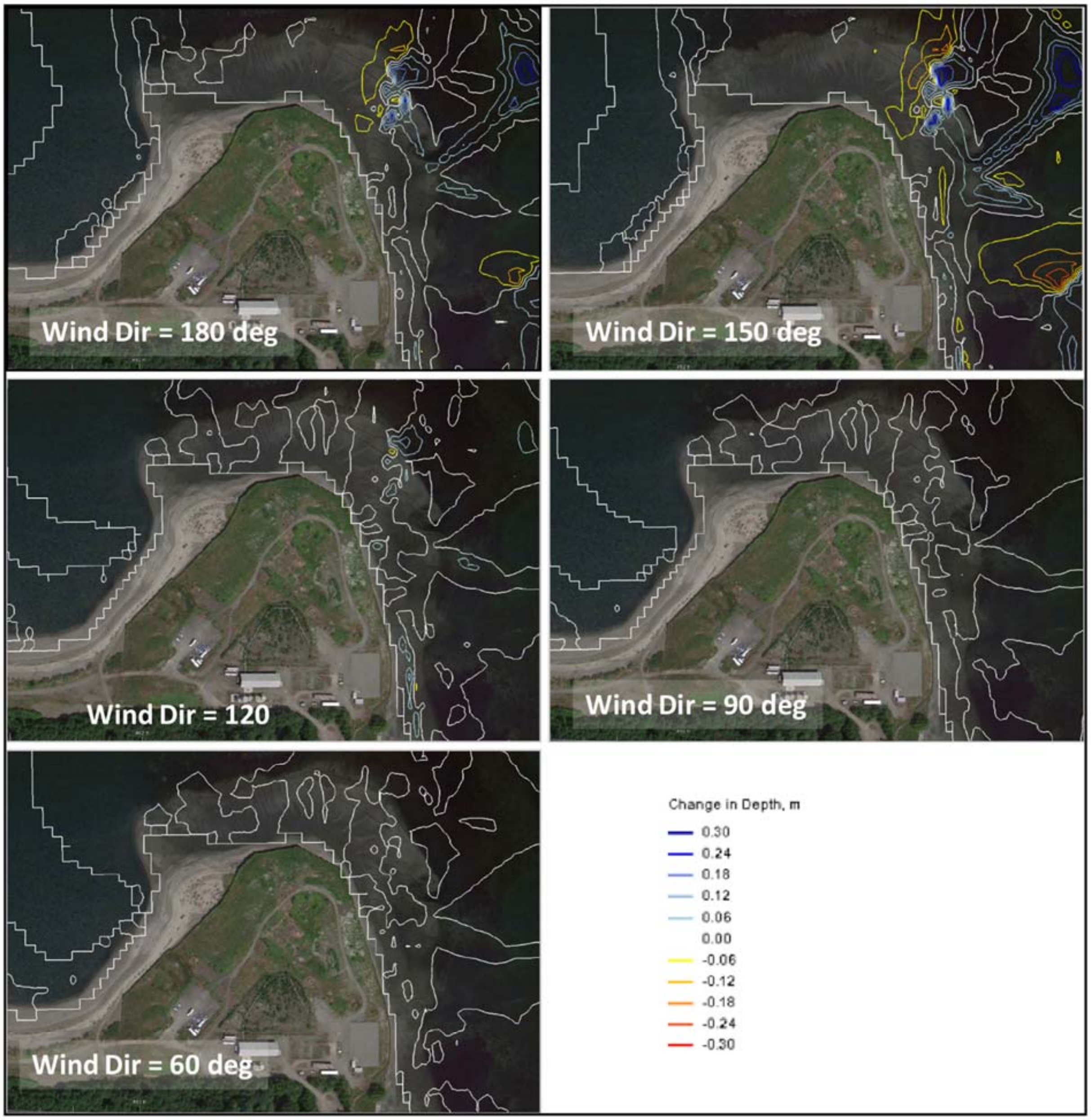

Figure 15
Calculated Morphology Change
Wyckoff OU-1 Focused Feasibility Study

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Appendix D
Intertidal Sediment Analytical Data Review, Wyckoff OU-1 Focused Feasibility Study Project Area

Intertidal Sediment Analytical Data Review
Wyckoff OU-1 Focused Feasibility Study Project Area

PREPARED FOR: Howard Orlean/EPA

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Justine Barton/EPA

PREPARED BY: Rick Moore/SEA; Joy Chen/SEA

DATE: April 24, 2013

1. Introduction

Wyckoff site monitoring events in 2001, 2002-2003, and 2011 included collection of sediment samples from the East Beach and North Shoal areas for laboratory analysis of polycyclic aromatic hydrocarbons (PAHs). Laboratory testing results from these monitoring events were reported and summarized in the East Beach Investigation Report (EPA and USACE 2002), 2002–2003 Year 8 Environmental Monitoring Report (Integral Consulting 2004), and the Third Five-Year Review Report (EPA 2012) and Final 2011 Year 17 Monitoring Report (USACE 2012), respectively. These sediment monitoring events followed completion of the sheet pile wall between the Wyckoff site uplands and Operable Unit 1 (OU-1) intertidal area in 2001.

EPA's Third Five Year Review Report (2012) summarized and compared sediment sample testing results from the 2002-2003 and 2011 monitoring events. The following discussion provides additional data analyses relative to analytical testing results of surface sediment samples (0 to 10 cm below grade) and other near-surface samples collected up to 2 feet below grade. Inclusion of samples up to 2 feet below grade is consistent with the approach used in the OU-1 Data Gaps Technical Memorandum (Quality Assurance Project Plan Appendix C, CH2M HILL 2012) to evaluate potential impacts of non-aqueous phase liquids (NAPL) from historical releases of creosote at the former Wyckoff facility.

2. Compiled Surface and Near-Surface Sediment Analytical Data

Tables 1 and 2 included with this Technical Memorandum compile laboratory analytical data for naphthalene and low and high molecular weight polycyclic aromatic hydrocarbons (LPAHs and HPAHs) indicator parameters to assess changes in sediment quality over time. Table 1 presents results for 0-10 cm surface samples and Table 2 presents results for samples collected at various intervals between zero to two feet depth. The summary tables present dry weight concentrations to provide a consistent basis of comparison. The tables also list the lowest apparent effects threshold (LAET) values as numerical criteria (Washington State Department of Ecology 2008) for determining potential impacts to the benthic community. Use of dry weight concentrations and LAET criteria is more suitable than carbon normalization given the relatively low total organic carbon (TOC) levels of generally less than 0.5 milligrams per kilogram (mg/kg) for the sediment samples. This Technical Memorandum also includes figures excerpted from the referenced source documents to identify the sediment sample locations for each monitoring event.

2.1 2001 Monitoring Event (EPA and USACE 2002)

Available data from the 2001 sampling event include one surface sediment sample and nine samples collected at depth intervals up two feet below grade from eight of the push probe exploration locations along the north central portion of the East Beach. Analytical results for the 2001 samples provide a "snapshot" of near-surface sediment quality soon after completion of the sheet pile wall. Concentrations of indicator parameters from the 2001 samples were below their respective LAET values except at four locations noted in Table 2 and shown on the excerpted Figure 2 from this 2002 EPA and USACE report. Two other samples exceeded a concentration of 1,200 micrograms per kilogram (ug/kg) HPAH representing the intertidal objective to address human health risks for shellfish consumption from the East Harbor Operable Unit Record of Decision (EPA 1994). The 2001 locations were not further sampled during the 2002-2003 and 2011 monitoring events.

2.2 2002-2003 (Integral Consulting 2004) and 2011 Monitoring Events (EPA 2012 and USACE 2012)

As discussed in EPA's Third Five Year Review Report (2012), PAH concentrations generally declined in surface sediment samples between the 2002-2003 monitoring event and the 2011 event (see Table 1). Sample locations and results for the 2002-2003 monitoring event are shown on excerpted Figures 3-7, 3-8a, 3-8b, and 3-9 (Integral 2004). Sample locations and results for the 2011 monitoring event are shown on excerpted Figure 3-13 (USACE 2012).

Concentrations of each indicator parameter decreased substantially at 11 of the 21 surface locations sampled during the 2011 event. At other locations, some parameters decreased but others increased. Regardless, concentrations of indicator parameters detected during the 2011 event were consistently below their associated LAETs. However, HPAHs exceeded the 1,200 ug/kg human health objective in East Beach samples M10-E4 and N10-A4, and in North Shoal samples K9-D3 and M9-A3 (Table 1). For comparison, HPAH concentrations exceeded 1,200 ug/kg in nine of the 2002 samples, excluding 2002 seep locations shown on excerpted Figures 3-8a, 3-8b, and 3-9 (Integral 2004) that were not resampled in 2011. This suggests an overall downward trend of PAH concentrations between 2002-2003 and 2011.

The 2011 exceedances of the 1,200 ug/kg human health objective were distributed heterogeneously across the OU-1 intertidal area. Differences in results from the 2002-2003 and 2011 events may also be attributable in part to changes in surface sample collection methods, i.e. compositing of East Beach samples over a grid area in 2002-2003 versus discrete samples collected in 2011. Results also varied on a local scale. For example, a discrete sediment sample from seep location N11-A1 and a composite sample from this same grid were collected during the 2002-2003 event. Naphthalene and LPAH concentrations were substantially higher in the seep sample whereas HPAH concentrations were higher in the surface composite.

Table 2 presents results for deeper interval samples collected from the East Beach to 2 feet below grade. Elevated concentrations of PAHs in many of the 2011 samples indicate continuing contaminant impacts. Samples from the 2011 East Beach locations contained HPAHs exceeding the 1,200 ug/kg human health concentration objective, and locations N10-A4 and N11-B5, and N11-A2 contained concentrations of indicator constituents above LAETs. Analytical testing results are more difficult to compare between the 2002-2003 and 2011 monitoring events because of different sampling intervals, but the general indication is that NAPL continues to be a potential contaminant source to near-surface sediments. Concentrations of indicator parameters are also generally lower in the2011 surface samples than deeper interval samples from this same event.

3. Conclusions

As noted in EPA's Third Five Year Review Report, the overall decrease in surface sediment PAH concentrations noted from the 2011 sampling event suggests that natural recovery is occurring. The most prominent natural recovery mechanisms are likely physical "washout" of near-surface NAPL sheen and entrained contaminants from wave and tidal action, and winnowing/redistribution of uppermost beach sediments from long-shore coastal transport. Although general weight of evidence indicates that natural recovery is occurring, a considerable volume of resident NAPL remains in the subsurface within the OU-1 intertidal zone. This resident NAPL represents a potential continuing source of contamination to near-surface sediments.

4. References

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Tables

Table 1. Summary of 2001, 2002, and 2011 Surface Sediment Analytical Data for Naphthalene, LPAH, and HPAH Indicator Parameters (0 to 10 cm depth)

Wyckoff OU-1 Focused Feasibility Study
23-Apr-13

Sample ID	Sample Year*	Parameter (µg/kg dry weight)		
		Naphthalene	Total LPAH	Total HPAH
LAET (Ecology 2008):		*2,100*	*5,200*	*12,000*
ROD Human Health Risk Intertidal Objective (EPA 1994):				*1,200*
Central East Beach Samples				
EHITE010815	2001	1,000 U	3,000 U	5,500
M10-E4	2002	**5,630**	**49,071**	**117,651**
	2011	150	1,078	5,500
N11-A1	2002	120	502	7,846
	2011	46	101	353
N11-A2	2002	19 U	19 U	125
	2011	6	34	191
N11-B5	2002	15 J	68	182
	2011	10	33	101
N11-B4	2002	22	71	202
	2011	9	32	81
N11-B2	2002	83	187	832
	2011	65	177	480
N10-B5	2002	211	1,538.1	**24,873**
	2011	160	370	563
N11-D5	2002	17 J	17	197
	2011	26	58	80
N10-B4	2002	19 U	27	323
	2011	38	184	457
N10-A5	2002	**55,000**	32	2,660
	2011	63	159	280
N11-C2	2002	32	32	208
	2011	38	132	957
N11-B3	2002	**2,660**	**39,009**	**396,690**
	2011	35	124	425
N11-C4	2002	20 U	20 U	211
	2011	99	173	141
N11-C5	2002	20 U	20 U	38
	2011	8.0	30	88
N10-A4	2002	1,230	2,687	11,977
	2011	120	386	1,654
N11-A5 SEEP	2002	**7,520**	**13,973**	2,360.9
	2011	21	78	427

Table 1. Summary of 2001, 2002, and 2011 Surface Sediment Analytical Data for Naphthalene, LPAH, and HPAH Indicator Parameters (0 to 10 cm depth)

Wyckoff OU-1 Focused Feasibility Study
23-Apr-13

Sample ID	Sample Year*	Parameter (µg/kg dry weight)		
		Naphthalene	Total LPAH	Total HPAH
LAET (Ecology 2008):		*2,100*	*5,200*	*12,000*
ROD Human Health Risk Intertidal Objective (EPA 1994):				*1,200*
N11-A1-SEEP	2002	**3,590**	**6,380**	1,026.6
M11-E1 SEEP	2002	**1,740,000**	**2,703,160**	**331,200**
N12-B4 SEEP	2002	691	4,192	1,721
M10-D4 SEEP	2002	**56,600**	**272,444**	**156,954**
North Shoal Samples				
L9-B4	2002	93	316	1,471
	2011	450	939	1,068
K9-D3	2002	1,800	**63,800**	**387,380**
	2011	2,000	4,435	**9,094**
M9-A3	2002	16 J	32	153
	2011	43	104	201
K9-B4	2011	480	1,163	**3,476**
L9-D4	2011	53	180	586

Notes:
LPAHs: naphthalene, acenaphthalene, acenaphthene, fluorene, phenanthrene, and anthracene (WAC 173-204-320)
HPAHs: fluoranthene, pyrene, benz(a)anthracene, chrysene, total benzofluoranthenes, benzo(a)pyrene, indeno(1,2,3,-c,d)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene (WAC 173-204-320)

*Data Sources:
2001: USACE and EPA 2002
2002: Integral Consulting 2004
2011: USACE 2012
Bolded entries indicate concentrations exceeding LAET criteria
Shaded cells indicate concentrations exceeding the EPA human health intertidal objective
U = undetected
J = estimated value

Table 2. Summary of 2001, 2003, and 2011 Near-Surface Sediment Analytical Data for Indicator Parameters: Naphthalene, LPAHs, and HPAHs (within 0 to 2-foot depth interval)

Wyckoff OU-1 Focused Feasibility Study
23-Apr-13

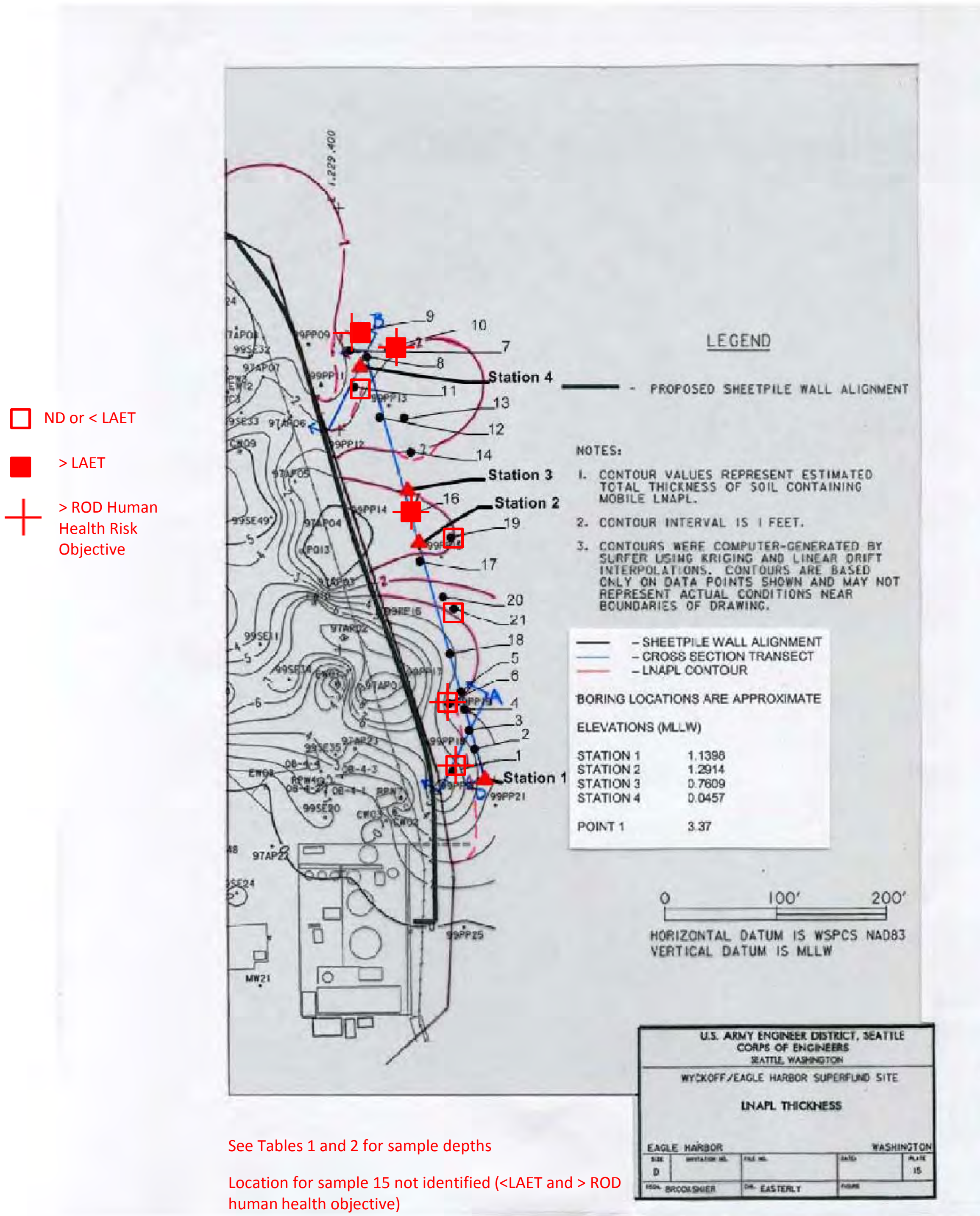
Sample ID	Sample Year*	Reported Depth bgs	Parameter (µg/kg dry weight)		
			Naphthalene	Total LPAH	Total HPAH
SMS LAET (Ecology 2008):			*2,100*	*5,200*	*12,000*
ROD Human Health Risk Intertidal Objective (EPA 2004):					*1,200*
Central East Beach Samples					
EHITE060816	2001	0-1 ft	1,000 U	3,000 U	5,500
EHITE090817	2001	0-2 ft	**15,000**	**76,000**	**40,800**
EHITE100817 1A	2001	0-2 ft	1,700	5,100	**13,100**
EHITE110817 1A	2001	0-2 ft	1,000 U	3,000 U	5,000 U
EHITE150818 1A	2001	0-1 ft (shoe)	1,000 U	**5,300**	5,000 U
EHITE150818 1B	2001	0-1 ft	1,000 U	**8,200**	**28,300**
EHITE160818 1	2001	0-1 ft	1,000 U	3,700	**17,000**
EHITE190818 1	2001	0-2 ft	1,000 U	3,000 U	5,000 U
EHITE210818	2001	0-2 ft	1,000 U	3,000 U	5,000 U
N10-A4	2003	13-28 cm	**8,620**	**15,019**	**29,568**
	2003	28-43 cm	285	452.2	260.9
	2003	43-58 cm	180	257	53.9
	2011	10-33 cm	**3,700**	**16,630**	**62,720**
N11-B2	2003	20-48 cm	100	186	36
N11-B5	2003	20-48 cm	**123,000**	**178,199**	**40,440**
	2011	10-53 cm	960	**12,243**	5,785
N11-D5	2003	23-60 cm	28	808	2,215
N10-B4	2003	20-50 cm	44	333	2,319
	2011	10-52 cm	100	340	1,993
N11-A2	2003	30-53 cm	958	**18,198**	11,626
	2011	10-43 cm	170	**8,407**	**31,180**
M10-E4	2003	30-60 cm	**110,000**	**181,454**	**34,536**

Notes:
LPAHs: naphthalene, acenaphthalene, acenaphthene, fluorene, phenanthrene, and anthracene (WAC 173-204-320)
HPAHs: fluoranthene, pyrene, benz(a)anthracene, chrysene, total benzofluoranthenes, benzo(a)pyrene, indeno(1,2,3,-c,d)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene (WAC 173-204-320)

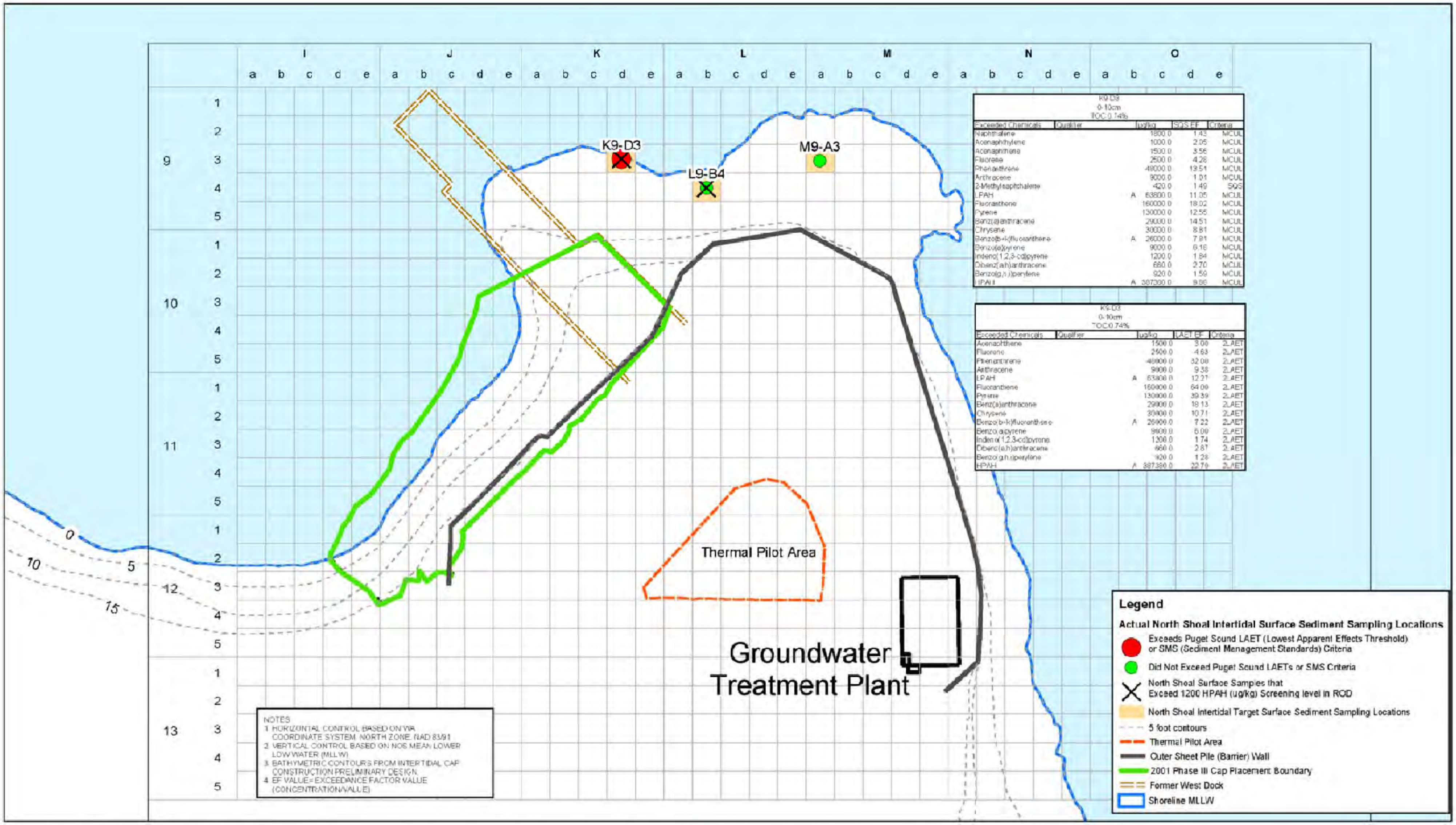
*Data Sources:
2001: USACE and EPA 2002
2002: Integral Consulting 2004
2011: USACE 2012
Bolded entries indicate concentrations exceeding LAET criteria
Shaded cells indicate concentrations exceeding the EPA human health intertidal objective
U = undetected

Figures

Figure 2. Conceptual East Beach NAPL map, planar view.



Excerpted and modified from Figure 2 of Wyckoff Eagle Harbor East Beach Investigation Report (EPA and USACE 2002



K9-D3
0-10cm
TOC 0.74%

Exceeded Chemicals	Qualifier	ug/kg	SQS EF	Criteria
Naphthalene		1800.0	1.43	MCUL
Acenaphthylene		1000.0	2.05	MCUL
Acenaphthene		1500.0	3.56	MCUL
Fluorene		2500.0	4.28	MCUL
Phenanthrene		48000.0	19.51	MCUL
Anthracene		9000.0	1.01	MCUL
2-Methylnaphthalene		420.0	1.49	SQS
LPAH	A	63800.0	11.05	MCUL
Fluoranthene		160000.0	18.02	MCUL
Pyrene		130000.0	12.55	MCUL
Benz(a)anthracene		29000.0	14.51	MCUL
Chrysene		30000.0	8.81	MCUL
Benzo(b+k)fluoranthene	A	26000.0	7.81	MCUL
Benzo(a)pyrene		9800.0	8.16	MCUL
Indeno(1,2,3-cd)pyrene		1200.0	1.84	MCUL
Dibenz(a,h)anthracene		660.0	2.70	MCUL
Benzo(g,h,i)perylene		920.0	1.59	MCUL
HPAH	A	387300.0	9.86	MCUL

K9-D3
0-10cm
TOC 0.74%

Exceeded Chemicals	Qualifier	ug/kg	LAET EF	Criteria
Acenaphthene		1500.0	3.00	2LAET
Fluorene		2500.0	4.63	2LAET
Phenanthrene		48000.0	32.00	2LAET
Anthracene		9000.0	9.38	2LAET
LPAH	A	63800.0	12.27	2LAET
Fluoranthene		160000.0	64.00	2LAET
Pyrene		130000.0	39.39	2LAET
Benz(a)anthracene		29000.0	18.13	2LAET
Chrysene		30000.0	10.71	2LAET
Benzo(b+k)fluoranthene	A	26000.0	7.22	2LAET
Benzo(a)pyrene		9800.0	6.00	2LAET
Indeno(1,2,3-cd)pyrene		1200.0	1.74	2LAET
Dibenz(a,h)anthracene		660.0	2.87	2LAET
Benzo(g,h,i)perylene		920.0	1.28	2LAET
HPAH	A	387300.0	22.79	2LAET

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Map Document: (C:\GIS\Projects\Eagle_Harbor\Monitoring MXD\Final_MXDs_2004\0\2803-7_Actual_CM_AET_NoShoalSur_040811.mxd)
Plot Date: 08/11/2004

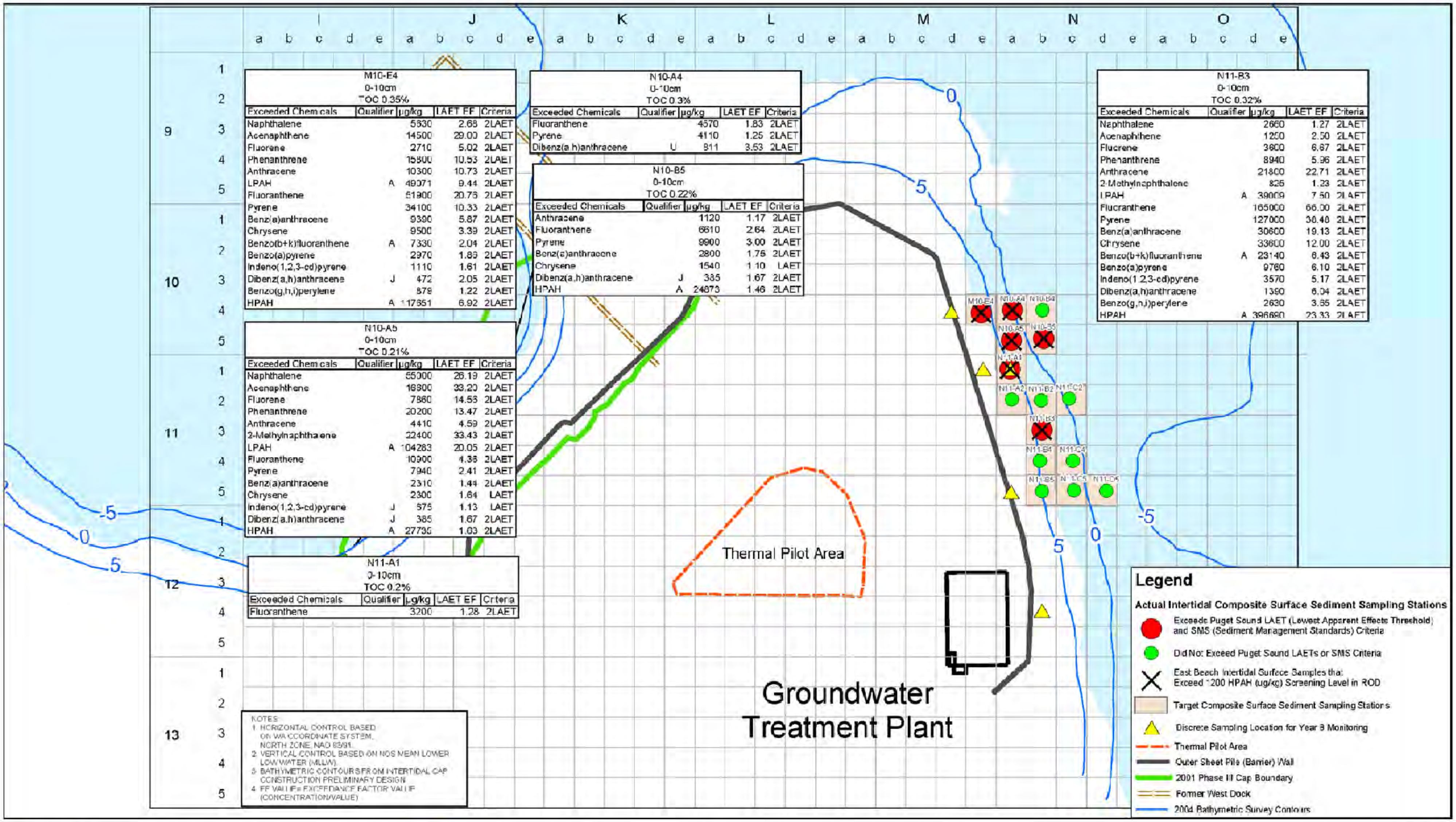
Basemap from USACE 2002

0 100 200 400 Feet

N

Figure 3-7
Polynuclear Aromatic Hydrocarbon (PAH) that Exceed Dry Weight Lowest Apparent Effects Threshold (LAET) or TOC-normalized Sediment Management Standards (SMS) Criteria in the North Shoal Surface (0-10 cm) Sediment Samples. (TOC-normalized SMS comparisons only conducted for sediment samples with TOC concentrations greater than or equal to 0.5%.)

Excerpted and modified from Figure 3-7of 2002-2003 Year 8 Environmental Monitoring Report, Wyckoff /Eagle Superfund Site, East Harbor Operable Unit (Integral Consulting 2004)



M10-E4, 0-10cm, TOC 0.35%

Exceeded Chemicals	Qualifier	µg/kg	LAET EF	Criteria
Naphthalene		5630	2.68	2LAET
Acenaphthene		14500	29.00	2LAET
Fluorene		2710	5.02	2LAET
Phenanthrene		15800	10.53	2LAET
Anthracene		10300	10.73	2LAET
LPAH	A	49071	9.44	2LAET
Fluoranthene		51900	20.76	2LAET
Pyrene		34100	10.33	2LAET
Benz(a)anthracene		9390	5.87	2LAET
Chrysene		9500	3.39	2LAET
Benzo(b+k)fluoranthene	A	7330	2.04	2LAET
Benzo(a)pyrene		2970	1.89	2LAET
Indeno(1,2,3-cd)pyrene		1110	1.61	2LAET
Dibenz(a,h)anthracene	J	472	2.05	2LAET
Benzo(g,h,i)perylene		878	1.22	2LAET
HPAH	A	117651	6.92	2LAET

N10-A4, 0-10cm, TOC 0.3%

Exceeded Chemicals	Qualifier	µg/kg	LAET EF	Criteria
Fluoranthene		4570	1.83	2LAET
Pyrene		4110	1.25	2LAET
Dibenz(a,h)anthracene	U	811	3.53	2LAET

N10-B5, 0-10cm, TOC 0.22%

Exceeded Chemicals	Qualifier	µg/kg	LAET EF	Criteria
Anthracene		1120	1.17	2LAET
Fluoranthene		6610	2.64	2LAET
Pyrene		9900	3.00	2LAET
Benz(a)anthracene		2800	1.75	2LAET
Chrysene		1540	1.10	LAET
Dibenz(a,h)anthracene	J	385	1.67	2LAET
HPAH	A	24873	1.46	2LAET

N11-B3, 0-10cm, TOC 0.32%

Exceeded Chemicals	Qualifier	µg/kg	LAET EF	Criteria
Naphthalene		2660	1.27	2LAET
Acenaphthene		1250	2.50	2LAET
Fluorene		3600	6.67	2LAET
Phenanthrene		8940	5.96	2LAET
Anthracene		21800	22.71	2LAET
2-Methylnaphthalene		825	1.23	2LAET
LPAH	A	39009	7.50	2LAET
Fluoranthene		165000	66.00	2LAET
Pyrene		127000	38.48	2LAET
Benz(a)anthracene		30600	19.13	2LAET
Chrysene		33600	12.00	2LAET
Benzo(b+k)fluoranthene	A	23140	6.43	2LAET
Benzo(a)pyrene		9760	6.10	2LAET
Indeno(1,2,3-cd)pyrene		3570	5.17	2LAET
Dibenz(a,h)anthracene		1390	6.04	2LAET
Benzo(g,h,i)perylene		2630	3.65	2LAET
HPAH	A	396690	23.33	2LAET

N10-A5, 0-10cm, TOC 0.21%

Exceeded Chemicals	Qualifier	µg/kg	LAET EF	Criteria
Naphthalene		55000	26.19	2LAET
Acenaphthene		16600	33.20	2LAET
Fluorene		7860	14.56	2LAET
Phenanthrene		20200	13.47	2LAET
Anthracene		4410	4.59	2LAET
2-Methylnaphthalene		22400	33.43	2LAET
LPAH	A	104283	20.05	2LAET
Fluoranthene		10900	4.36	2LAET
Pyrene		7940	2.41	2LAET
Benz(a)anthracene		2310	1.44	2LAET
Chrysene		2300	1.64	LAET
Indeno(1,2,3-cd)pyrene	J	575	1.13	LAET
Dibenz(a,h)anthracene	J	385	1.67	2LAET
HPAH	A	27735	1.03	2LAET

N11-A1, 0-10cm, TOC 0.2%

Exceeded Chemicals	Qualifier	µg/kg	LAET EF	Criteria
Fluoranthene		3200	1.28	2LAET

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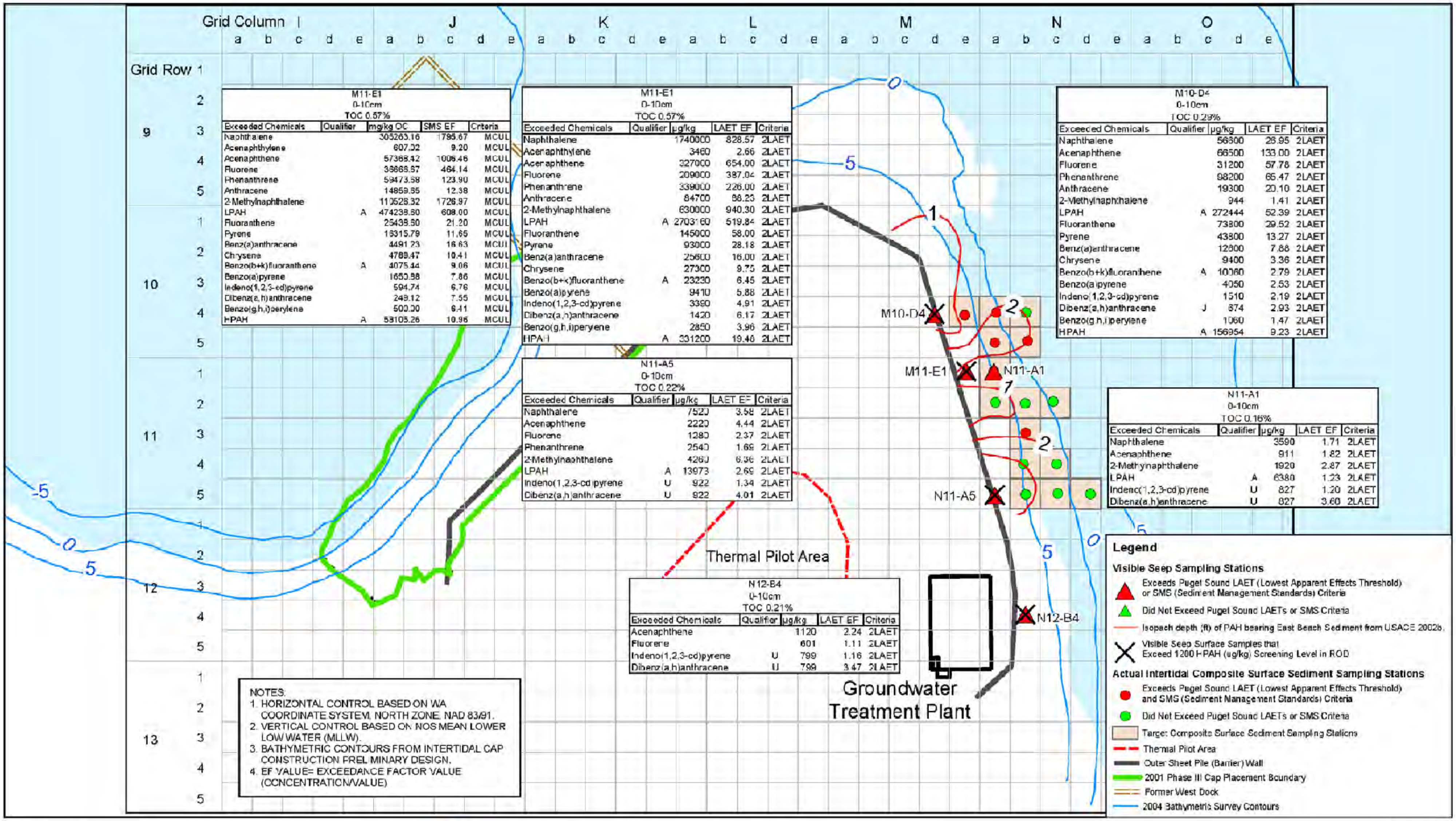
Map Document: (C:\GIS\Projects\Eagle_Harbor\Monitoring MXD\Final_Final_MXDs_20040811\3-8a_Actual_CM_AET_EastBeachSur_040811.mxd)
Plot Date: 08/11/2004

Basemap from USACE 2002

0 100 200 400 Feet

Figure 3-8a
Polynuclear Aromatic Hydrocarbon (PAH) that Exceed Dry Weight Lowest Apparent Effects Threshold (LAET) or TOC-normalized Sediment Managment Standards (SMS) Criteria in East Beach Intertidal Surface (0-10 cm) Sediment Samples. (TOC-normalized SMS comparisons only conducted for sediment samples with TOC concentrations greater than or equal to 0.5%.)

Excerpted and modified from Figure 3-8a of 2002-2003 Year 8 Environmental Monitoring Report, Wyckoff /Eagle Superfund Site, East Harbor Operable Unit (Integral Consulting 2004)



M11-E1
0-10cm
TOC 0.57%

Exceeded Chemicals	Qualifier	mg/kg OC	SMS EF	Criteria
Naphthalene		305263.16	1795.67	MCUL
Acenaphthylene		607.02	9.20	MCUL
Acenaphthene		57368.42	1006.46	MCUL
Fluorene		36666.67	464.14	MCUL
Phenanthrene		59473.68	123.90	MCUL
Anthracene		14859.65	12.38	MCUL
2-Methylnaphthalene		110526.32	1726.97	MCUL
LPAH	A	474238.60	608.00	MCUL
Fluoranthene		25438.60	21.20	MCUL
Pyrene		16315.79	11.65	MCUL
Benz(a)anthracene		4491.23	16.63	MCUL
Chrysene		4789.47	10.41	MCUL
Benzo(b+k)fluoranthene	A	4075.44	9.06	MCUL
Benzo(a)pyrene		1650.88	7.86	MCUL
Indeno(1,2,3-cd)pyrene		594.74	6.76	MCUL
Dibenz(a,h)anthracene		249.12	7.55	MCUL
Benzo(g,h,i)perylene		500.00	6.41	MCUL
HPAH	A	58105.26	10.96	MCUL

M11-E1
0-10cm
TOC 0.57%

Exceeded Chemicals	Qualifier	µg/kg	LAET EF	Criteria
Naphthalene		1740000	828.57	2LAET
Acenaphthylene		3460	2.66	2LAET
Acenaphthene		327000	654.00	2LAET
Fluorene		209000	387.04	2LAET
Phenanthrene		339000	226.00	2LAET
Anthracene		84700	88.23	2LAET
2-Methylnaphthalene		630000	940.30	2LAET
LPAH	A	2703160	519.84	2LAET
Fluoranthene		145000	58.00	2LAET
Pyrene		93000	28.18	2LAET
Benz(a)anthracene		25600	16.00	2LAET
Chrysene		27300	9.75	2LAET
Benzo(b+k)fluoranthene	A	23230	6.45	2LAET
Benzo(a)pyrene		9410	5.88	2LAET
Indeno(1,2,3-cd)pyrene		3390	4.91	2LAET
Dibenz(a,h)anthracene		1420	6.17	2LAET
Benzo(g,h,i)perylene		2850	3.96	2LAET
HPAH	A	331200	19.46	2LAET

M10-D4
0-10cm
TOC 0.29%

Exceeded Chemicals	Qualifier	µg/kg	LAET EF	Criteria
Naphthalene		56600	26.95	2LAET
Acenaphthene		66500	133.00	2LAET
Fluorene		31200	57.78	2LAET
Phenanthrene		98200	65.47	2LAET
Anthracene		19300	20.10	2LAET
2-Methylnaphthalene		944	1.41	2LAET
LPAH	A	272444	52.39	2LAET
Fluoranthene		73800	29.52	2LAET
Pyrene		43800	13.27	2LAET
Benz(a)anthracene		12600	7.88	2LAET
Chrysene		9400	3.36	2LAET
Benzo(b+k)fluoranthene	A	10060	2.79	2LAET
Benzo(a)pyrene		4050	2.53	2LAET
Indeno(1,2,3-cd)pyrene		1510	2.19	2LAET
Dibenz(a,h)anthracene	J	674	2.93	2LAET
Benzo(g,h,i)perylene		1060	1.47	2LAET
HPAH	A	156954	9.23	2LAET

N11-A5
0-10cm
TOC 0.22%

Exceeded Chemicals	Qualifier	µg/kg	LAET EF	Criteria
Naphthalene		7520	3.58	2LAET
Acenaphthene		2220	4.44	2LAET
Fluorene		1280	2.37	2LAET
Phenanthrene		2540	1.69	2LAET
2-Methylnaphthalene		4260	6.36	2LAET
LPAH	A	13973	2.69	2LAET
Indeno(1,2,3-cd)pyrene	U	922	1.34	2LAET
Dibenz(a,h)anthracene	U	922	4.01	2LAET

N11-A1
0-10cm
TOC 0.16%

Exceeded Chemicals	Qualifier	µg/kg	LAET EF	Criteria
Naphthalene		3590	1.71	2LAET
Acenaphthene		911	1.82	2LAET
2-Methylnaphthalene		1920	2.87	2LAET
LPAH	A	6380	1.23	2LAET
Indeno(1,2,3-cd)pyrene	U	827	1.20	2LAET
Dibenz(a,h)anthracene	U	827	3.60	2LAET

N12-B4
0-10cm
TOC 0.21%

Exceeded Chemicals	Qualifier	µg/kg	LAET EF	Criteria
Acenaphthene		1120	2.24	2LAET
Fluorene		601	1.11	2LAET
Indeno(1,2,3-cd)pyrene	U	799	1.16	2LAET
Dibenz(a,h)anthracene	U	799	3.47	2LAET

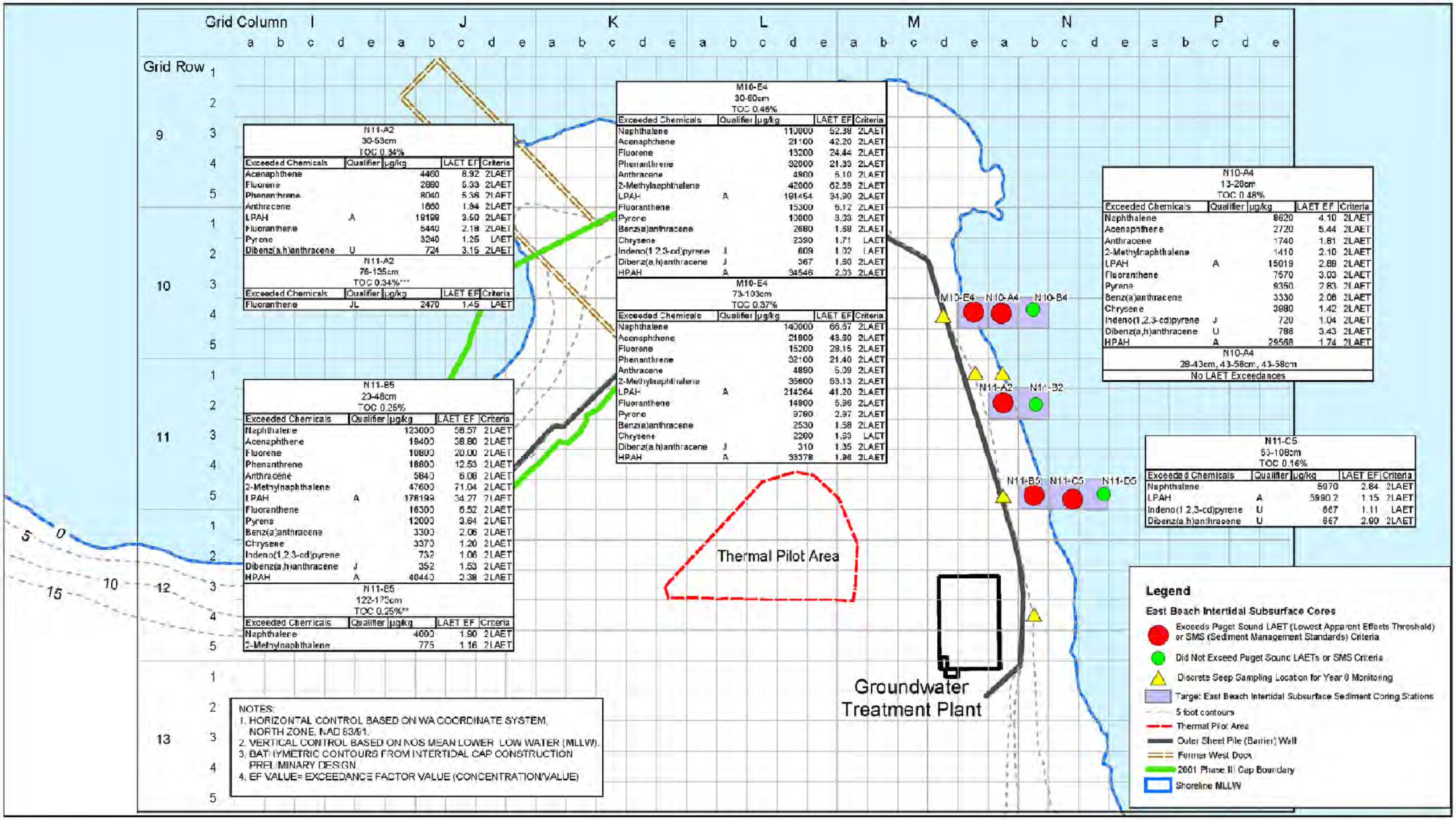
integral consulting inc.

Map Document: (C:\GIS\Projects\Eagle_Harbor\Monitoring MXD\Final_Final_MXDs_20040811\3-8b_Actual_CM_SMS_Discrete Sur_040811.mxd)
Plot Date: 08/11/2004

Basemap from USACE 2002

Figure 3-8b
Polynuclear Aromatic Hydrocarbon (PAH) that Exceed Dry Weight Lowest Apparent Effects Threshold (LAET) or TOC-normalized Sediment Managment Standards (SMS) Criteria in Visible Seep Surface (0-10 cm) Samples. (TOC-normalized SMS comparisons only conducted for sediment samples with TOC concentrations greater than or equal to 0.5%.)

Excerpted and modified from Figure 3-8b of 2002-2003 Year 8 Environmental Monitoring Report, Wyckoff /Eagle Superfund Site, East Harbor Operable Unit (Integral Consulting 2004)



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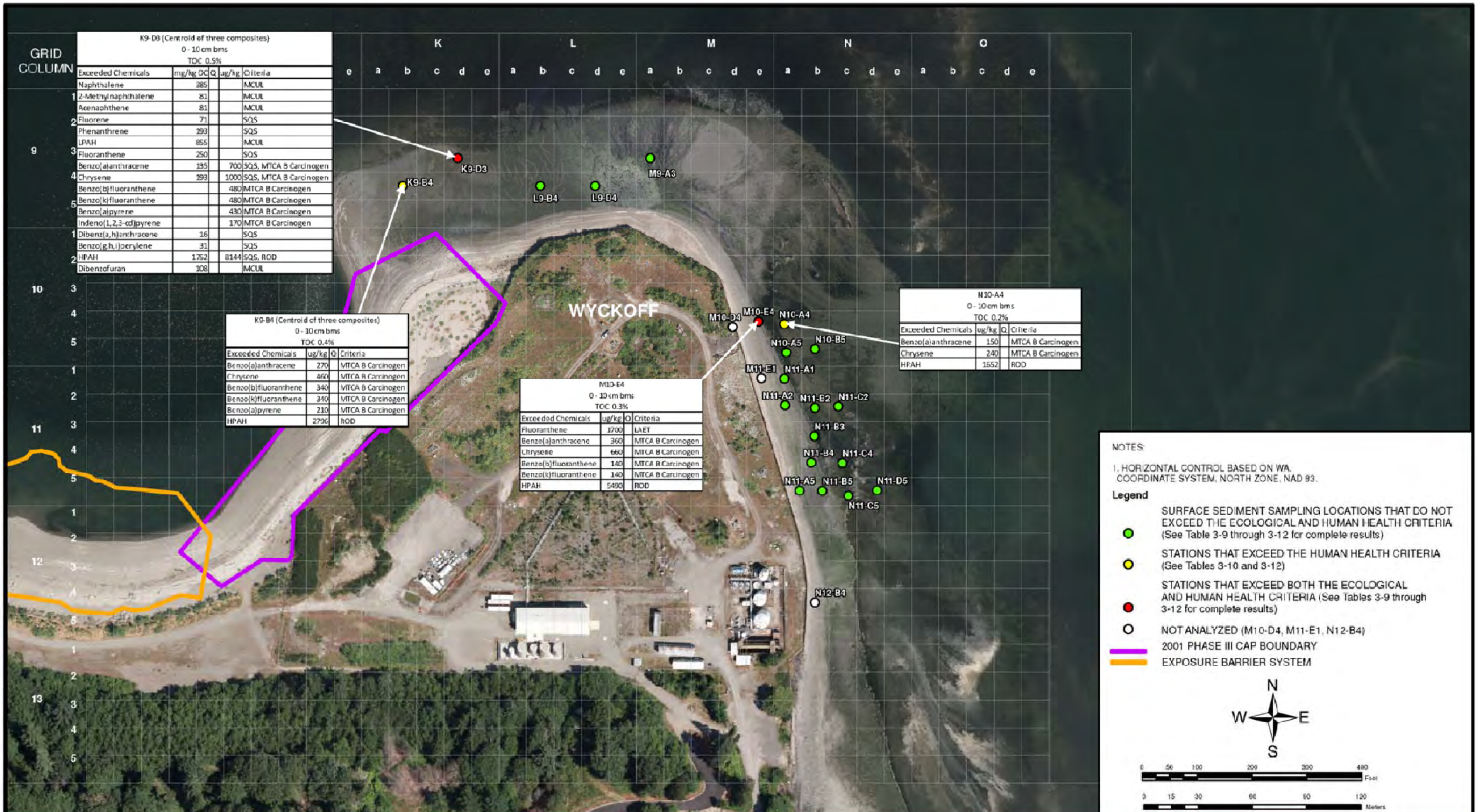
Basemap from USACE 2002

0 100 200 400 Feet

N

Figure 3-9
Polynuclear Aromatic Hydrocarbon (PAH) that Exceed Dry Weight Lowest Apparent Effects Threshold (LAET)
or TOC-normalized Sediment Managment Standards (SMS) Criteria in East Beach Intertidal Subsurface Cores.
(TOC-normalized SMS comparisons only conducted for sediment samples with TOC concentrations greater than or equal to 0.5%.)

Excerpted and modified from Figure 3-9 of 2002-2003 Year 8 Environmental Monitoring Report, Wyckoff /Eagle Superfund Site, East Harbor Operable Unit (Integral Consulting 2004)



K9-D3 (Centroid of three composites)
0 - 10 cm bms
TOC 0.5%

Exceeded Chemicals	mg/kg OC	Q	ug/kg	Criteria
Naphthalene	385			MCUL
2-Methylnaphthalene	81			MCUL
Acenaphthene	81			MCUL
Fluorene	71			SQS
Phenanthrene	393			SQS
LPAH	855			MCUL
Fluoranthene	250			SQS
Benzo[a]anthracene	135		700	SQS, MTCA B Carcinogen
Chrysene	393		1000	SQS, MTCA B Carcinogen
Benzo[b]fluoranthene			480	MTCA B Carcinogen
Benzo[k]fluoranthene			480	MTCA B Carcinogen
Benzo[a]pyrene			430	MTCA B Carcinogen
Indeno(1,2,3-cd)pyrene			170	MTCA B Carcinogen
Dibenz(a,h)anthracene	16			SQS
Benzo[g,h,i]perylene	31			SQS
HPAH	1752		8144	SQS, ROD
Dibenzofuran	108			MCUL

K9-B4 (Centroid of three composites)
0 - 10 cm bms
TOC 0.4%

Exceeded Chemicals	ug/kg	Q	Criteria
Benzo(a)anthracene	270		MTCA B Carcinogen
Chrysene	460		MTCA B Carcinogen
Benzo(b)fluoranthene	340		MTCA B Carcinogen
Benzo(k)fluoranthene	340		MTCA B Carcinogen
Benzo(a)pyrene	210		MTCA B Carcinogen
HPAH	2796		ROD

M10-E4
0 - 10 cm bms
TOC 0.3%

Exceeded Chemicals	ug/kg	Q	Criteria
Fluoranthene	1700		LAET
Benzo(a)anthracene	360		MTCA B Carcinogen
Chrysene	660		MTCA B Carcinogen
Benzo(b)fluoranthene	140		MTCA B Carcinogen
Benzo(k)fluoranthene	140		MTCA B Carcinogen
HPAH	5490		ROD

N10-A4
0 - 10 cm bms
TOC 0.2%

Exceeded Chemicals	ug/kg	Q	Criteria
Benzo(a)anthracene	150		MTCA B Carcinogen
Chrysene	240		MTCA B Carcinogen
HPAH	1652		ROD

SEE LLC Science & Engineering for the Environment | HDR | KTA

Project Name	Figure Name	
2011 OMMP Implementation East Harbor Operable Unit Wyckoff/Eagle Harbor Superfund Site	North Shoal and East Beach Surface Sediment Chemistry Results Compared to Sediment Management Standards and Human Health Criteria	Figure 3-13

Excerpted and modified from Figure 3-13of FINAL 2011 Year 17 Monitoring Report, East Harbor Operable Unit , Wyckoff /Eagle Superfund Site (USACE 2012)

Appendix E
Wyckoff/Eagle Harbor Superfund Site, Operable Unit 1 Focused Feasibility Study Dewatering Estimate

Wyckoff/Eagle Harbor Superfund Site, Operable Unit 1 Focused Feasibility Study Dewatering Estimate

PREPARED FOR: File

PREPARED BY: Healy, Rob/SEA

DATE: January 31, 2014

PROJECT NUMBER: 427757.FS.01

This technical memorandum summarizes the dewatering flux estimate prepared in support of the Focused Feasibility Study (FFS) for the intertidal portions of the Wyckoff OU-1 area. This flux estimate was prepared for planning and costing the potential dewatering for the following FFS alternatives:

- Alternative 2 – Targeted Amended Capping for Seeps and Monitored Natural Recovery (MNR)
- Alternative 3 – Phased Amended Capping and MNR
- Alternative 4 – Vertical Containment with MAN and Targeted Amended Capping

These alternatives include capping elements that require shallow excavations completed in the intertidal zone during low tide. Beach surface elevations for the excavations range from about 0 to above 5 feet Mean Lower Low Water. Determining the flux needed to dewater an excavation area on the beach in a tidal exchange area is a complex hydrologic problem. It is a dynamic system where the dewatering flux will depend on tides, beach geometry, and offshore aquifer hydraulic properties. Note these properties have not been measured at the site and are estimated from available upland Upper Aquifer information presented in the April 2007 *Groundwater Conceptual Site Model Update Report for the Former Process Area*.

For each alternative, shallow beach excavations would occur over periods up to about 5 hours, beginning on the ebb tide and stopping on the incoming tide. Three feet is the expected maximum depth of the excavations, and as such this is the target depth for dewatering. Under expected site conditions the maximum dewatering flux is anticipated when the tide is close to the seaward extent of the excavation footprint, on both the ebb and incoming tides. At some point the tide would be so close to the excavation that continued dewatering is impossible. Conversely, depending on the slope of the beach and tidal stage, dewatering may not be needed during lower tides, and certainly lower flux rates would be required than at higher tides.

A preliminary estimate of the dewatering flux was estimated using the Theis analytical solution within Aqtesolv, a software package for the analysis of aquifer tests. Exhibit 1 presents a summary of the analytical solution output. To approximate the tidal effect on dewatering, a constant head boundary is applied at different distances from the excavation. This represents the ocean and its potential effect on the flux as the tide moves closer to the excavation. A forward or predictive solution was prepared using site data applied from the Upland Aquifer to Offshore conditions, including estimates of aquifer hydraulic conductivity (26 feet/day) and aquifer thickness (100 feet). Dewatering is assumed to occur through use of a (hypothetical) extraction well in the center of the excavation, pumping over a five hour period. An observation point is placed at 30 feet from the center of the excavation to estimate the effects of pumping on water levels at the edge of the excavation. A rough schematic of the dewatering conditions are presented on the upper right-hand corner of Exhibit 1.

With the solution inputs above (see Exhibit 1 – Table 1), the potential tidal effect on the flux rate was evaluated by varying the distance from the extraction well to the constant head boundary. The solution output under the varying conditions is provided in Exhibit 1 – Table 2. The results are presented in a matrix format, with three flux rates in the first row, and the projected drawdown in feet at different boundary distances. The drawdown at 100 minutes after initiating pumping is provided, as this is the approximate time when drawdown begins to level off. See the example graphic inserted from Aqtesolv for a semi-log graph of displacement versus time focused on the observation point. Under the solution inputs applied, the results indicate that a 100 gallon per minute (gpm) flux rate will achieve the target dewatering elevation at the excavation extent for all boundary distance assumptions. The fifty gpm flux will not achieve the target dewatering elevations, while the 200 gpm flux is estimated to achieve approximately twice the target dewatering elevations.

Based on this evaluation a constant 100 gpm flux is recommended for use in planning and costing Alternative 3. This is considered a reasonable approach for evaluating the amount of water that will need to be managed during dewatering activities. The 100 gpm estimate is an approximation of likely flow rates that could be encountered during high flux periods. But during low tides the anticipated flow rate is expected to significantly less than 100 gpm. In aggregate the total water generated for each tidal cycle and excavation is estimated to be on the order of approximately 30,000 gallons (100 gpm x 300 minutes).

While this preliminary flux evaluation is sufficient for Feasibility Study level design, additional evaluation is recommended prior to remedial design. The most expedient approach would be to complete a dewatering field test during a tidal cycle. A test pit could be excavated as the tide ebbs in an area of OU-1 where NAPL product is not present. The test pit would be dewatered throughout the tidal cycle, to better quantify expected dewatering fluxes.

Exhibit 1

Results Summary: Potential Pumping Rates - Theis Analysis, AQTESOLV

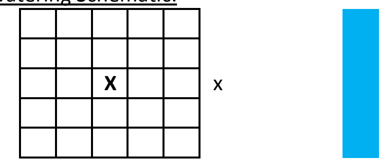
Table 1 - Theis Analysis Inputs

K	26	ft/day
T	2600	ft2/day
S	0.1	
Kz/Kr	0.1	
b	100	ft

Table 2 - Summary of Results

	drawdown (ft) at 100 minutes 30 ft from pumping well			
Flux (gpm)	No Boundary	Boundary at 75 ft	Boundary at 50 ft	Boundary at 40 ft
50	2.7	2.7	2.2	1.6
100	5.5	5.4	4.4	3.1
200	11	10.8	8.8	6.1

Example Dewatering Schematic:



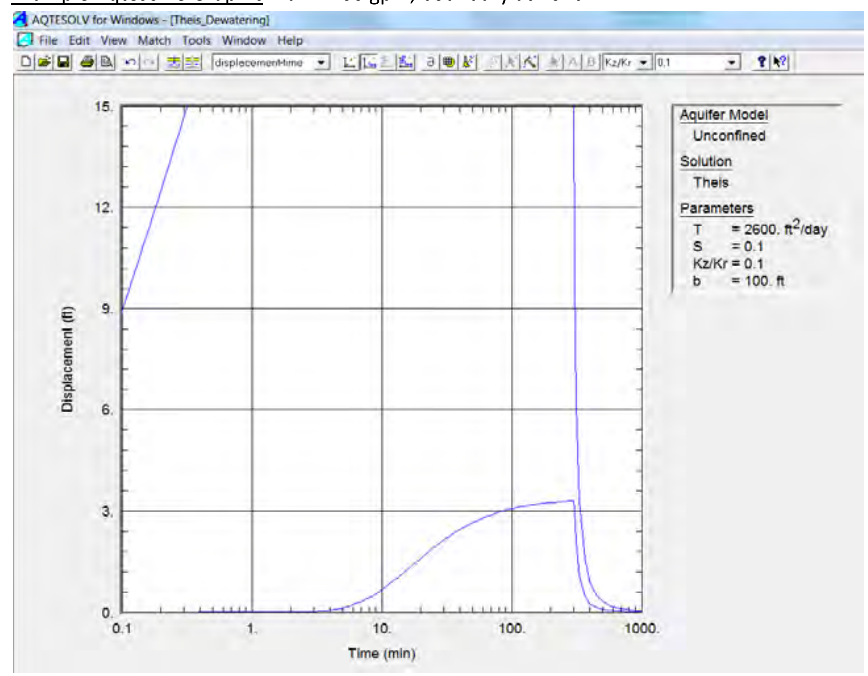
Excavation = 40 x 40 ft

Ocean as constant head boundary

X dewatering well

x estimated drawdown observations, 30 ft from dewatering well

Example Aqtesolve Graphic: flux = 100 gpm, boundary at 40 ft



Appendix F
Wyckoff/Eagle Harbor Superfund Site, Operable Unit 1
Focused Feasibility Study-Level Cost Estimate

Table F-1 Capital Implementation Costs for Alternative 2: Seep Capping and MNR
Wyckoff OU-1 Focused Feasibility Study

INSTITUTIONAL CONTROLS

PAY ITEM No.	PAY ITEM DESCRIPTION	LINE ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	CONTRACTOR COST	CONTRACTOR FEE	CONTRACTOR PM/OH	TOTAL	NOTES
1	**Includes estimated labor, equipment, & ODC costs for supporting the implementation of Institutional Controls**	**Institutional Controls**	**1**	**LS**	**$35,000**	**$29,000**	**$4,000**	**$1,000**	**$35,000**	
		Field Scientist	40	HR	$100	$4,000	$600	$200		
		Sign Replacement	10	EA	$1,000	$10,000	$1,500	$500		Engineer's Estimate
		Technical Support for EPA	1	LS	$15,000	$15,000	$2,250	$750		Engineer's Estimate

PRE-DESIGN SAMPLING AND TESTING

PAY ITEM No.	PAY ITEM DESCRIPTION	LINE ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	CONTRACTOR COST	CONTRACTOR FEE	CONTRACTOR PM/OH	TOTAL	
2	**Includes all labor, equipment, & ODC costs for Waste Characterization Testing/Evaluation**	**Waste Characterization Testing & Evaluation**	**1**	**LS**	**$29,000**	**$25,000**	**$4,000**	**$1,000**	**$29,000**	
		Field Technician	8	HR	$95	$760	$114	$38		
		T&D Coordinator	12	HR	$165	$1,980	$297	$99		
		Field Scientist	8	HR	$100	$800	$120	$40		
		Travel Costs	1	DAY	$129	$129	$19	$6		
		Sampling Equipment	1	DAY	$900	$900	$135	$45		
		Sampling Costs - NAPL and Material Properties	8	EA	$2,500	$20,000	$3,000	$1,000		
3	**Includes all labor, equipment, & ODC costs for Sediment Physical/Chemical Characterization Testing/Evaluation**	**Additional Sediment Physical/Chemical Characterization Testing & Evaluation**	**1**	**LS**	**$34,000**	**$29,000**	**$4,000**	**$1,000**	**$34,000**	
		Field Technician	0	HR	$95	$0	$0	$0		
		T&D Coordinator	6	HR	$165	$990	$149	$50		
		Field Scientist	32	HR	$100	$3,200	$480	$160		
		Travel Costs	2	DAY	$129	$258	$39	$13		
		Sampling Equipment	2	DAY	$900	$1,800	$270	$90		
		Sampling Costs (Laboratory Analysis)	30	EA	$750	$22,500	$3,375	$1,125		**Baseline sampling sediment quality.**
4	**Includes all labor, equipment, & ODC costs for Bench Scale Testing of NAPL**	**NAPL Bench Scale Testing**	**1**	**LS**	**$70,000**	**$58,000**	**$9,000**	**$3,000**	**$70,000**	
		Field Scientist	40	HR	$100	$4,000	$600	$200		
		Travel Costs	5	DAY	$129	$645	$97	$32		
		Field Scientist	40	HR	$100	$4,000	$600	$200		
		Drilling	1	LS	$20,000	$20,000	$3,000	$1,000		**MEANS 31 23 19.30.0050**
		Sampling Equipment	5	DAY	$900	$4,500	$675	$225		
		Sampling & Analysis Costs	1	LS	$25,000	$25,000	$3,750	$1,250		
5	**Includes all labor, equipment, & ODC costs for Test Excavations**	**Test Excavations: Seep Test Pits**	**1**	**LS**	**$7,000**	**$6,000**	**$1,000**	**$0**	**$7,000**	
		Field Scientist	24	HR	$100	$2,400	$360	$120		
		Travel Costs	3	DAY	$129	$387	$58	$19		
		Excavator w/Environmental Bucket	3	DAY	$600	$1,800	$270	$90		
		OPERATOR	24	HR	$49	$1,182	$177	$59		

Table F-1 Capital Implementation Costs for Alternative 2: Seep Capping and MNR
Wyckoff OU-1 Focused Feasibility Study

6	**Includes all labor, equipment, & ODC costs for Land/Bathymetric Survey**	**Land/Bathymetric Survey**	**1**	**LS**	**$36,000**	**$30,000**	**$4,500**	**$1,500**	**$36,000**	
		High Resolution Bathymetric/Land Survey	3	DAY	$10,000	$30,000	$4,500	$1,500		PER MEANS 31 41 16.10.1800
7	**Includes all labor, equipment, & ODC costs for Habitat Surveys**	**Baseline Habitat Survey**	**1**	**LS**	**$10,000**	**$8,000**	**$1,000**	**$0**	**$10,000**	
		Field Scientist	48	HR	$100	$4,800	$720	$240		
		Travel Costs	6	DAY	$129	$774	$116	$39		
		GIS Mapping	1	LS	$2,500	$2,500	$375	$125		
8	**Includes all labor, equipment, & ODC costs for Dewatering/Stabilization Bench Scale Testing**	**Benchscale Testing: Dewatering/Stabilization**	**1**	**LS**	**$39,000**	**$32,000**	**$5,000**	**$2,000**	**$39,000**	
		Field Technician	32	HR	$95	$3,040	$456	$152		
		Field Scientist	32	HR	$100	$3,200	$480	$160		
		Travel Costs	8	DAY	$129	$1,032	$155	$52		
		Sampling & Analysis Costs	1	LS	$25,000	$25,000	$3,750	$1,250		
		Portland Cement	0.5	TON	$150	$75	$11	$4		
9	**Includes all labor, equipment, & ODC costs for TarGOST Survey**	**TarGOST Survey**	**1**	**LS**	**$78,000**	**$65,000**	**$10,000**	**$3,000**	**$78,000**	
		TarGOST Survey	1	LS	$62,500	$62,500	$9,375	$3,125		
		Reporting	1	LS	$2,500	$2,500	$375	$125		

PRE-REMEDIATION SITE WORK

PAY ITEM No.	PAY ITEM DESCRIPTION	LINE ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	CONTRACTOR COST	CONTRACTOR FEE	CONTRACTOR PM/OH	TOTAL	
10	**Includes all labor, equipment, & ODC costs for Constructing Temporary Access Roads/Fencing/Security**	**Temporary Measures**	**1**	**LS**	**$109,000**	**$91,000**	**$14,000**	**$5,000**	**$109,000**	
		Temporary Access Road Construction	2,889	SY	$11	$32,786	$4,918	$1,639		**PER MEANS 01 55 23.50.0100**
		Equipment Storage Area	2,421	SY	$24	$57,762	$8,664	$2,888		**PER MEANS 01 55 23.50.0100**
11	**Includes all labor, equipment, & ODC costs for Upland Survey Confirmation**	**Upland Survey Confirmation**	**1**	**LS**	**$2,700**	**$2,250**	**$338**	**$113**	**$2,700**	
		Land Survey	2	DAY	$1,125	$2,250	$338	$113		**PER MEANS 01 71 23.13.1100**
12	**Includes all labor, equipment, & ODC costs for Preping Upland Staging Area**	**Upland Staging Area and Stockpile Area Construction**	**1**	**LS**	**$69,000**	**$58,000**	**$9,000**	**$3,000**	**$69,000**	
		Stockpile Area Construction	2,420	SY	$24	$57,735	$8,660	$2,887		**PER MEANS 01 55 23.50.0100**

Table F-1 Capital Implementation Costs for Alternative 2: Seep Capping and MNR
Wyckoff OU-1 Focused Feasibility Study

SEDIMENT REMOVAL

PAY ITEM No.	PAY ITEM DESCRIPTION	LINE ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	CONTRACTOR COST	CONTRACTOR FEE	CONTRACTOR PM/OH	TOTAL	
13	**Includes all labor, equipment, & ODC costs for Mechanical Excavation (Pilot Test)**	**Mechanical Excavation Pilot Test**	**1**	**LS**	**$42,000**	**$35,000**	**$5,000**	**$2,000**	**$42,000**	
		Excavator w/Environmental Bucket	4	DAY	$600	$2,400	$360	$120		
		Excavator w/Environmental Bucket	4	DAY	$600	$2,400	$360	$120		
		D6 Dozer LGP	4	DAY	$520	$2,080	$312	$104		
		OPERATOR	32	HR	$49	$1,577	$236	$79		
		OPERATOR	32	HR	$49	$1,577	$236	$79		
		OPERATOR	32	HR	$49	$1,577	$236	$79		
		LABORER	32	HR	$45	$1,429	$214	$71		
		LABORER	32	HR	$45	$1,429	$214	$71		
		Project Manager	32	HR	$235	$7,520	$1,128	$376		
		FOGM	1	LS	$3,440	$3,440	$516	$172		
		Trench Boxes (4' x 14': 4 Ea)	2	DAY	$380	$760	$114	$38		
		Crane Mats	2	DAY	$1,053	$2,106	$316	$105		
		Transfer Pump	4	DAY	$1,300	$5,200	$780	$260		
		Baker Tank	4	DAY	$400	$1,600	$240	$80		
14	**Includes all labor, equipment, & ODC costs for Mechanical Excavation**	**Cap Skirts: Mechanical Excavation**	**0**	**CY**	**#DIV/0!**	**$41,000**	**$6,000**	**$2,000**	**$49,000**	**25 percent bulkng factor**
		Excavator w/Environmental Bucket	0	DAY	$600	$0	$0	$0		
		Excavator w/Environmental Bucket	0	DAY	$600	$0	$0	$0		
		D6 Dozer LGP	0	DAY	$520	$0	$0	$0		
		OPERATOR	0	HR	$49	$0	$0	$0		
		OPERATOR	0	HR	$49	$0	$0	$0		
		OPERATOR	0	HR	$49	$0	$0	$0		
		LABORER	0	HR	$45	$0	$0	$0		
		LABORER	0	HR	$45	$0	$0	$0		
		FOGM	1	LS	$0	$0	$0	$0		
		Crane Mats	0	DAY	$1,053	$0	$0	$0		
		Odor Control	0	DAY	$869	$0	$0	$0		
		Adsorbent Boom	1,018	LF	$40	$40,720	$6,108	$2,036		
		Transfer Pump	0	DAY	$1,300	$0	$0	$0		
		Baker Tank	0	DAY	$400	$0	$0	$0		
15	**Includes all labor, equipment, & ODC costs for Mechanical Excavation**	**Cap Surface Sections: Mechanical Excavation**	**1,111**	**CY**	**$130**	**$117,000**	**$18,000**	**$6,000**	**$141,000**	**25 percent bulkng factor**
		Excavator w/Environmental Bucket	7	DAY	$600	$4,200	$630	$210		
		Excavator w/Environmental Bucket	7	DAY	$600	$4,200	$630	$210		
		D6 Dozer LGP	7	DAY	$520	$3,640	$546	$182		
		OPERATOR	56	HR	$49	$2,759	$414	$138		
		OPERATOR	56	HR	$49	$2,759	$414	$138		
		OPERATOR	56	HR	$49	$2,759	$414	$138		
		LABORER	56	HR	$45	$2,501	$375	$125		
		LABORER	56	HR	$45	$2,501	$375	$125		
		Fuel/Oil/Gas/Maintenance	1	LS	$6,020	$6,020	$903	$301		
		Crane Mats - Freight	1	LS	$29,160	$29,160	$4,374	$1,458		Vendor Quote - 1750 sq. ft.
		Crane Mats - Installation/Removal	1	LS	$16,740	$16,740	$2,511	$837		Vendor Quote - 1750 sq. ft.
		Crane Mats - Rental	7	DAY	$1,053	$7,371	$1,106	$369		Vendor Quote - 1750 sq. ft.
		Transfer Pump - 100 gpm	7	DAY	$1,300	$9,100	$1,365	$455		
		Temporary Piping (Baker Tank Feed)	1,000	LF	$15	$15,000	$2,250	$750		
		Odor Control	7	DAY	$869	$6,084	$913	$304		Vendor Quote
		Trench Boxes (4' x 14': 4 Ea)	7	DAY	$380	$2,660	$399	$133		

16	**Includes all labor, equipment, & ODC costs for Sediment Transport**	**Sediment Transport To Upland Dewatering Area**	**1,111**	**CY**	**$60**	**$57,000**	**$9,000**	**$3,000**	**$68,000**	
		Dump Truck - 8 CY	7	DAY	$480	$3,360	$504	$168		
		Dump Truck - 8 CY	7	DAY	$480	$3,360	$504	$168		
		Dump Truck - 8 CY	7	DAY	$480	$3,360	$504	$168		
		Dump Truck - 8 CY	7	DAY	$480	$3,360	$504	$168		
		Dump Truck - 8 CY	7	DAY	$480	$3,360	$504	$168		
		Dump Truck - 8 CY	7	DAY	$480	$3,360	$504	$168		
		Truck Liners	12	EA	$500	$6,000	$900	$300		
		Truck Driver	56	HR	$46	$2,576	$386	$129		
		Truck Driver	56	HR	$46	$2,576	$386	$129		
		Truck Driver	56	HR	$46	$2,576	$386	$129		
		Truck Driver	56	HR	$46	$2,576	$386	$129		
		Truck Driver	56	HR	$46	$2,576	$386	$129		
		Truck Driver	56	HR	$46	$2,576	$386	$129		
		LABORER	112	HR	$45	$5,002	$750	$250		
		FOGM	1	LS	$10,080	$10,080	$1,512	$504		
17	**Includes all labor, equipment, & ODC costs for Sediment Testing**	**Physical Characterization Events: Sediment Testing**	**1**	**LS**	**$3,000**	**$3,000**	**$0**	**$0**	**$3,000**	
		Sediment Test	2	EA	$250	$500	$75	$25		
		Field Technician	4	HR	$95	$380	$57	$19		
		Sampling & Analysis Costs	1	LS	$2,000	$2,000	$300	$100		**Samples to be collected during Physical Characterization Event**
SEDIMENT DEWATERING										
18	**Includes all labor, equipment, & ODC costs for Sediment Dewatering**	**Sediment Dewatering**	**1**	**LS**	**$204,000**	**$170,000**	**$26,000**	**$9,000**	**$204,000**	
		Dewatering Pad	2,420	SY	$39	$94,912	$14,237	$4,746		**PER MEANS 01 55 23.50.0100**
		Sump	1	LS	$2,000	$2,000	$300	$100		
		Transfer Pump	14	DAY	$2,600	$36,400	$5,460	$1,820		
		Baker Tank	28	DAY	$400	$11,200	$1,680	$560		
		Water Sampling and Analysis	1	LS	$3,250	$3,250	$488	$163		
		Temporary Piping (Baker Tank Feed)	1,500	LF	$15	$22,500	$3,375	$1,125		
CAP PLACEMENT										
19	**Includes all labor, equipment, & ODC costs for Fill Material Transport**	**Cap Skirt Installation: Fill Material Transport**	**0**	**CY**	**$0**	**$53,000**	**$8,000**	**$3,000**	**$64,000**	**25 percent bulkng factor**
		Dump Truck - 8 CY	7	DAY	$480	$3,360	$504	$168		
		Dump Truck - 8 CY	7	DAY	$480	$3,360	$504	$168		
		Dump Truck - 8 CY	7	DAY	$480	$3,360	$504	$168		
		Dump Truck - 8 CY	7	DAY	$480	$3,360	$504	$168		
		Dump Truck - 8 CY	7	DAY	$480	$3,360	$504	$168		
		Dump Truck - 8 CY	7	DAY	$480	$3,360	$504	$168		
		CAT 953 Loader	7	DAY	$480	$3,360	$504	$168		
		OPERATOR	56	HR	$49	$2,759	$414	$138		
		Truck Driver	56	HR	$46	$2,576	$386	$129		
		Truck Driver	56	HR	$46	$2,576	$386	$129		
		Truck Driver	56	HR	$46	$2,576	$386	$129		
		Truck Driver	56	HR	$46	$2,576	$386	$129		
		Truck Driver	56	HR	$46	$2,576	$386	$129		
		Truck Driver	56	HR	$46	$2,576	$386	$129		
		FOGM	1	LS	$11,760	$11,760	$1,764	$588		

Table F-1 Capital Implementation Costs for Alternative 2: Seep Capping and MNR
Wyckoff OU-1 Focused Feasibility Study

20	**Includes all labor, equipment, & ODC costs for 4 Layer Cap Installation**	**Cap and Skirt Installation At Seep Areas**	**0**	**CY**	**$0**	**$63,000**	**$9,000**	**$3,000**	**$75,000**	**25 percent bulking factor**
		Geoweb	1,067	SY	$24	$25,958	$3,894	$1,298		**PER MEANS 01 55 23.50.0100**
		Geotextile Layer	1,067	SY	$5	$5,333	$800	$267		**PER MEANS 01 55 23.50.0100**
		Granular Absorbent Media - AquaGate+OC	0	CY	$1,750	$0	$0	$0		
		Granular Absorbent Media - AquaGate+PAC	0	CY	$625	$0	$0	$0		
		Crushed Stone	0	CY	$30	$0	$0	$0		
		Beach Sand	0	CY	$20	$0	$0	$0		
		Excavator w/Plate Compactor	7	DAY	$600	$4,200	$630	$210		
		Excavator w/Plate Compactor	7	DAY	$600	$4,200	$630	$210		
		D6 Dozer LGP	7	DAY	$520	$3,640	$546	$182		
		OPERATOR	56	HR	$49	$2,759	$414	$138		
		OPERATOR	56	HR	$49	$2,759	$414	$138		
		OPERATOR	56	HR	$49	$2,759	$414	$138		
		LABORER	56	HR	$45	$2,501	$375	$125		
		LABORER	56	HR	$45	$2,501	$375	$125		
		FOGM	1	LS	$6,020	$6,020	$903	$301		
CONSTRUCTION MONITORING										
21	**Includes all labor, equipment, & ODC costs for Air Monitoring**	**Air Monitoring**	**1**	**LS**	**$5,000**	**$4,000**	**$1,000**	**$0**	**$5,000**	
		Air Monitoring	1	MO	$2,000	$2,636	$395	$132		
		Air Monitoring Sample Analysis	5	EA	$250	$1,250	$188	$63		
22	**Includes all labor, equipment, & ODC costs for Habit/Cultural Resource Monitoring**	**Habitat/Cultural Monitoring**	**1**	**LS**	**$1,440**	**$1,200**	**$180**	**$60**	**$1,440**	
		Field Scientist	12	HR	$100	$1,200	$180	$60		
CONFIRMATION SURVEYS										
23	**Includes all labor, equipment, & ODC costs for Land/Bathymetric Surveys**	**Surface Land/Bathymetric Survey**	**1**	**LS**	**$7,000**	**$6,000**	**$1,000**	**$0**	**$7,000**	
		Land Survey	5	DAY	$1,125	$5,625	$844	$281		
EXCAVATED MATERIAL STABILIZATION & DISPOSAL										
24	**Includes all labor, equipment, & ODC costs for Sediment Stabilization**	**Sediment Stabilization**	**1,111**	**CY**	**$20**	**$17,000**	**$3,000**	**$1,000**	**$20,000**	
		Excavator	2	DAY	$600	$1,200	$180	$60		
		CAT 953 Loader	2	DAY	$480	$960	$144	$48		
		OPERATOR	16	HR	$49	$788	$118	$39		
		OPERATOR	16	HR	$49	$788	$118	$39		
		LABORER	16	HR	$45	$715	$107	$36		
		LABORER	16	HR	$45	$715	$107	$36		
		FOGM	1	LS	$1,080	$1,080	$162	$54		
		Portland Cement	71	TON	$150	$10,667	$1,600	$533		

Table F-1 Capital Implementation Costs for Alternative 2: Seep Capping and MNR
Wyckoff OU-1 Focused Feasibility Study

25	**Includes all labor, equipment, & ODC costs for Sediment & WaterT&D**	**Transportation & Disposal: Sediment & Water**	**1,493**	**TON**	**$360**	**$454,000**	**$68,000**	**$23,000**	**$544,000**	
		Transportation & Disposal: Soil	1,493	TON	$100	$149,333	$22,400	$7,467		
		Characterization Sampling and Analysis	3	EA	$1,500	$4,480	$672	$224		
		Transportation & Disposal: Water	97,778	GAL	$3	$293,333	$44,000	$14,667		**Inclusive Cost for Transportion/Disposal/Processing of Water**
		T&D Coordinator	40	HR	$165	$6,600	$990	$330		
		ESTIMATED COST							**$1,742,000**	
					Contingency		**30%**		**$523,000**	
					Mobilization/Demobilization		**2%**		**$35,000**	
					Construction Management/Oversight		**6%**		**$72,000**	
					Remedial Design		**15%**		**$180,000**	
					Project Management		**5%**		**$60,000**	
		TOTAL							**$2,612,000**	

Table F-2 Long-Term Operation and Maintenance (O&M) Costs for Alternative 2: Seep Capping and MNR

Wyckoff OU-1 Focused Feasibility Study

Site:	Wyckoff OU1	**Description:**	Operations and Maintenance Detailed Costing			
Location:	Washington					
PERFORMANCE MONITO	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	**NOTES**
Monitoring Events						Montor every five years to Year 30 Monitor every ten years from Year 40 to Year 100
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring						
	Field Technician	120	HR	$85	$10,200	
	Travel/Per Diem	15	Day	$200	$3,000	
	Bathymetric/Topographic Survey	1	LS	$10,000	$10,000	
	Sediment Chemical Quality Monitoring Sample Analysis	45	EA	$130	$5,850	
	Clam Tissue Sample Analysis	15	EA	$300	$4,500	
	QC: Sediment Chemical Quality Monitoring Sample Analysis	5	EA	$130	$650	
	QC: Clam Tissue Sample Analysis	2	EA	$150	$300	
	BOA Sampling: VOCs	6	EA	$750	$4,500	
	Reporting	1	LS	$15,000	$15,000	
	Total Monitoring Events				**$54,000**	
SPME Porewater Monitoring/Surface Water Monitoring						
	Field Technician: Field Prep	0	HR	$85	$0	
	Field Technician	0	HR	$85	$0	
	SPMD Deployment & Retrieval	0	LS	$15,000	$0	
	Travel/Per Diem	0	Day	$200	$0	
	SPMD Processing	0	EA	$250	$0	
	Sediment/Surface Water PAH Sample Analysis	0	EA	$130	$0	
	Sediment/Surface Water VOC Sample Analysis	0	EA	$130	$0	
	Lab Support (Up to 40 Samples)	0	LS	$50,000	$0	
	Reporting	0	LS	$25,000	$0	
	Total SPME Porewater Monitoring/Surface Water Monitoring				**$0**	
TarGOST Monitoring						
	TarGOST Monitoring	0	LS	$125,000	$0	
	Reporting	0	LS	$10,000	$0	
	Total TarGOST Monitoring				**$0**	
LTOM ANNUAL INSPECTI	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	**NOTES**
Inspections						Visual cap integrity and seep inspections
	Field Technician	32	HR	$85	$2,720	
	Travel/Per Diem	4	Day	$200	$800	
	Reporting	1	LS	$2,500	$2,500	
	Total Inspections				**$6,020**	
FIVE-YEAR REVIEWS	**DESCRIPTION**	**QTY**	**UNIT**	**COST**	**TOTAL**	**NOTES**
Input to EPA Five-Year Report						
	Project Engineer	40	HR	$105	$4,200	
	Reporting	1	LS	$20,000	$20,000	
	Total Input to EPA Five-Year Report				**$24,200**	
MAINTENANCE COSTS	**DESCRIPTION**	**QTY**	**UNIT**	**COST**	**TOTAL**	**NOTES**
Cap Replacement						
	Seep Area Cap Replacement	0.25	CAP	$224,000	$56,000	0.25 cap replaced in Year 9 at two locations, and 0.25 cap in year 30 at one location
	Total Cap Replacement				**$56,000**	

PRESENT VALUE ANALYSIS (30-year)		Discount Rate = 7.0%			
End Year	**COST TYPE**	**O&M Cost**	**DISCOUNT FACTOR**	**PRESENT VALUE**	All O&M items include 30% contingency
0	CAPITAL COST	$0	100.00%	$0	
1	PERIODIC COST - O&M	$21,000	93.46%	$20,000	
2	PERIODIC COST - O&M	$21,000	87.34%	$18,000	
3	PERIODIC COST - O&M	$91,000	81.63%	$74,000	
4	PERIODIC COST - O&M	$8,000	76.29%	$6,000	
5	PERIODIC COST - O&M	$39,000	71.30%	$28,000	
6	PERIODIC COST - O&M	$78,000	66.63%	$52,000	
7	PERIODIC COST - O&M	$8,000	62.27%	$5,000	
8	PERIODIC COST - O&M	$8,000	58.20%	$5,000	
9	PERIODIC COST - O&M	$190,000	54.39%	$103,000	
10	PERIODIC COST - O&M	$39,000	50.83%	$20,000	
11	PERIODIC COST - O&M	$8,000	47.51%	$4,000	
12	PERIODIC COST - O&M	$8,000	44.40%	$4,000	
13	PERIODIC COST - O&M	$8,000	41.50%	$3,000	
14	PERIODIC COST - O&M	$8,000	38.78%	$3,000	
15	PERIODIC COST - O&M	$109,000	36.24%	$40,000	
16	PERIODIC COST - O&M	$8,000	33.87%	$3,000	
17	PERIODIC COST - O&M	$8,000	31.66%	$3,000	
18	PERIODIC COST - O&M	$8,000	29.59%	$2,000	
19	PERIODIC COST - O&M	$8,000	27.65%	$2,000	
20	PERIODIC COST - O&M	$109,000	25.84%	$28,000	
21	PERIODIC COST - O&M	$8,000	24.15%	$2,000	
22	PERIODIC COST - O&M	$8,000	22.57%	$2,000	
23	PERIODIC COST - O&M	$8,000	21.09%	$2,000	
24	PERIODIC COST - O&M	$8,000	19.71%	$2,000	
25	PERIODIC COST - O&M	$109,000	18.42%	$20,000	
26	PERIODIC COST - O&M	$8,000	17.22%	$1,000	
27	PERIODIC COST - O&M	$8,000	16.09%	$1,000	
28	PERIODIC COST - O&M	$8,000	15.04%	$1,000	
29	PERIODIC COST - O&M	$8,000	14.06%	$1,000	
30	PERIODIC COST - O&M	$165,000	13.14%	$22,000	

Table F-2 Long-Term Operation and Maintenance (O&M) Costs for Alternative 2: Seep Capping and MNR

Wyckoff OU-1 Focused Feasibility Study

Site:	Wyckoff OU1	**Description:**	Operations and Maintenance Detailed Costing		
Location:	Washington				
35	PERIODIC COST - O&M		$39,000	9.37%	$4,000
40	PERIODIC COST - O&M		$109,000	6.68%	$7,000
45	PERIODIC COST - O&M		$39,000	4.76%	$2,000
50	PERIODIC COST - O&M		$109,000	3.39%	$4,000
55	PERIODIC COST - O&M		$39,000	2.42%	$1,000
60	PERIODIC COST - O&M		$109,000	1.73%	$2,000
65	PERIODIC COST - O&M		$39,000	1.23%	$0
70	PERIODIC COST - O&M		$109,000	0.88%	$1,000
75	PERIODIC COST - O&M		$39,000	0.63%	$0
80	PERIODIC COST - O&M		$109,000	0.45%	$0
85	PERIODIC COST - O&M		$39,000	0.32%	$0
90	PERIODIC COST - O&M		$109,000	0.23%	$0
95	PERIODIC COST - O&M		$39,000	0.16%	$0
100	PERIODIC COST - O&M		$109,000	0.12%	$0
				TOTAL O&M VALUE (non-discounted)	**$2,159,000**
				TOTAL PRESENT VALUE OF O&M (discounted)	**$498,000**

Table F-3 Capital Implementation Costs for Alternative 3: Partial Excavation and Capping
Wyckoff OU-1 Focused Feasibility Study

INSTITUTIONAL CONTROLS

PAY ITEM No.	PAY ITEM DESCRIPTION	LINE ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	CONTRACTOR COST	CONTRACTOR FEE	CONTRACTOR PM/OH	TOTAL	NOTES
1	**Includes estimated labor, equipment, & ODC costs for Supporting the Implementation of Institutional Controls**	**Institutional Controls**	**1**	**LS**	**$35,000**	**$29,000**	**$4,400**	**$1,500**	**$35,000**	
		Field Scientist	40	HR	$100	$4,000	$600	$200		
		Sign Replacement	10	EA	$1,000	$10,000	$1,500	$500		Engineer's Estimate
		Technical Support for EPA	1	LS	$15,000	$15,000	$2,250	$750		Engineer's Estimate

PRE-DESIGN SAMPLING AND TESTING

PAY ITEM No.	PAY ITEM DESCRIPTION	LINE ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	CONTRACTOR COST	CONTRACTOR FEE	CONTRACTOR PM/OH	TOTAL	
2	**Includes all labor, equipment, & ODC costs for Waste Characterization Testing/Evaluation**	**Waste Characterization Testing & Evaluation**	**1**	**LS**	**$53,000**	**$43,800**	**$6,600**	**$2,200**	**$53,000**	
		Field Technician	8	HR	$95	$760	$114	$38		
		T&D Coordinator	16	HR	$165	$2,640	$396	$132		
		Field Scientist	8	HR	$100	$800	$120	$40		
		Travel Costs	2	DAY	$129	$258	$39	$13		
		Sampling Equipment	2	DAY	$900	$1,800	$270	$90		
		Sampling Costs - NAPL and Material Properties	15	EA	$2,500	$37,500	$5,625	$1,875		
3	**Includes all labor, equipment, & ODC costs for Sediment Physical/Chemical Characterization Testing/Evaluation**	**Additional Sediment Physical Characterization Testing & Evaluation**	**1**	**LS**	**$35,000**	**$29,100**	**$4,400**	**$1,500**	**$35,000**	
		Field Technician	0	HR	$95	$0	$0	$0		
		T&D Coordinator	8	HR	$165	$1,320	$198	$66		
		Field Scientist	32	HR	$100	$3,200	$480	$160		
		Travel Costs	2	DAY	$129	$258	$39	$13		
		Sampling Equipment	2	DAY	$900	$1,800	$270	$90		
		Sampling Costs (Laboratory Analysis)	30	EA	$750	$22,500	$3,375	$1,125		
4	**Includes all labor, equipment, & ODC costs for Bench Scale Testing of NAPL**	**NAPL Bench Scale Testing**	**1**	**LS**	**$70,000**	**$58,000**	**$9,000**	**$3,000**	**$70,000**	
		Field Scientist	40	HR	$100	$4,000	$600	$200		
		Travel Costs	5	DAY	$129	$645	$97	$32		
		Field Scientist	40	HR	$100	$4,000	$600	$200		
		Drilling	1	LS	$20,000	$20,000	$3,000	$1,000		**MEANS 31 23 19.30.0050**
		Sampling Equipment	5	DAY	$900	$4,500	$675	$225		
		Sampling & Analysis Costs	1	LS	$25,000	$25,000	$3,750	$1,250		

Table F-3 Capital Implementation Costs for Alternative 3: Partial Excavation and Capping
Wyckoff OU-1 Focused Feasibility Study

5	**Includes all labor, equipment, & ODC costs for Test Excavations**	**Test Excavations: Test Pits**	**1**	**LS**	**$7,000**	**$6,000**	**$1,000**	**$0**	**$7,000**	
		Field Scientist	24	HR	$100	$2,400	$360	$120		
		Travel Costs	3	DAY	$129	$387	$58	$19		
		Excavator w/Environmental Bucket	3	DAY	$600	$1,800	$270	$90		
		OPERATOR	24	HR	$49	$1,182	$177	$59		
6	**Includes all labor, equipment, & ODC costs for Land/Bathymetric Survey**	**Land/Bathymetric Survey**	**1**	**LS**	**$36,000**	**$30,000**	**$4,500**	**$1,500**	**$36,000**	
		Bathymetric/Land Survey	3	DAY	$10,000	$30,000	$4,500	$1,500		PER MEANS 31 41 16.10.1800
7	**Includes all labor, equipment, & ODC costs for Habitat Surveys**	**Baseline Habitat Survey**	**1**	**LS**	**$10,000**	**$8,000**	**$1,000**	**$0**	**$10,000**	
		Field Scientist	48	HR	$100	$4,800	$720	$240		
		Travel Costs	6	DAY	$129	$774	$116	$39		
		GIS Mapping	1	LS	$2,500	$2,500	$375	$125		
8	**Includes all labor, equipment, & ODC costs for Dewatering/Stabilization Bench Scale Testing**	**Benchscale Testing: Dewatering/Stabilization**	**1**	**LS**	**$34,000**	**$29,000**	**$4,000**	**$1,000**	**$34,000**	
		Field Technician	16	HR	$95	$1,520	$228	$76		
		Field Scientist	16	HR	$100	$1,600	$240	$80		
		Travel Costs	4	DAY	$129	$516	$77	$26		
		Sampling & Analysis Costs	1	LS	$25,000	$25,000	$3,750	$1,250		**Samples to be collected during Physical Characterization Event**
		Portland Cement	0.5	TON	$150	$75	$11	$4		
9	**Includes all labor, equipment, & ODC costs for TarGOST Survey**	**TarGOST Survey**	**1**	**LS**	**$78,000**	**$65,000**	**$9,750**	**$3,250**	**$78,000**	
		TarGOST Survey	1	LS	$62,500	$62,500	$9,375	$3,125		
		Reporting	1	LS	$2,500	$2,500	$375	$125		

PRE-REMEDIATION SITE WORK

PAY ITEM No.	PAY ITEM DESCRIPTION	LINE ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	CONTRACTOR COST	CONTRACTOR FEE	CONTRACTOR PM/OH	TOTAL	
10	**Includes all labor, equipment, & ODC costs for Constructing Temporary Access Roads/Fencing/Security**	**Temporary Measures**	**1**	**LS**	**$109,000**	**$91,000**	**$14,000**	**$5,000**	**$109,000**	
		Temporary Access Road Construction	2,889	SY	$11	$32,786	$4,918	$1,639		**PER MEANS 01 55 23.50.0100**
		Equipment Storage Area	2,421	SY	$24	$57,762	$8,664	$2,888		**PER MEANS 01 55 23.50.0100**

Table F-3 Capital Implementation Costs for Alternative 3: Partial Excavation and Capping
Wyckoff OU-1 Focused Feasibility Study

PAY ITEM No.	PAY ITEM DESCRIPTION	LINE ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	CONTRACTOR COST	CONTRACTOR FEE	CONTRACTOR PM/OH	TOTAL	
11	**Includes all labor, equipment, & ODC costs for Survey Confirmation**	**Survey Confirmation**	**1**	**LS**	**$3,000**	**$2,000**	**$0**	**$0**	**$3,000**	
		Land Survey	2	DAY	$1,125	$2,250	$338	$113		**PER MEANS 01 71 23.13.1100**
12	**Includes all labor, equipment, & ODC costs for Preping Upland Staging Area**	**Upland Staging Area and Stockpile Area Construction**	**1**	**LS**	**$104,000**	**$87,000**	**$13,000**	**$4,000**	**$104,000**	
		Stockpile Area Construction	3,630	SY	$24	$86,603	$12,990	$4,330		**PER MEANS 01 55 23.50.0100**

SEDIMENT REMOVAL

PAY ITEM No.	PAY ITEM DESCRIPTION	LINE ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	CONTRACTOR COST	CONTRACTOR FEE	CONTRACTOR PM/OH	TOTAL	
13	**Includes all labor, equipment, & ODC costs for Mechanical Excavation (Pilot Test)**	**Mechanical Excavation Pilot Test**	**1**	**LS**	**$42,000**	**$35,000**	**$5,000**	**$2,000**	**$42,000**	
		Excavator w/Environmental Bucket	4	DAY	$600	$2,400	$360	$120		
		Excavator w/Environmental Bucket	4	DAY	$600	$2,400	$360	$120		
		D6 Dozer LGP	4	DAY	$520	$2,080	$312	$104		
		OPERATOR	32	HR	$49	$1,577	$236	$79		
		OPERATOR	32	HR	$49	$1,577	$236	$79		
		OPERATOR	32	HR	$49	$1,577	$236	$79		
		LABORER	32	HR	$45	$1,429	$214	$71		
		LABORER	32	HR	$45	$1,429	$214	$71		
		Project Manager	32	HR	$235	$7,520	$1,128	$376		
		FOGM	1	LS	$3,440	$3,440	$516	$172		
		Trench Boxes (4' x 14': 4 Ea)	2	DAY	$380	$760	$114	$38		
		Crane Mats	2	DAY	$1,053	$2,106	$316	$105		
		Transfer Pump	4	DAY	$1,300	$5,200	$780	$260		
		Baker Tank	4	DAY	$400	$1,600	$240	$80		
14	**Includes all labor, equipment, & ODC costs for Mechanical Excavation & Pile Cutting**	**Cap Skirts: Mechanical Excavation**	**0**	**CY**	**$0**	**$126,000**	**$19,000**	**$6,000**	**$151,000**	**25 percent bulking factor**
		Excavator w/Environmental Bucket	0	DAY	$600	$0	$0	$0		
		Excavator w/Environmental Bucket	0	DAY	$600	$0	$0	$0		
		D6 Dozer LGP	0	DAY	$520	$0	$0	$0		
		OPERATOR	0	HR	$49	$0	$0	$0		
		OPERATOR	0	HR	$49	$0	$0	$0		
		OPERATOR	0	HR	$49	$0	$0	$0		
		LABORER	0	HR	$45	$0	$0	$0		
		LABORER	0	HR	$45	$0	$0	$0		
		FOGM	1	LS	$0	$0	$0	$0		
		Odor Suppression System	0	DAY	$150	$0	$0	$0		
		Crane Mats - Freight	1	LS	$29,160	$29,160	$4,374	$1,458		
		Crane Mats - Installation/Removal	1	LS	$16,740	$16,740	$2,511	$837		
		Crane Mats - Rental	0	DAY	$1,053	$0	$0	$0		
		Trench Boxes (4' x 14': 4 Ea)	0	DAY	$380	$0	$0	$0		

		Odor Control	0	DAY	$869	$0	$0	$0		
		Adsorbent Boom	1,640	LF	$40	$65,600	$9,840	$3,280		
		Transfer Pump	0	DAY	$1,300	$0	$0	$0		
		Baker Tank	1	DAY	$400	$400	$60	$20		
		Excavator w/Environmental Bucket	6	DAY	$600	$3,750	$563	$188		
		LABORER	6	HR	$45	$279	$42	$14		
		LABORER	6	HR	$45	$279	$42	$14		
		FOGM	6	DAY	$400	$2,500	$375	$125		
		Chainsaws	6	DAY	$250	$1,563	$234	$78		
		Dump Truck - 8 CY	6	DAY	$480	$3,000	$450	$150		
		Truck Driver	50	HR	$46	$2,300	$345	$115		
15	**Includes all labor, equipment, & ODC costs for Mechanical Excavation**	**Cap Surface Sections: Mechanical Excavation**	**8,235**	**CY**	**$50**	**$328,000**	**$49,000**	**$16,000**	**$393,000**	**25 percent bulkng factor**
		Excavator w/Environmental Bucket	38	DAY	$600	$22,800	$3,420	$1,140		
		Excavator w/Environmental Bucket	38	DAY	$600	$22,800	$3,420	$1,140		
		D6 Dozer LGP	38	DAY	$520	$19,760	$2,964	$988		
		OPERATOR	304	HR	$49	$14,977	$2,247	$749		
		OPERATOR	304	HR	$49	$14,977	$2,247	$749		
		OPERATOR	304	HR	$49	$14,977	$2,247	$749		
		LABORER	304	HR	$45	$13,576	$2,036	$679		
		LABORER	304	HR	$45	$13,576	$2,036	$679		
		FOGM	1	LS	$32,680	$32,680	$4,902	$1,634		
		Odor Suppression System	38	DAY	$150	$5,700	$855	$285		**Allowance**
		Crane Mats	38	DAY	$1,053	$40,014	$6,002	$2,001		
		Trench Boxes (4' x 14': 4 Ea)	38	DAY	$380	$14,440	$2,166	$722		
		Odor Control	38	DAY	$869	$33,027	$4,954	$1,651		Vendor Quote
		Transfer Pump	38	DAY	$1,300	$49,400	$7,410	$2,470		
		Baker Tank	38	DAY	$400	$15,200	$2,280	$760		
16	**Includes all labor, equipment, & ODC costs for Sediment Transport**	**Sediment Transport To Upland Dewatering Area**	**8,235**	**CY**	**$40**	**$251,000**	**$38,000**	**$13,000**	**$302,000**	
		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		
		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		
		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		
		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		
		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		
		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		
		Truck Liners	16	EA	$500	$8,000	$1,200	$400		
		Truck Driver	304	HR	$46	$13,984	$2,098	$699		
		Truck Driver	304	HR	$46	$13,984	$2,098	$699		
		Truck Driver	304	HR	$46	$13,984	$2,098	$699		
		Truck Driver	304	HR	$46	$13,984	$2,098	$699		
		Truck Driver	304	HR	$46	$13,984	$2,098	$699		
		Truck Driver	304	HR	$46	$13,984	$2,098	$699		
		LABORER	304	HR	$45	$13,576	$2,036	$679		
		FOGM	1	LS	$36,480	$36,480	$5,472	$1,824		

Table F-3 Capital Implementation Costs for Alternative 3: Partial Excavation and Capping

Wyckoff OU-1 Focused Feasibility Study

17	**Includes all labor, equipment, & ODC costs for Sediment Testing**	**Physical Characterization Events: Sediment Testing**	**1**	**LS**	**$12,000**	**$10,000**	**$2,000**	**$1,000**	**$12,000**	
		Sediment Test	16	EA	$250	$4,000	$600	$200		
		Field Technician	32	HR	$95	$3,040	$456	$152		
		Field Technician	32	HR	$95	$3,040	$456	$152		
SEDIMENT DEWATERING										
18	**Includes all labor, equipment, & ODC costs for Sediment Dewatering**	**Sediment Dewatering**	**1**	**LS**	**$359,000**	**$299,000**	**$45,000**	**$15,000**	**$359,000**	
		Dewatering Pad	3,630	SY	$39	$142,354	$21,353	$7,118		**PER MEANS 01 55 23.50.0100**
		Sump	1	LS	$2,000	$2,000	$300	$100		
		Transfer Pump	38	DAY	$2,600	$98,800	$14,820	$4,940		
		Baker Tank	76	DAY	$400	$30,400	$4,560	$1,520		
		Water Sampling and Analysis	1	LS	$3,250	$3,250	$488	$163		
		Temporary Piping (Baker Tank Feed)	1,500	LF	$15	$22,500	$3,375	$1,125		
19	**Includes all labor, equipment, & ODC costs for Water Treatment Plant Operation**	**Water Treatment Plant Operation**	**300,825**	**GAL**	**$0**	**$0**	**$0**	**$0**	**$0**	
		LABORER	0	HR	$45	$0	$0	$0		
		LABORER	0	HR	$45	$0	$0	$0		**Assue GWTP in operation and excess capacity available**
		Plant Start-Up	0	LS	$50,000	$0	$0	$0		
		Plant O&M	0	MO	$55,000	$0	$0	$0		
20	**Includes all labor, equipment, & ODC costs for Fill Material Transport**	**Cap Installation: Fill Material Transport**	**8,235**	**CY**	**$40**	**$290,000**	**$44,000**	**$15,000**	**$348,000**	
		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		
		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		
		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		
		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		
		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		
		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		
		CAT 953 Loader	38	DAY	$480	$18,240	$2,736	$912		
		OPERATOR	304	HR	$49	$14,977	$2,247	$749		
		Truck Driver	304	HR	$46	$13,984	$2,098	$699		
		Truck Driver	304	HR	$46	$13,984	$2,098	$699		
		Truck Driver	304	HR	$46	$13,984	$2,098	$699		
		Truck Driver	304	HR	$46	$13,984	$2,098	$699		
		Truck Driver	304	HR	$46	$13,984	$2,098	$699		
		Truck Driver	304	HR	$46	$13,984	$2,098	$699		
		FOGM	1	LS	$63,840	$63,840	$9,576	$3,192		

21	**Includes all labor, equipment, & ODC costs for 4 Layer Cap Installation**	**Cap Surface Section Installation**	**8,235**	**CY**	**$270**	**$1,871,000**	**$281,000**	**$94,000**	**$2,245,000**	
		Geoweb	7,905	SY	$24	$192,385	$28,858	$9,619		**PER MEANS 01 55 23.50.0100**
		Geotextile Layer	7,905	SY	$5	$39,524	$5,929	$1,976		**PER MEANS 01 55 23.50.0100**
		Granular Absorbent Media - AquaGate+OC	549	CY	$1,750	$960,745	$144,112	$48,037		
		Granular Absorbent Media - AquaGate+PAC	549	CY	$625	$343,123	$51,468	$17,156		
		Crushed Stone	2,196	CY	$30	$65,880	$9,882	$3,294		
		Beach Sand	4,941	CY	$20	$98,819	$14,823	$4,941		
		Excavator w/Plate Compactor	38	DAY	$600	$22,800	$3,420	$1,140		
		Excavator w/Plate Compactor	38	DAY	$600	$22,800	$3,420	$1,140		
		D6 Dozer LGP	38	DAY	$520	$19,760	$2,964	$988		
		OPERATOR	304	HR	$49	$14,977	$2,247	$749		
		OPERATOR	304	HR	$49	$14,977	$2,247	$749		
		OPERATOR	304	HR	$49	$14,977	$2,247	$749		
		LABORER	304	HR	$45	$13,576	$2,036	$679		
		LABORER	304	HR	$45	$13,576	$2,036	$679		
		FOGM	1	LS	$32,680	$32,680	$4,902	$1,634		
22	**Includes all labor, equipment, & ODC costs for 4 Layer Cap Installation**	**Cap Skirt Installation**	**0**	**CY**	**$0**	**$13,000**	**$2,000**	**$1,000**	**$16,000**	
		Geoweb	547	SY	$24	$13,303	$1,996	$665		**PER MEANS 01 55 23.50.0100**
		Granular Absorbent Media - AquaGate+OC	0	CY	$1,750	$0	$0	$0		
		Granular Absorbent Media - AquaGate+PAC	0	CY	$625	$0	$0	$0		
		Crushed Stone	0	CY	$30	$0	$0	$0		
		Beach Sand	0	CY	$20	$0	$0	$0		
		Excavator w/Plate Compactor	0	DAY	$600	$0	$0	$0		
		Excavator w/Plate Compactor	0	DAY	$600	$0	$0	$0		
		D6 Dozer LGP	0	DAY	$520	$0	$0	$0		
		OPERATOR	0	HR	$49	$0	$0	$0		
		OPERATOR	0	HR	$49	$0	$0	$0		
		OPERATOR	0	HR	$49	$0	$0	$0		
		LABORER	0	HR	$45	$0	$0	$0		
		LABORER	0	HR	$45	$0	$0	$0		
		FOGM	1	LS	$0	$0	$0	$0		
CONSTRUCTION MONITORING										
23	**Includes all labor, equipment, & ODC costs for Air Monitoring**	**Air Monitoring**	**1**	**LS**	**$16,000**	**$13,000**	**$2,000**	**$1,000**	**$16,000**	
		Air Monitoring	4	MO	$2,000	$8,909	$1,336	$445		
		Air Monitoring Sample Analysis	18	EA	$250	$4,500	$675	$225		
24	**Includes all labor, equipment, & ODC costs for Habit/Cultural Resource Monitoring**	**Habitat/Cultural Monitoring**	**1**	**LS**	**$12,000**	**$10,000**	**$1,500**	**$500**	**$12,000**	
		Field Scientist	100	HR	$100	$10,000	$1,500	$500		
CONFIRMATION SURVEYS										
25	**Includes all labor, equipment, & ODC costs for Land/Bathymetric Surveys**	**Final Surface Land/Bathymetric Survey**	**1**	**LS**	**$82,000**	**$69,000**	**$10,000**	**$3,000**	**$82,000**	
		Land Survey	61	DAY	$1,125	$68,625	$10,294	$3,431		

Table F-3 Capital Implementation Costs for Alternative 3: Partial Excavation and Capping
Wyckoff OU-1 Focused Feasibility Study

EXCAVATED MATERIAL STABILIZATION & DISPOSAL										
26	**Includes all labor, equipment, & ODC costs for Sediment Stabilization**	**Sediment Stabilization**	**8,235**	**CY**	**$20**	**$129,000**	**$19,000**	**$6,000**	**$155,000**	
27	**Includes all labor, equipment, & ODC costs for Sediment T&D**	**Transportation & Disposal: Sediment**	**11,068**	**TON**	**$120**	**$1,144,000**	**$172,000**	**$57,000**	**$1,373,000**	
		T&D	11,068	TON	$100	$1,106,778	$166,017	$55,339		
		Characterization Sampling and Analysis	22	EA	$1,500	$33,203	$4,981	$1,660		
		T&D: Cut Pilings	5	TON	$100	$500	$75	$25		
		T&D Coordinator	40	HR	$100	$4,000	$600	$200		
		ESTIMATED COST							**$6,080,000**	
					Contingency		**30%**		**$1,824,000**	
					Mobilization/Demobilization		**2%**		**$122,000**	
					Construction Management/Oversight		**6%**		**$282,000**	
					Remedial Design		**8%**		**$377,000**	
					Project Management		**5%**		**$235,000**	
		TOTAL							**$8,920,000**	

Table F-4 Long-Term Operation and Maintenance (O&M) Costs for Alternative 3: Partial Excavation and Capping

Wyckoff OU-1 Focused Feasibility Study

Site:	Wyckoff OU1	**Description:**	Operations and Maintenance Detailed Costing			
Location:	Washington					

PERFORMANCE MONITORING	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	**NOTES**
Monitoring Events						Montor every five years to Year 30 Monitor every ten years from Year 40 to Year 100
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring						
	Field Technician	120	HR	$85	$10,200	
	Travel/Per Diem	15	Day	$200	$3,000	
	Bathymetric Survey	1	LS	$5,000	$5,000	
	Sediment Chemical Quality Monitoring Sample Analysis	45	EA	$130	$5,850	
	Clam Tissue Sample Analysis	15	EA	$150	$2,250	
	QC: Sediment Chemical Quality Monitoring Sample Analysis	5	EA	$130	$650	
	QC: Clam Tissue Sample Analysis	2	EA	$150	$300	
	BOA Sampling: VOCs	6	EA	$750	$4,500	
	Reporting	1	LS	$15,000	$15,000	
	Total Monitoring Events				**$46,750**	
SPME Portwater Monitoring/Surface Water Monitoring						
	Field Technician: Field Prep	0	HR	$85	$0	
	Field Technician	0	HR	$85	$0	
	SPMD Deployment & Retrieval	0	LS	$15,000	$0	
	Travel/Per Diem	0	Day	$200	$0	
	SPMD Processing	0	EA	$250	$0	
	Sediment/Surface Water PAH Sample Analysis	0	EA	$130	$0	
	Sediment/Surface Water VOC Sample Analysis	0	EA	$130	$0	
	Lab Support (Up to 40 Samples)	0	LS	$50,000	$0	
	Reporting	0	LS	$25,000	$0	
	Total SPME Portwater Monitoring/Surface Water Monitoring				**$0**	
TarGOST Monitoring						
	TarGOST Monitoring	0	LS	$125,000	$0	
	Reporting	0	LS	$10,000	$0	
	Total TarGOST Monitoring				**$0**	
LTOM ANNUAL INSPECTION	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	**NOTES**
Inspections						Visual cap integrity and seep inspections
	Field Technician	32	HR	$85	$2,720	
	Travel/Per Diem	4	Day	$200	$800	
	Reporting	1	LS	$2,500	$2,500	
	Total Inspections				**$6,020**	
FIVE-YEAR REVIEWS	**DESCRIPTION**	**QTY**	**UNIT**	**COST**	**TOTAL**	**NOTES**
Input to EPA Five-Year Report						
	Project Engineer	80	HR	$105	$8,400	
	Reporting	1	LS	$20,000	$20,000	
	Total Input to EPA Five-Year Report				**$28,400**	
MAINTENANCE COSTS	**DESCRIPTION**	**QTY**	**UNIT**	**COST**	**TOTAL**	**NOTES**
Cap Replacement						
	Cap Replacement	1	CAP	$1,995,000	$1,995,000	0.25 cap replaced in Year 9 at two locations, and 0.25 cap in year 30 at one location
	Total Cap Replacement				**$1,995,000**	

PRESENT VALUE ANALYSIS (30-year) Discount Rate = 7.0%

End Year	**COST TYPE**	**TOTAL COST/YEAR**	**DISCOUNT FACTOR**	**PRESENT VALUE**	All O&M items include 30% contingency
0	CAPITAL COST	$0	100.00%	$0	
1	PERIODIC COST - O&M	$21,000	93.46%	$20,000	
2	PERIODIC COST - O&M	$21,000	87.34%	$18,000	
3	PERIODIC COST - O&M	$82,000	81.63%	$67,000	
4	PERIODIC COST - O&M	$8,000	76.29%	$6,000	
5	PERIODIC COST - O&M	$45,000	71.30%	$32,000	
6	PERIODIC COST - O&M	$69,000	66.63%	$46,000	
7	PERIODIC COST - O&M	$8,000	62.27%	$5,000	
8	PERIODIC COST - O&M	$8,000	58.20%	$5,000	
9	PERIODIC COST - O&M	$4,059,000	54.39%	$2,208,000	
10	PERIODIC COST - O&M	$45,000	50.83%	$23,000	
11	PERIODIC COST - O&M	$8,000	47.51%	$4,000	
12	PERIODIC COST - O&M	$8,000	44.40%	$4,000	
13	PERIODIC COST - O&M	$8,000	41.50%	$3,000	
14	PERIODIC COST - O&M	$8,000	38.78%	$3,000	
15	PERIODIC COST - O&M	$106,000	36.24%	$38,000	
16	PERIODIC COST - O&M	$8,000	33.87%	$3,000	
17	PERIODIC COST - O&M	$8,000	31.66%	$3,000	
18	PERIODIC COST - O&M	$8,000	29.59%	$2,000	
19	PERIODIC COST - O&M	$8,000	27.65%	$2,000	
20	PERIODIC COST - O&M	$106,000	25.84%	$27,000	
21	PERIODIC COST - O&M	$8,000	24.15%	$2,000	
22	PERIODIC COST - O&M	$8,000	22.57%	$2,000	
23	PERIODIC COST - O&M	$8,000	21.09%	$2,000	
24	PERIODIC COST - O&M	$8,000	19.71%	$2,000	
25	PERIODIC COST - O&M	$106,000	18.42%	$20,000	
26	PERIODIC COST - O&M	$8,000	17.22%	$1,000	
27	PERIODIC COST - O&M	$8,000	16.09%	$1,000	
28	PERIODIC COST - O&M	$8,000	15.04%	$1,000	
29	PERIODIC COST - O&M	$8,000	14.06%	$1,000	
30	PERIODIC COST - O&M	$2,101,000	13.14%	$276,000	
35	PERIODIC COST - O&M	$45,000	9.37%	$4,000	

Table F-4 Long-Term Operation and Maintenance (O&M) Costs for Alternative 3: Partial Excavation and Capping

Wyckoff OU-1 Focused Feasibility Study

Site:	Wyckoff OU1	**Description:** Operations and Maintenance Detailed Costing			
Location:	Washington				
40	PERIODIC COST - O&M		$106,000	6.68%	$7,000
45	PERIODIC COST - O&M		$45,000	4.76%	$2,000
50	PERIODIC COST - O&M		$106,000	3.39%	$4,000
55	PERIODIC COST - O&M		$45,000	2.42%	$1,000
60	PERIODIC COST - O&M		$106,000	1.73%	$2,000
65	PERIODIC COST - O&M		$45,000	1.23%	$1,000
70	PERIODIC COST - O&M		$106,000	0.88%	$1,000
75	PERIODIC COST - O&M		$45,000	0.63%	$0
80	PERIODIC COST - O&M		$106,000	0.45%	$0
85	PERIODIC COST - O&M		$45,000	0.32%	$0
90	PERIODIC COST - O&M		$106,000	0.23%	$0
95	PERIODIC COST - O&M		$45,000	0.16%	$0
100	PERIODIC COST - O&M		$106,000	0.12%	$0
		TOTAL O&M VALUE (non-discounted)			**$7,970,000**
		TOTAL PRESENT VALUE OF O&M (discounted)			**$2,849,000**

Table F-5 Capital Implementation Costs for Alternative 4: Vertical Containment wirh Partial Excavation and Capping
Wyckoff OU-1 Focused Feasibility Study

INSTITUTIONAL CONTROLS

PAY ITEM No.	PAY ITEM DESCRIPTION	LINE ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	CONTRACTOR COST	CONTRACTOR FEE	CONTRACTOR PM/OH	TOTAL	NOTES
1	Includes estimated labor, equipment, & ODC costs for Supporting the Implementation of Institutional Controls	**Institutional Controls**	**1**	**LS**	**$35,000**	**$29,000**	**$4,000**	**$1,000**	**$35,000**	
		Field Scientist	40	HR	$100	$4,000	$600	$200		
		Sign Replacement	10	EA	$1,000	$10,000	$1,500	$500		Engineer's Estimate
		Technical Support for EPA	1	LS	$15,000	$15,000	$2,250	$750		Engineer's Estimate

PRE-DESIGN SAMPLING AND TESTING

PAY ITEM No.	PAY ITEM DESCRIPTION	LINE ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	CONTRACTOR COST	CONTRACTOR FEE	CONTRACTOR PM/OH	TOTAL	
2	Includes all labor, equipment, & ODC costs for Waste Characterization Testing/Evaluation	**Waste Characterization Testing & Evaluation**	**1**	**LS**	**$53,000**	**$44,000**	**$7,000**	**$2,000**	**$53,000**	
		Field Technician	8	HR	$95	$760	$114	$38		
		T&D Coordinator	16	HR	$165	$2,640	$396	$132		
		Field Scientist	8	HR	$100	$800	$120	$40		
		Travel Costs	2	DAY	$129	$258	$39	$13		
		Sampling Equipment	2	DAY	$900	$1,800	$270	$90		
		Sampling Costs - NAPL and Material Properties	15	EA	$2,500	$37,500	$5,625	$1,875		
3	Includes all labor, equipment, & ODC costs for Sediment Physical/Chemical Characterization Testing/Evaluation	**Additional Sediment Physical Characterization Testing & Evaluation**	**1**	**LS**	**$35,000**	**$29,000**	**$4,000**	**$1,000**	**$35,000**	
		Field Technician	0	HR	$95	$0	$0	$0		
		T&D Coordinator	8	HR	$165	$1,320	$198	$66		
		Field Scientist	32	HR	$100	$3,200	$480	$160		
		Travel Costs	2	DAY	$129	$258	$39	$13		
		Sampling Equipment	2	DAY	$900	$1,800	$270	$90		
		Sampling Costs (Laboratory Analysis)	30	EA	$750	$22,500	$3,375	$1,125		
4	Includes all labor, equipment, & ODC costs for Land/Bathymetric Survey	**Land/Bathymetric Survey**	**1**	**LS**	**$36,000**	**$30,000**	**$4,500**	**$1,500**	**$36,000**	
		Bathymetric/Land Survey	3	DAY	$10,000	$30,000	$4,500	$1,500		PER MEANS 31 41 16.10.1800

Table F-5 Capital Implementation Costs for Alternative 4: Vertical Containment wirh Partial Excavation and Capping

Wyckoff OU-1 Focused Feasibility Study

5	**Includes all labor, equipment, & ODC costs for Bench Scale Testing of NAPL**	**NAPL Bench Scale Testing**	**1**	**LS**	**$70,000**	**$58,000**	**$9,000**	**$3,000**	**$70,000**	
		Field Scientist	40	HR	$100	$4,000	$600	$200		
		Travel Costs	5	DAY	$129	$645	$97	$32		
		Field Scientist	40	HR	$100	$4,000	$600	$200		
		Drilling	1	LS	$20,000	$20,000	$3,000	$1,000		
		Sampling Equipment	5	DAY	$900	$4,500	$675	$225		
		Sampling & Analysis Costs	1	LS	$25,000	$25,000	$3,750	$1,250		
6	**Includes all labor, equipment, & ODC costs for Test Excavations**	**Test Excavations: Test Pits**	**1**	**LS**	**$7,000**	**$6,000**	**$1,000**	**$0**	**$7,000**	
		Field Scientist	24	HR	$100	$2,400	$360	$120		
		Travel Costs	3	DAY	$129	$387	$58	$19		
		Excavator w/Environmental Bucket	3	DAY	$600	$1,800	$270	$90		
		OPERATOR	24	HR	$49	$1,182	$177	$59		
7	**Includes all labor, equipment, & ODC costs for Habitat Surveys**	**Baseline Habitat Survey**	**1**	**LS**	**$10,000**	**$8,000**	**$1,000**	**$0**	**$10,000**	
		Field Scientist	48	HR	$100	$4,800	$720	$240		
		Travel Costs	6	DAY	$129	$774	$116	$39		
		GIS Mapping	1	LS	$2,500	$2,500	$375	$125		
8	**Includes all labor, equipment, & ODC costs for Dewatering/Stabilization Bench Scale Testing**	**Benchscale Testing: Dewatering/Stabilization**	**1**	**LS**	**$20,000**	**$17,000**	**$2,000**	**$1,000**	**$20,000**	
		Field Scientist	40	HR	$100	$4,000	$600	$200		
		Travel Costs	5	DAY	$129	$645	$97	$32		
		Drilling	5	DAY	$1,000	$5,000	$750	$250		
		Sampling Equipment	5	DAY	$900	$4,500	$675	$225		
		Sampling & Analysis Costs	1	LS	$2,500	$2,500	$375	$125		
9	**Includes all labor, equipment, & ODC costs for TarGOST Survey**	**TarGOST Survey**	**1**	**LS**	**$78,000**	**$65,000**	**$10,000**	**$3,000**	**$78,000**	
		TarGOST Monitoring	1	LS	$62,500	$62,500	$9,375	$3,125		
		Reporting	1	LS	$2,500	$2,500	$375	$125		

Table F-5 Capital Implementation Costs for Alternative 4: Vertical Containment wirh Partial Excavation and Capping

Wyckoff OU-1 Focused Feasibility Study

PRE-REMEDIATION SITE WORK

PAY ITEM No.	PAY ITEM DESCRIPTION	LINE ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	CONTRACTOR COST	CONTRACTOR FEE	CONTRACTOR PM/OH	TOTAL	
10	**Includes all labor, equipment, & ODC costs for Constructing Temporary Access Roads/Fencing/Security**	**Temporary Measures**	**1**	**LS**	**$109,000**	**$91,000**	**$14,000**	**$5,000**	**$109,000**	
		Temporary Access Road Construction	2,889	SY	$11	$32,786	$4,918	$1,639		**PER MEANS 01 55 23.50.0100**
		Equipment Storage Area	2,421	SY	$24	$57,762	$8,664	$2,888		**PER MEANS 01 55 23.50.0100**
11	**Includes all labor, equipment, & ODC costs for Preping Upland Staging Area/Survey Confirmation**	**Upland Staging Area Preparation/Survey Confirmation**	**1**	**LS**	**$107,000**	**$89,000**	**$13,000**	**$4,000**	**$107,000**	
		Stockpile Area Construction	3,630	SY	$24	$86,603	$12,990	$4,330		**PER MEANS 01 55 23.50.0100**
		Land Survey	2	DAY	$1,125	$2,250	$338	$113		**PER MEANS 01 71 23.13.1100**

INSTALLATION OF VERTICAL BARRIER

PAY ITEM No.	PAY ITEM DESCRIPTION	LINE ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	CONTRACTOR COST	CONTRACTOR FEE	CONTRACTOR PM/OH	TOTAL	
12	**Includes all labor, equipment, & ODC costs for installation/Removal Of Sheet Pile Vertical Barrier**	**Sheetpile Vertical Barrier Installation**	**1**	**LS**	**$2,429,000**	**$2,024,000**	**$304,000**	**$101,000**	**$2,429,000**	
		Sheet Piling Installation	50,600	SF	$40	$2,024,000	$303,600	$101,200		**PER MEANS 01 55 23.50.0100**

SEDIMENT REMOVAL

PAY ITEM No.	PAY ITEM DESCRIPTION	LINE ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	CONTRACTOR COST	CONTRACTOR FEE	CONTRACTOR PM/OH	TOTAL	
13	**Includes all labor, equipment, & ODC costs for Mechanical Excavation (Pilot Test)**	**Mechanical Excavation Pilot Test**	**1**	**LS**	**$42,000**	**$35,000**	**$5,000**	**$1,755**	**$42,112**	
		Excavator w/Environmental Bucket	4	DAY	$600	$2,400	$360	$120		
		Excavator w/Environmental Bucket	4	DAY	$600	$2,400	$360	$120		
		D6 Dozer LGP	4	DAY	$520	$2,080	$312	$104		
		OPERATOR	32	HR	$49	$1,577	$236	$79		
		OPERATOR	32	HR	$49	$1,577	$236	$79		
		OPERATOR	32	HR	$49	$1,577	$236	$79		
		LABORER	32	HR	$45	$1,429	$214	$71		
		LABORER	32	HR	$45	$1,429	$214	$71		
		Project Manager	32	HR	$235	$7,520	$1,128	$376		
		FOGM	1	LS	$3,440	$3,440	$516	$172		
		Trench Boxes (4' x 14': 4 Ea)	2	DAY	$380	$760	$114	$38		
		Crane Mats	2	DAY	$1,053	$2,106	$316	$105		
		Transfer Pump	4	DAY	$1,300	$5,200	$780	$260		
		Baker Tank	4	DAY	$400	$1,600	$240	$80		

Table F-5 Capital Implementation Costs for Alternative 4: Vertical Containment wirh Partial Excavation and Capping

Wyckoff OU-1 Focused Feasibility Study

14	**Includes all labor, equipment, & ODC costs for Mechanical Excavation**	**Cap Surface Sections: Mechanical Excavation (East Beach)**	**4,117**	**CY**	**$51**	**$175,041**	**$26,000**	**$9,000**	**$210,000**	**25 percent bulkng factor**
		Excavator w/Environmental Bucket	19	DAY	$600	$11,400	$1,710	$570		
		Excavator w/Environmental Bucket	19	DAY	$600	$11,400	$1,710	$570		
		D6 Dozer LGP	19	DAY	$520	$9,880	$1,482	$494		
		OPERATOR	152	HR	$49	$7,488	$1,123	$374		
		OPERATOR	152	HR	$49	$7,488	$1,123	$374		
		OPERATOR	152	HR	$49	$7,488	$1,123	$374		
		LABORER	152	HR	$45	$6,788	$1,018	$339		
		LABORER	152	HR	$45	$6,788	$1,018	$339		
		FOGM	1	LS	$16,340	$16,340	$2,451	$817		
		Trench Boxes (4' x 14': 4 Ea)	2	DAY	$380	$760	$114	$38		
		Crane Mats - Freight	1	LS	$29,160	$29,160	$4,374	$1,458		
		Crane Mats - Installation/Removal	1	LS	$16,740	$16,740	$2,511	$837		
		Crane Mats	2	DAY	$1,053	$2,106	$316	$105		
		Odor Control	19	DAY	$869	$16,514	$2,477	$826		
		Transfer Pump	19	DAY	$1,300	$24,700	$3,705	$1,235		
		Baker Tank	19	DAY	$400					
15	**Includes all labor, equipment, & ODC costs for Mechanical Excavation**	**Cap Surface Sections: Mechanical Excavation (North Shoal)**	**4,117**	**CY**	**$40**	**$154,000**	**$23,000**	**$8,000**	**$184,000**	**25 percent bulkng factor**
		Excavator w/Environmental Bucket	19	DAY	$600	$11,400	$1,710	$570		
		Excavator w/Environmental Bucket	19	DAY	$600	$11,400	$1,710	$570		
		D6 Dozer LGP	19	DAY	$520	$9,880	$1,482	$494		
		OPERATOR	152	HR	$49	$7,488	$1,123	$374		
		OPERATOR	152	HR	$49	$7,488	$1,123	$374		
		OPERATOR	152	HR	$49	$7,488	$1,123	$374		
		LABORER	152	HR	$45	$6,788	$1,018	$339		
		LABORER	152	HR	$45	$6,788	$1,018	$339		
		FOGM	1	LS	$16,340	$16,340	$2,451	$817		
		Trench Boxes (4' x 14': 4 Ea)	19	DAY	$380	$7,220	$1,083	$361		
		Crane Mats	19	DAY	$1,053	$20,007	$3,001	$1,000		
		Odor Control	19	DAY	$869	$16,514	$2,477	$826		Vendor Quote
		Transfer Pump	19	DAY	$1,300	$24,700	$3,705	$1,235		
		Baker Tank	19	DAY	$400					
16	**Includes all labor, equipment, & ODC costs for Mechanical Excavation**	**Cap Skirts: Mechanical Excavation (East Beach and North Shoal)**	**0**	**CY**	**$0**	**$56,866**	**$8,530**	**$2,843**	**$68,000**	
		Excavator w/Environmental Bucket	0	DAY	$600	$0	$0	$0		
		Excavator w/Environmental Bucket	0	DAY	$600	$0	$0	$0		
		D6 Dozer LGP	0	DAY	$520	$0	$0	$0		
		OPERATOR	0	HR	$49	$0	$0	$0		
		OPERATOR	0	HR	$49	$0	$0	$0		
		OPERATOR	0	HR	$49	$0	$0	$0		
		LABORER	0	HR	$45	$0	$0	$0		
		LABORER	0	HR	$45	$0	$0	$0		
		FOGM	1	LS	$0	$0	$0	$0		
		Trench Boxes (4' x 14': 4 Ea)	2	DAY	$380	$760	$114	$38		
		Crane Mats	2	DAY	$1,053	$2,106	$316	$105		
		Adsorbent Boom	1,350	LF	$40	$54,000	$8,100	$2,700		
		Transfer Pump	0	DAY	$1,300	$0	$0	$0		
		Baker Tank	0	DAY	$400					

17	**Includes all labor, equipment, & ODC costs for Sediment Transport**	**Sediment Transport To Upland Dewatering Area**	**8,235**	**CY**	**$40**	**$252,000**	**$38,000**	**$13,000**	**$302,000**	
		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		
		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		
		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		
		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		
		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		
		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		
		Truck Driver	304	HR	$46	$13,984	$2,098	$699		
		Truck Driver	304	HR	$46	$13,984	$2,098	$699		
		Truck Driver	38	HR	$480	$18,240	$2,736	$912		
		Truck Driver	38	HR	$480	$18,240	$2,736	$912		
		Truck Driver	304	HR	$46	$13,984	$2,098	$699		
		Truck Driver	304	HR	$46	$13,984	$2,098	$699		
		LABORER	304	HR	$45	$13,576	$2,036	$679		
		FOGM	1	LS	$36,480	$36,480	$5,472	$1,824		
18	**Includes all labor, equipment, & ODC costs for Sediment Testing**	**Physical Characterization Events: Sediment Testing**	**1**	**LS**	**$4,000**	**$4,000**	**$1,000**	**$180**	**$4,000**	
		Sediment Test	8	EA	$250	$2,000	$300	$100		
		Field Technician	8	HR	$95	$760	$114	$38		
		Field Technician	8	HR	$95	$760	$114	$38		
SEDIMENT DEWATERING										
19	**Includes all labor, equipment, & ODC costs for Sediment Dewatering**	**Sediment Dewatering**	**1**	**LS**	**$359,000**	**$299,000**	**$45,000**	**$15,000**	**$359,000**	
		Dewatering Pad	3,630	SY	$39	$142,354	$21,353	$7,118		**PER MEANS 01 55 23.50.0100**
		Sump	1	LS	$2,000	$2,000	$300	$100		
		Transfer Pump	38	DAY	$2,600	$98,800	$14,820	$4,940		
		Baker Tank	76	DAY	$400	$30,400	$4,560	$1,520		**Allowance**
		Water Sampling and Analysis	1	LS	$3,250	$3,250	$488	$163		
		Temporary Piping (Baker Tank Feed)	1,500	LF	$15	$22,500	$3,375	$1,125		
20	**Includes all labor, equipment, & ODC costs for Water Treatment Plant Operation**	**Water Treatment Plant Operation**	**226,665**	**GAL**	**$0**	**$0**	**$0**	**$0**	**$0**	
		LABORER	0	HR	$45	$0	$0	$0		
		LABORER	0	HR	$45	$0	$0	$0		**Assue GWTP in operation and excess capacity available**
		Plant Start-Up	0	LS	$49	$0	$0	$0		
		Plant O&M	0	MO	$55,000	$0	$0	$0		
CAP PLACEMENT										
21	**Includes all labor, equipment, & ODC costs for Fill Material Transport**	**Cap Installation: Fill Material Transport**	**8,235**	**CY**	**$40**	**$290,000**	**$44,000**	**$15,000**	**$348,000**	
		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		
		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		

		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		
		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		
		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		
		Dump Truck - 8 CY	38	DAY	$480	$18,240	$2,736	$912		
		CAT 953 Loader	38	DAY	$480	$18,240	$2,736	$912		
		OPERATOR	304	HR	$49	$14,977	$2,247	$749		
		Truck Driver	304	HR	$46	$13,984	$2,098	$699		
		Truck Driver	304	HR	$46	$13,984	$2,098	$699		
		Truck Driver	304	HR	$46	$13,984	$2,098	$699		
		Truck Driver	304	HR	$46	$13,984	$2,098	$699		
		Truck Driver	304	HR	$46	$13,984	$2,098	$699		
		Truck Driver	304	HR	$46	$13,984	$2,098	$699		
		FOGM	1	LS	$63,840	$63,840	$9,576	$3,192		
22	**Includes all labor, equipment, & ODC costs for 4 Layer Cap Installation**	**Cap Surface Section and Skirt Installation: (East Beach and North Shoal)**	**8,235**	**CY**	**$270**	**$1,884,000**	**$283,000**	**$94,000**	**$2,261,000**	
		Geoweb	8,355	SY	$24	$203,336	$30,500	$10,167		**PER MEANS 01 55 23.50.0100**
		Geotextile Layer	8,355	SY	$5	$41,774	$6,266	$2,089		**PER MEANS 01 55 23.50.0100**
		Granular Absorbent Media - AquaGate+OC	549	CY	$1,750	$960,745	$144,112	$48,037		
		Granular Absorbent Media - AquaGate+PAC	549	CY	$625	$343,123	$51,468	$17,156		
		Crushed Stone	2,196	CY	$30	$65,880	$9,882	$3,294		
		Beach Sand	4,941	CY	$20	$98,819	$14,823	$4,941		
		Excavator w/Plate Compactor	38	DAY	$600	$22,800	$3,420	$1,140		
		Excavator w/Plate Compactor	38	DAY	$600	$22,800	$3,420	$1,140		
		D6 Dozer LGP	38	DAY	$520	$19,760	$2,964	$988		
		OPERATOR	304	HR	$49	$14,977	$2,247	$749		
		OPERATOR	304	HR	$49	$14,977	$2,247	$749		
		OPERATOR	304	HR	$49	$14,977	$2,247	$749		
		LABORER	304	HR	$45	$13,576	$2,036	$679		
		LABORER	304	HR	$45	$13,576	$2,036	$679		
		FOGM	1	LS	$32,680	$32,680	$4,902	$1,634		
23	**Includes all labor, equipment, & ODC costs for 4 Layer Cap Installation**	**Skirt Installation: (East Beach and North Shoal)**	**0**	**CY**	**$0**	**$268,000**	**$40,000**	**$13,000**	**$322,000**	
		Geoweb	450	SY	$24	$10,951	$1,643	$548		**PER MEANS 01 55 23.50.0100**
		Geotextile Layer	450	SY	$5	$2,250	$337	$112		**PER MEANS 01 55 23.50.0100**
		Granular Absorbent Media - AquaGate+OC	0	CY	$1,750	$0	$0	$0		
		Granular Absorbent Media - AquaGate+PAC	0	CY	$625	$0	$0	$0		
		Crushed Stone	0	CY	$30	$0	$0	$0		
		Beach Sand	0	CY	$20	$0	$0	$0		
		Excavator w/Plate Compactor	57	DAY	$600	$34,200	$5,130	$1,710		
		Excavator w/Plate Compactor	57	DAY	$600	$34,200	$5,130	$1,710		
		D6 Dozer LGP	57	DAY	$520	$29,640	$4,446	$1,482		
		OPERATOR	456	HR	$49	$22,465	$3,370	$1,123		
		OPERATOR	456	HR	$49	$22,465	$3,370	$1,123		
		OPERATOR	456	HR	$49	$22,465	$3,370	$1,123		
		LABORER	456	HR	$45	$20,364	$3,055	$1,018		
		LABORER	456	HR	$45	$20,364	$3,055	$1,018		
		FOGM	1	LS	$49,020	$49,020	$7,353	$2,451		

Table F-5 Capital Implementation Costs for Alternative 4: Vertical Containment wirh Partial Excavation and Capping

Wyckoff OU-1 Focused Feasibility Study

CONSTRUCTION MONITORING										
24	**Includes all labor, equipment, & ODC costs for Air Monitoring**	**Air Monitoring**	**1**	**LS**	**$18,000**	**$15,000**	**$2,000**	**$1,000**	**$18,000**	
		Air Monitoring	5	MO	$2,000	$9,818	$1,473	$491		
		Air Monitoring Sample Analysis	20	EA	$250	$5,000	$750	$250		
25	**Includes all labor, equipment, & ODC costs for Habit/Cultural Resource Monitoring**	**Habitat/Cultural Monitoring**	**1**	**LS**	**$12,000**	**$10,000**	**$1,500**	**$500**	**$12,000**	
		Field Scientist	100	HR	$100	$10,000	$1,500	$500		
CONFIRMATION SURVEYS										
26	**Includes all labor, equipment, & ODC costs for Land/Bathymetric Surveys**	**Final Surface Land/Bathymetric Survey**	**1**	**LS**	**$57,000**	**$47,000**	**$7,000**	**$2,363**	**$56,700**	
		Land Survey	42	DAY	$1,125	$47,250	$7,088	$2,363		**PER MEANS 01 71 23.13.1100**
EXCAVATED MATERIAL STABILIZATION & DISPOSAL										
27	**Includes all labor, equipment, & ODC costs for Sediment Stabilization**	**Sediment Stabilization**	**8,235**	**CY**	**$20**	**$130,000**	**$20,000**	**$7,000**	**$157,000**	
		Excavator	16	DAY	$600	$9,882	$1,482	$494		
		CAT 953 Loader	16	DAY	$480	$7,906	$1,186	$395		
		OPERATOR	132	HR	$49	$6,491	$974	$325		
		OPERATOR	132	HR	$49	$6,491	$974	$325		
		LABORER	132	HR	$45	$5,884	$883	$294		
		LABORER	132	HR	$45	$5,884	$883	$294		
		FOGM	1	LS	$8,894	$8,894	$1,334	$445		
		Portland Cement	527	TON	$150	$79,056	$11,858	$3,953		
28	**Includes all labor, equipment, & ODC costs for Sediment T&D**	**Transportation & Disposal: Sediment**	**1**	**LS**	**$1,336,000**	**$1,113,000**	**$167,000**	**$56,000**	**$1,336,000**	
		T&D	11,068	TON	$100	$1,106,778	$166,017	$55,339		
		T&D Coordinator	40	HR	$165	$6,600	$990	$330		
		ESTIMATED COST							**$8,669,000**	
					Contingency		**30%**		**$2,601,000**	
					Mobilization/Demobilization		**2%**		**$173,000**	
					Construction Management/Oversight		**6%**		**$440,000**	
					Remedial Design		**8%**		**$587,000**	
					Project Management		**5%**		**$367,000**	
		TOTAL							**$12,837,000**	

Table F-6 Long-Term Operation and Maintenance (O&M) Costs for Alternative 4: Vertical Containment wirh Partial Excavation and Capping

Wyckoff OU-1 Focused Feasibility Study

Site:	Wyckoff OU1	**Description:** Operations and Maintenance Detailed Costing					
Location:	Washington						
PERFORMANCE MO	**DESCRIPTION**		**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	**NOTES**
Monitoring Events							Montor every five years to Year 30 Monitor every ten years from Year 40 to Year 100
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring							
	Field Technician		120	HR	$85	$10,200	
	Travel/Per Diem		15	Day	$200	$3,000	
	Bathymetric Survey		1	LS	$5,000	$5,000	
	Sediment Chemical Quality Monitoring Sample Analysis		45	EA	$130	$5,850	
	Clam Tissue Sample Analysis		15	EA	$150	$2,250	
	QC: Sediment Chemical Quality Monitoring Sample Analysis		5	EA	$130	$650	
	QC: Clam Tissue Sample Analysis		2	EA	$150	$300	
	BOA Sampling: VOCs		6	EA	$750	$4,500	
	Reporting		1	LS	$15,000	$15,000	
	Total Monitoring Events					**$46,750**	
SPME Portwater Monitoring/Surface Water Monitoring							
	Field Technician: Field Prep		40	HR	$85	$3,400	
	Field Technician		120	HR	$85	$10,200	
	SPMD Deployment & Retrieval		1	LS	$15,000	$15,000	
	Travel/Per Diem		15	Day	$200	$3,000	
	SPMD Processing		40	EA	$250	$10,000	
	Sediment/Surface Water PAH Sample Analysis		40	EA	$130	$5,200	
	Sediment/Surface Water VOC Sample Analysis		40	EA	$130	$5,200	
	Lab Support (Up to 40 Samples)		1	LS	$50,000	$50,000	
	Reporting		1	LS	$25,000	$25,000	
	Total SPME Portwater Monitoring/Surface Water Monitoring					**$127,000**	
TarGOST Monitoring							
	TarGOST Monitoring		1	LS	$125,000	$125,000	
	Reporting		1	LS	$10,000	$10,000	
	Total TarGOST Monitoring					**$135,000**	
LTOM ANNUAL INSP	**DESCRIPTION**		**QTY**	**UNIT**	**UNIT COST**	**TOTAL**	**NOTES**
Inspections							Visual cap integrity and seep inspections
	Field Technician		32	HR	$85	$2,720	
	Travel/Per Diem		4	Day	$200	$800	
	Reporting		1	LS	$2,500	$2,500	
	Total Inspections					**$6,020**	
FIVE-YEAR REVIEWS	**DESCRIPTION**		**QTY**	**UNIT**	**COST**	**TOTAL**	**NOTES**
Input to EPA Five-Year Report							
	Project Engineer		80	HR	$105	$8,400	
	Reporting		1	LS	$20,000	$20,000	
	Total Input to EPA Five-Year Report					**$28,400**	
MAINTENANCE COS	**DESCRIPTION**		**QTY**	**UNIT**	**COST**	**TOTAL**	**NOTES**
Cap Replacement							
	Cap Replacement		1	EA	$1,549,000	$1,549,000	Replace 10% of cap area in each of Years 10, 20, 30, 40, and 50
	Total Cap Replacement					**$1,549,000**	
SHEETPILE BARRIE	**DESCRIPTION**	**YEAR**	**QTY**	**UNIT**	**COST**	**TOTAL**	**NOTES**
Sheetpile Barrier Inspection							
	Field Technician		8	HR	$85	$680	
	Inspection Equipment Allowance		1	LS	$10,000	$10,000	Method(s) to be determined
	Travel/Per Diem		2	Day	$200	$400	
	Reporting		1	LS	$2,500	$2,500	
	Total Sheetpile Barrier Inspection					**$13,580**	

PRESENT VALUE ANALYSIS (30-year) Discount Rate = 7.0%

End Year	COST TYPE	TOTAL COST/YEAR	DISCOUNT FACTOR	PRESENT VALUE	All O&M items include 30% contingency
0	CAPITAL COST	$0	100.00%	$0	
1	PERIODIC COST - O&M	$34,000	93.46%	$32,000	
2	PERIODIC COST - O&M	$34,000	87.34%	$30,000	
3	PERIODIC COST - O&M	$95,000	81.63%	$78,000	
4	PERIODIC COST - O&M	$21,000	76.29%	$16,000	
5	PERIODIC COST - O&M	$58,000	71.30%	$41,000	
6	PERIODIC COST - O&M	$69,000	66.63%	$46,000	
7	PERIODIC COST - O&M	$8,000	62.27%	$5,000	
8	PERIODIC COST - O&M	$8,000	58.20%	$5,000	
9	PERIODIC COST - O&M	$3,167,000	54.39%	$1,723,000	
10	PERIODIC COST - O&M	$58,000	50.83%	$29,000	
11	PERIODIC COST - O&M	$8,000	47.51%	$4,000	
12	PERIODIC COST - O&M	$8,000	44.40%	$4,000	
13	PERIODIC COST - O&M	$8,000	41.50%	$3,000	
14	PERIODIC COST - O&M	$8,000	38.78%	$3,000	
15	PERIODIC COST - O&M	$119,000	36.24%	$43,000	
16	PERIODIC COST - O&M	$8,000	33.87%	$3,000	
17	PERIODIC COST - O&M	$8,000	31.66%	$3,000	
18	PERIODIC COST - O&M	$8,000	29.59%	$2,000	
19	PERIODIC COST - O&M	$8,000	27.65%	$2,000	
20	PERIODIC COST - O&M	$119,000	25.84%	$31,000	
21	PERIODIC COST - O&M	$8,000	24.15%	$2,000	
22	PERIODIC COST - O&M	$8,000	22.57%	$2,000	

Table F-6 Long-Term Operation and Maintenance (O&M) Costs for Alternative 4: Vertical Containment wirh Partial Excavation and Capping

Wyckoff OU-1 Focused Feasibility Study

Site:	Wyckoff OU1	**Description:** Operations and Maintenance Detailed Costing		
Location:	Washington			
23	PERIODIC COST - O&M	$8,000	21.09%	$2,000
24	PERIODIC COST - O&M	$8,000	19.71%	$2,000
25	PERIODIC COST - O&M	$119,000	18.42%	$22,000
26	PERIODIC COST - O&M	$8,000	17.22%	$1,000
27	PERIODIC COST - O&M	$8,000	16.09%	$1,000
28	PERIODIC COST - O&M	$8,000	15.04%	$1,000
29	PERIODIC COST - O&M	$8,000	14.06%	$1,000
30	PERIODIC COST - O&M	$1,668,000	13.14%	$219,000
35	PERIODIC COST - O&M	$58,000	9.37%	$5,000
40	PERIODIC COST - O&M	$119,000	6.68%	$8,000
45	PERIODIC COST - O&M	$58,000	4.76%	$3,000
50	PERIODIC COST - O&M	$119,000	3.39%	$4,000
55	PERIODIC COST - O&M	$58,000	2.42%	$1,000
60	PERIODIC COST - O&M	$119,000	1.73%	$2,000
65	PERIODIC COST - O&M	$58,000	1.23%	$1,000
70	PERIODIC COST - O&M	$119,000	0.88%	$1,000
75	PERIODIC COST - O&M	$58,000	0.63%	$0
80	PERIODIC COST - O&M	$119,000	0.45%	$1,000
85	PERIODIC COST - O&M	$58,000	0.32%	$0
90	PERIODIC COST - O&M	$119,000	0.23%	$0
95	PERIODIC COST - O&M	$58,000	0.16%	$0
100	PERIODIC COST - O&M	$119,000	0.12%	$0
			TOTAL O&M VALUE (non-discounted)	**$6,944,000**
			TOTAL PRESENT VALUE OF O&M Costs (discounted)	**$2,382,000**

Table F-7 Capital Implementation Costs for Alternative 5:Dredging
Wyckoff OU-1 Focused Feasibility Study

INSTITUTIONAL CONTROLS

PAY ITEM No.	PAY ITEM DESCRIPTION	LINE ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	CONTRACTOR COST	CONTRACTOR FEE	CONTRACTOR PM/OH	TOTAL	NOTES
1	**Includes all labor, equipment, & ODC costs for Implementing Institutional Controls**	**Institutional Controls**	**1**	**LS**	**$35,000**	**$29,000**	**$4,000**	**$1,000**	**$35,000**	
		Field Scientist	40	HR	$100	$4,000	$600	$200		
		Sign Replacement	10	EA	$1,000	$10,000	$1,500	$500		Engineer's Estimate
		Technical Support for EPA	1	LS	$15,000	$15,000	$2,250	$750		Engineer's Estimate

PRE-DESIGN SAMPLING AND TESTING

PAY ITEM No.	PAY ITEM DESCRIPTION	LINE ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	CONTRACTOR COST	CONTRACTOR FEE	CONTRACTOR PM/OH	TOTAL	
2	**Includes all labor, equipment, & ODC costs for Waste Characterization Testing/Evaluation**	**Waste Characterization Testing & Evaluation**	**1**	**LS**	**$53,000**	**$44,000**	**$7,000**	**$2,000**	**$53,000**	
		Field Technician	8	HR	$95	$760	$114	$38		
		T&D Coordinator	16	HR	$165	$2,640	$396	$132		
		Field Scientist	8	HR	$100	$800	$120	$40		
		Travel Costs	2	DAY	$129	$258	$39	$13		
		Sampling Equipment	2	DAY	$900	$1,800	$270	$90		
		Sampling Costs - NAPL and Material Properties	15	EA	$2,500	$37,500	$5,625	$1,875		
3	**Includes all labor, equipment, & ODC costs for Sediment Physical/Chemical Characterization Testing/Evaluation**	**Additional Sediment Physical Characterization Testing & Evaluation**	**1**	**LS**	**$35,000**	**$29,000**	**$4,000**	**$1,000**	**$35,000**	
		Field Technician	0	HR	$95	$0	$0	$0		
		T&D Coordinator	8	HR	$165	$1,320	$198	$66		
		Field Scientist	32	HR	$100	$3,200	$480	$160		
		Travel Costs	2	DAY	$129	$258	$39	$13		
		Sampling Equipment	2	DAY	$900	$1,800	$270	$90		
		Sampling Costs (Laboratory Analysis)	30	EA	$750	$22,500	$3,375	$1,125		
4	**Includes all labor, equipment, & ODC costs for Land/Bathymetric Survey**	**Land/Bathymetric Survey**	**1**	**LS**	**$36,000**	**$30,000**	**$4,500**	**$1,500**	**$36,000**	
		Bathymetric/Land Survey	3	DAY	$10,000	$30,000	$4,500	$1,500		
5	**Includes all labor, equipment, & ODC costs for Bench Scale Testing of NAPL**	**NAPL Bench Scale Testing**	**1**	**LS**	**$70,000**	**$58,000**	**$9,000**	**$3,000**	**$70,000**	
		Field Scientist	40	HR	$100	$4,000	$600	$200		
		Travel Costs	5	DAY	$129	$645	$97	$32		
		Field Scientist	40	HR	$100	$4,000	$600	$200		
		Drilling	1	LS	$20,000	$20,000	$3,000	$1,000		
		Sampling Equipment	5	DAY	$900	$4,500	$675	$225		
		Sampling & Analysis Costs	1	LS	$25,000	$25,000	$3,750	$1,250		

6	**Includes all labor, equipment, & ODC costs for Habitat Surveys**	**Baseline Habitat Survey**	**1**	**LS**	**$10,000**	**$8,000**	**$1,000**	**$400**	**$10,000**	
		Field Scientist	48	HR	$100	$4,800	$720	$240		
		Travel Costs	6	DAY	$129	$774	$116	$39		
		GIS Mapping	1	LS	$2,500	$2,500	$375	$125		
7	**Includes all labor, equipment, & ODC costs for Dewatering/Stabilization Bench Scale Testing**	**Benchscale Testing: Dewatering/Stabilization**	**1**	**LS**	**$20,000**	**$17,000**	**$2,000**	**$1,000**	**$20,000**	
		Field Scientist	40	HR	$100	$4,000	$600	$200		
		Travel Costs	5	DAY	$129	$645	$97	$32		
		Drilling	5	DAY	$1,000	$5,000	$750	$250		
		Sampling Equipment	5	DAY	$900	$4,500	$675	$225		
		Sampling & Analysis Costs	1	LS	$2,500	$2,500	$375	$125		
8	**Includes all labor, equipment, & ODC costs for Geosurvey For Sheetpile Installation**	**Geosurvey For Sheetpile Installation (CPT Probes)**	**1**	**LS**	**$20,000**	**$17,000**	**$2,000**	**$1,000**	**$20,000**	
		Field Scientist	40	HR	$100	$4,000	$600	$200		
		Travel Costs	5	DAY	$129	$645	$97	$32		
		Drilling	5	DAY	$1,000	$5,000	$750	$250		
		Sampling Equipment	5	DAY	$900	$4,500	$675	$225		**MEANS 31 23 19.30.0050**
		Sampling & Analysis Costs	1	LS	$2,500	$2,500	$375	$125		
9	**Includes all labor, equipment, & ODC costs for TarGOST Survey**	**TarGOST Survey**	**1**	**LS**	**$78,000**	**$65,000**	**$10,000**	**$3,000**	**$78,000**	
		TarGOST Monitoring	1	LS	$62,500	$62,500	$9,375	$3,125		
		Reporting	1	LS	$2,500	$2,500	$375	$125		

PRE-REMEDIATION SITE WORK

PAY ITEM No.	PAY ITEM DESCRIPTION	LINE ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	CONTRACTOR COST	CONTRACTOR FEE	CONTRACTOR PM/OH	TOTAL	
10	**Includes all labor, equipment, & ODC costs for Constructing Temporary Access Roads/Fencing/Security**	**Temporary Measures**	**1**	**LS**	**$178,000**	**$148,000**	**$22,000**	**$7,000**	**$178,000**	
		Temporary Access Road Construction	2,889	SY	$11	$32,786	$4,918	$1,639		**PER MEANS 01 55 23.50.0100**
		Equipment Storage Area	4,842	SY	$24	$115,524	$17,329	$5,776		**PER MEANS 01 55 23.50.0100**
11	**Includes all labor, equipment, & ODC costs for Preping Upland Staging Area/Survey Confirmation**	**Upland Staging Area Preparation/Survey Confirmation**	**1**	**LS**	**$107,000**	**$89,000**	**$13,000**	**$4,000**	**$107,000**	
		Stockpile Area Construction	3,630	SY	$24	$86,603	$12,990	$4,330		PER MEANS 31 41 16.10.1800
		Land Survey	2	DAY	$1,125	$2,250	$338	$113		**PER MEANS 01 71 23.13.1100**

Table F-7 Capital Implementation Costs for Alternative 5:Dredging
Wyckoff OU-1 Focused Feasibility Study

PAY ITEM No.	PAY ITEM DESCRIPTION	LINE ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	CONTRACTOR COST	CONTRACTOR FEE	CONTRACTOR PM/OH	TOTAL	
12	**Includes all labor, equipment, & ODC costs for Vibratory Hammer Piling Removal**	**Piling Removal**	**300**	**EA**	**$2,000**	**$420,000**	**$63,000**	**$21,000**	**$504,000**	
		Pile Removal	300	EA	$1,400	$420,000	$63,000	$21,000		ENGINEER'S ESTIMATE: BASED ON RECENT SIMILAR PROJECT
INSTALLATION & REMOVAL OF TEMPORARY SHEET PILE CELLS										
PAY ITEM No.	**PAY ITEM DESCRIPTION**	**LINE ITEM DESCRIPTION**	**QUANTITY**	**UNIT**	**UNIT PRICE**	**CONTRACTOR COST**	**CONTRACTOR FEE**	**CONTRACTOR PM/OH**	**TOTAL**	
13	**Includes all labor, equipment, & ODC costs for installation/Removal Of Sheet Pile Cells**	**Sheetpile Cell Installation/Removal (East Beach)**	**1**	**LS**	**$1,527,000**	**$1,273,000**	**$191,000**	**$64,000**	**$1,527,000**	
		Sheet Piling Installation/Removal - ES	15,813	SF	$46	$727,375	$109,106	$36,369		**PER MEANS 01 55 23.50.0100**
		Sheet Piling Installation/Removal - ES	15,813	SF	$35	$545,531	$81,830	$27,277		**PER MEANS 01 55 23.50.0100**
14	**Includes all labor, equipment, & ODC costs for installation/Removal Of Sheet Pile Cells**	**Sheetpile Cell Installation/Removal (North Shoal)**	**1**	**LS**	**$1,527,000**	**$1,272,906**	**$190,936**	**$63,645**	**$1,527,488**	
		Sheet Piling Installation/Removal - NS	15,813	SF	$46	$727,375	$109,106	$36,369		**PER MEANS 01 55 23.50.0100**
		Sheet Piling Installation/Removal - NS	15,813	SF	$35	$545,531	$81,830	$27,277		**PER MEANS 01 55 23.50.0100**
SEDIMENT REMOVAL										
PAY ITEM No.	**PAY ITEM DESCRIPTION**	**LINE ITEM DESCRIPTION**	**QUANTITY**	**UNIT**	**UNIT PRICE**	**CONTRACTOR COST**	**CONTRACTOR FEE**	**CONTRACTOR PM/OH**	**TOTAL**	
15	**Includes all labor, equipment, & ODC costs for Mechanical Dredging (Pilot Test)**	**Mechanical Dredging Pilot Test**	**1**	**LS**	**$42,000**	**$35,000**	**$5,000**	**$2,000**	**$42,000**	
		Excavator w/Environmental Bucket	4	DAY	$600	$2,400	$360	$120		
		Excavator w/Environmental Bucket	4	DAY	$600	$2,400	$360	$120		
		D6 Dozer LGP	4	DAY	$520	$2,080	$312	$104		
		OPERATOR	32	HR	$49	$1,577	$236	$79		
		OPERATOR	32	HR	$49	$1,577	$236	$79		
		OPERATOR	32	HR	$49	$1,577	$236	$79		
		LABORER	32	HR	$45	$1,429	$214	$71		
		LABORER	32	HR	$45	$1,429	$214	$71		
		Project Manager	32	HR	$235	$7,520	$1,128	$376		
		FOGM	1	LS	$3,440	$3,440	$516	$172		
		Trench Boxes (4' x 14': 4 Ea)	2	DAY	$380	$760	$114	$38		
		Crane Mats	2	DAY	$1,053	$2,106	$316	$105		
		Transfer Pump	4	DAY	$1,300	$5,200	$780	$260		
		Baker Tank	4	DAY	$400	$1,600	$240	$80		
16	**Includes all labor, equipment, & ODC costs for Mechanical Dredging**	**Mechanical Dredging (East Beach)**	**16,470**	**CY**	**$100**	**$1,381,000**	**$207,000**	**$69,000**	**$1,657,000**	**25 percent bulkng factor**
		Cat 345B LA Excavator w/Environmental Bucket	88	DAY	$800	$70,400	$10,560	$3,520		
		Support Barge	88	DAY	$600	$52,800	$7,920	$2,640		
		OPERATOR	704	HR	$49	$34,684	$5,203	$1,734		
		Barge Operator	704	HR	$65	$45,760	$6,864	$2,288		
		Deckhand	704	HR	$60	$42,240	$6,336	$2,112		
		LABORER	704	HR	$45	$31,439	$4,716	$1,572		

		LABORER	704	HR	$45	$31,439	$4,716	$1,572		
		FOGM	1	LS	$61,600	$61,600	$9,240	$3,080		
		Excavator Platform	1	LS	$500,000	$500,000	$75,000	$25,000		
		Odor Control	88	DAY	$869	$76,484	$11,473	$3,824		
		Adsorbent Boom	7,115	LF	$40	$284,600	$42,690	$14,230		
		Transfer Pump	88	DAY	$1,300	$114,400	$17,160	$5,720		
		Baker Tank	88	DAY	$400	$35,200	$5,280	$1,760		
17	**Includes all labor, equipment, & ODC costs for Sediment Transport**	**SedimentTransport from East Beach To Upland Dewatering Area**	**16,470**	**CY**	**$40**	**$583,000**	**$88,000**	**$29,000**	**$700,000**	**25 percent bulkng factor**
		Dump Truck - 8 CY	88	DAY	$480	$42,240	$6,336	$2,112		
		Dump Truck - 8 CY	88	DAY	$480	$42,240	$6,336	$2,112		
		Dump Truck - 8 CY	88	DAY	$480	$42,240	$6,336	$2,112		
		Dump Truck - 8 CY	88	DAY	$480	$42,240	$6,336	$2,112		
		Dump Truck - 8 CY	88	DAY	$480	$42,240	$6,336	$2,112		
		Dump Truck - 8 CY	88	DAY	$480	$42,240	$6,336	$2,112		
		Truck Driver	704	HR	$46	$32,384	$4,858	$1,619		
		Truck Driver	704	HR	$46	$32,384	$4,858	$1,619		
		Truck Driver	88	HR	$480	$42,240	$6,336	$2,112		
		Truck Driver	88	HR	$480	$42,240	$6,336	$2,112		
		Truck Driver	704	HR	$46	$32,384	$4,858	$1,619		
		Truck Driver	704	HR	$46	$32,384	$4,858	$1,619		
		LABORER	704	HR	$45	$31,439	$4,716	$1,572		
		FOGM	1	LS	$84,480	$84,480	$12,672	$4,224		
18	**Includes all labor, equipment, & ODC costs for Mechanical Dredging**	**Mechanical Dredging (North Shoal)**	**16,470**	**CY**	**$60**	**$799,000**	**$120,000**	**$40,000**	**$958,000**	**25 percent bulkng factor**
		Cat 345B LA Excavator w/Environmental Bucket	53	DAY	$800	$42,400	$6,360	$2,120		
		Barge W/Excavator	53	DAY	$700	$37,100	$5,565	$1,855		
		Transport Barge/Scow	53	DAY	$600	$31,800	$4,770	$1,590		
		OPERATOR	424	HR	$49	$20,889	$3,133	$1,044		
		Barge Operator	424	HR	$65	$27,560	$4,134	$1,378		
		Operator - Barge	424	HR	$62	$26,288	$3,943	$1,314		
		Deckhand	424	HR	$60	$25,440	$3,816	$1,272		
		LABORER	424	HR	$45	$18,935	$2,840	$947		
		LABORER	424	HR	$45	$18,935	$2,840	$947		
		FOGM	1	LS	$55,650	$55,650	$8,348	$2,783		
		Gravel Platform - Trucks	2,889	SY	$11	$32,786	$4,918	$1,639		
		Crane Mats	5,000	SF	$8	$40,000	$6,000	$2,000		
		Odor Control	53	DAY	$869	$46,064	$6,910	$2,303		
		Adsorbent Boom	7,115	LF	$40	$284,600	$42,690	$14,230		
		Transfer Pump	53	DAY	$1,300	$68,900	$10,335	$3,445		
		Baker Tank	53	DAY	$400	$21,200	$3,180	$1,060		
19	**Includes all labor, equipment, & ODC costs for Sediment Transport**	**SedimentTransport from North Shoal To Upland Dewatering Area**	**16,470**	**CY**	**$30**	**$351,000**	**$53,000**	**$18,000**	**$422,000**	**25 percent bulkng factor**
		Dump Truck - 8 CY	53	DAY	$480	$25,440	$3,816	$1,272		
		Dump Truck - 8 CY	53	DAY	$480	$25,440	$3,816	$1,272		
		Dump Truck - 8 CY	53	DAY	$480	$25,440	$3,816	$1,272		
		Dump Truck - 8 CY	53	DAY	$480	$25,440	$3,816	$1,272		
		Dump Truck - 8 CY	53	DAY	$480	$25,440	$3,816	$1,272		
		Dump Truck - 8 CY	53	DAY	$480	$25,440	$3,816	$1,272		
		Truck Driver	424	HR	$46	$19,504	$2,926	$975		
		Truck Driver	424	HR	$46	$19,504	$2,926	$975		

		Truck Driver	53	HR	$480	$25,440	$3,816	$1,272		
		Truck Driver	53	HR	$480	$25,440	$3,816	$1,272		
		Truck Driver	424	HR	$46	$19,504	$2,926	$975		
		Truck Driver	424	HR	$46	$19,504	$2,926	$975		
		LABORER	424	HR	$45	$18,935	$2,840	$947		
		FOGM	1	LS	$50,880	$50,880	$7,632	$2,544		
20	**Includes all labor, equipment, & ODC costs for Sediment Testing**	**Physical Characterization Events: Sediment Testing**	**1**	**LS**	**$33,000**	**$28,000**	**$4,000**	**$1,000**	**$33,000**	
		Sediment Test	66	EA	$250	$16,500	$2,475	$825		
		Field Technician	60	HR	$95	$5,700	$855	$285		
		Field Technician	60	HR	$95	$5,700	$855	$285		
SEDIMENT DEWATERING										
21	**Includes all labor, equipment, & ODC costs for Sediment Dewatering**	**Sediment Dewatering**	**1**	**LS**	**$779,000**	**$650,000**	**$97,000**	**$32,000**	**$779,000**	
		Dewatering Pad	3,630	SY	$39	$142,354	$21,353	$7,118		**PER MEANS 01 55 23.50.0100**
		Sump	1	LS	$2,000	$2,000	$300	$100		
		Transfer Pump	141	DAY	$2,600	$366,600	$54,990	$18,330		
		Baker Tank	282	DAY	$400	$112,800	$16,920	$5,640		**Allowance**
		Water Sampling and Analysis	1	LS	$3,250	$3,250	$488	$163		
		Temporary Piping (Baker Tank Feed)	1,500	LF	$15	$22,500	$3,375	$1,125		
22	**Includes all labor, equipment, & ODC costs for Water Treatment Plant Operation**	**Water Treatment Plant Operation**	**1,364,579**	**GAL**	**$0**	**$0**	**$0**	**$0**	**$0**	
		LABORER	0	HR	$45	$0	$0	$0		
		LABORER	0	HR	$45	$0	$0	$0		**Assume GWTP available for use at no additional cost**
		Plant Start-Up	0	LS	$49	$0	$0	$0		
		Plant O&M	0	MO	$55,000	$0	$0	$0		
CAP PLACEMENT										
23	**Includes all labor, equipment, & ODC costs for Fill Material Transport**	**Thick Cap Placement: Fill Material Transport**	**32,940**	**CY**	**$20**	**$671,000**	**$101,000**	**$34,000**	**$806,000**	
		Dump Truck - 8 CY	88	DAY	$480	$42,163	$6,324	$2,108		
		Dump Truck - 8 CY	88	DAY	$480	$42,163	$6,324	$2,108		
		Dump Truck - 8 CY	88	DAY	$480	$42,163	$6,324	$2,108		
		Dump Truck - 8 CY	88	DAY	$480	$42,163	$6,324	$2,108		
		Dump Truck - 8 CY	88	DAY	$480	$42,163	$6,324	$2,108		
		Dump Truck - 8 CY	88	DAY	$480	$42,163	$6,324	$2,108		
		CAT 953 Loader	88	DAY	$480	$42,163	$6,324	$2,108		
		OPERATOR	703	HR	$49	$34,620	$5,193	$1,731		
		Truck Driver	703	HR	$46	$32,325	$4,849	$1,616		
		Truck Driver	703	HR	$46	$32,325	$4,849	$1,616		
		Truck Driver	703	HR	$46	$32,325	$4,849	$1,616		
		Truck Driver	703	HR	$46	$32,325	$4,849	$1,616		
		Truck Driver	703	HR	$46	$32,325	$4,849	$1,616		
		Truck Driver	703	HR	$46	$32,325	$4,849	$1,616		
		FOGM	1	LS	$147,570	$147,570	$22,136	$7,379		

Table F-7 Capital Implementation Costs for Alternative 5:Dredging
Wyckoff OU-1 Focused Feasibility Study

24	**Includes all labor, equipment, & ODC costs for Mechanical Dredge Cap Placement**	**Thick Cap Placement: East Beach**	**16,470**	**CY**	**$80**	**$1,130,000**	**$170,000**	**$57,000**	**$1,356,000**	
		Granular Absorbent Media - AquaGate+OC	329	CY	$1,750	$576,447	$86,467	$28,822		
		Geotextile Layer	0	SY	$5	$0	$0	$0		
		Crushed Stone	0	CY	$30	$0	$0	$0		
		Beach Sand	16,141	CY	$20	$322,810	$48,422	$16,141		
		Cat 345B LA Excavator w/Environmental Bucket	55	DAY	$800	$43,920	$6,588	$2,196		
		Support Barge	55	DAY	$600	$32,940	$4,941	$1,647		
		OPERATOR	439	HR	$49	$21,638	$3,246	$1,082		
		Barge Operator	439	HR	$65	$28,548	$4,282	$1,427		
		Deckhand	439	HR	$60	$26,352	$3,953	$1,318		
		LABORER	439	HR	$45	$19,613	$2,942	$981		
		LABORER	439	HR	$45	$19,613	$2,942	$981		
		FOGM	1	LS	$38,430	$38,430	$5,764	$1,921		
25	**Includes all labor, equipment, & ODC costs for Mechanical Dredge Cap Placement**	**Thick Cap Placement: North Shoal**	**16,470**	**CY**	**$80**	**$1,089,000**	**$163,000**	**$54,000**	**$1,307,000**	
		Granular Absorbent Media - AquaGate+OC	329	CY	$1,750	$576,447	$86,467	$28,822		**PER MEANS 01 55 23.50.0100**
		Geotextile Layer	0	SY	$5	$0	$0	$0		
		Crushed Stone	0	CY	$30	$0	$0	$0		
		Beach Sand	16,141	CY	$20	$322,810	$48,422	$16,141		
		Cat 345B LA Excavator w/Environmental Bucket	33	DAY	$800	$26,352	$3,953	$1,318		
		Barge W/Excavator	33	DAY	$700	$23,058	$3,459	$1,153		
		Transport Barge/Scow	33	DAY	$600	$19,764	$2,965	$988		
		OPERATOR	264	HR	$49	$12,983	$1,947	$649		
		Barge Operator	264	HR	$65	$17,129	$2,569	$856		
		Operator - Barge	264	HR	$62	$16,338	$2,451	$817		
		Deckhand	264	HR	$60	$15,811	$2,372	$791		
		LABORER	264	HR	$45	$11,768	$1,765	$588		
		LABORER	264	HR	$45	$11,768	$1,765	$588		
		FOGM	1	LS	$34,587	$34,587	$5,188	$1,729		
CONSTRUCTION MONITORING										
26	**Includes all labor, equipment, & ODC costs for Air Monitoring**	**Air Monitoring**	**1**	**LS**	**$43,000**	**$36,000**	**$5,411**	**$1,804**	**$43,292**	
		Air Monitoring	12	MO	$2,000	$24,076	$3,611	$1,204		
		Air Monitoring Sample Analysis	48	EA	$250	$12,000	$1,800	$600		
27	**Includes all labor, equipment, & ODC costs for Habit/Cultural Resource Monitoring**	**Habitat/Cultural Monitoring**	**1**	**LS**	**$12,000**	**$10,000**	**$2,000**	**$1,000**	**$12,000**	
		Field Scientist	100	HR	$100	$10,000	$1,500	$500		
CONFIRMATION SURVEYS										
28	**Includes all labor, equipment, & ODC costs for Land/Bathymetric Surveys**	**Final Surface Land/Bathymetric Survey**	**1**	**LS**	**$68,000**	**$56,000**	**$8,000**	**$3,000**	**$68,000**	
		Land Survey	50	DAY	$1,125	$56,250	$8,438	$2,813		**PER MEANS 01 71 23.13.1100**

Table F-7 Capital Implementation Costs for Alternative 5:Dredging
Wyckoff OU-1 Focused Feasibility Study

EXCAVATED MATERIAL STABILIZATION & DISPOSAL										
29	**Includes all labor, equipment, & ODC costs for Sediment Stabilization**	**Sediment Stabilization**	**32,940**	**CY**	**$30**	**$773,000**	**$116,000**	**$39,000**	**$928,000**	
		Excavator	66	DAY	$600	$39,528	$5,929	$1,976		
		CAT 953 Loader	66	DAY	$600	$39,528	$5,929	$1,976		
		OPERATOR	527	HR	$70	$36,893	$5,534	$1,845		
		OPERATOR	527	HR	$49	$25,965	$3,895	$1,298		
		LABORER	527	HR	$45	$23,536	$3,530	$1,177		
		LABORER	527	HR	$45	$23,536	$3,530	$1,177		
		Excavator	66	DAY	$600	$39,528	$5,929	$1,976		
		CAT 953 Loader	66	DAY	$600	$39,528	$5,929	$1,976		
		OPERATOR	527	HR	$70	$36,893	$5,534	$1,845		
		OPERATOR	527	HR	$49	$25,965	$3,895	$1,298		
		LABORER	527	HR	$45	$23,536	$3,530	$1,177		
		LABORER	527	HR	$45	$23,536	$3,530	$1,177		
		FOGM	1	LS	$79,056	$79,056	$11,858	$3,953		
		Portland Cement	2,108	TON	$150	$316,222	$47,433	$15,811		
30	**Includes all labor, equipment, & ODC costs for Sediment T&D**	**Transportation & Disposal: Sediment**	**1**	**LS**	**$6,653,000**	**$5,544,000**	**$832,000**	**$277,000**	**$6,653,000**	
		T&D - Contaminated	22,136	TON	$150	$3,320,333	$498,050	$166,017		
		T&D - Non-Haz	22,136	TON	$100	$2,213,556	$332,033	$110,678		
		T&D Coordinator	60	HR	$165	$9,900	$1,485	$495		
PILING DISPOSAL										
31	**Includes all labor, equipment, & ODC costs for Piling T&D**	**Transportation & Disposal: Pilings**	**1**	**LS**	**$56,000**	**$47,000**	**$7,000**	**$2,000**	**$56,000**	
		T&D - Contaminated	225	TON	$150	$33,750	$5,063	$1,688		
		T&D Coordinator	80	HR	$165	$13,200	$1,980	$660		
		ESTIMATED COST							**$20,021,000**	
					Contingency		**30%**		**$6,006,000**	
					Mobilization/Demobilization		**2%**		**$400,000**	
					Construction Management/Oversight		**6%**		**$799,000**	
					Remedial Design		**8%**		**$1,065,000**	
					Project Management		**5%**		**$666,000**	
		TOTAL							**$28,957,000**	

Table F-8 Long-Term Operation and Maintenance (O&M) Costs for Alternative 5:Dredging

Wyckoff OU-1 Focused Feasibility Study

Site:	Wyckoff OU1	**Description:**	Operations and Maintenance Detailed Costing			
Location:	Washington					

MNR COSTS	DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Five Year Monitoring Events						Montor every five years to Year 30 Monitor every ten years from Year 40 to Year 100
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring						
	Field Technician	120	HR	$85	$10,200	
	Travel/Per Diem	15	Day	$200	$3,000	
	Bathymetric Survey	1	LS	$5,000	$5,000	
	Sediment Chemical Quality Monitoring Sample Analysis	45	EA	$130	$5,850	
	Clam Tissue Sample Analysis	15	EA	$150	$2,250	
	QC: Sediment Chemical Quality Monitoring Sample Analysis	5	EA	$130	$650	
	QC: Clam Tissue Sample Analysis	2	EA	$150	$300	
	BOA Sampling: VOCs	6	EA	$750	$4,500	
	Reporting	1	LS	$15,000	$15,000	
	Total Five Year Monitoring Events				**$46,750**	
SPME Portwater Monitoring/Surface Water Monitoring						
	Field Technician: Field Prep	40	HR	$85	$3,400	
	Field Technician	120	HR	$85	$10,200	
	SPMD Deployment & Retrieval	1	LS	$15,000	$15,000	
	Travel/Per Diem	15	Day	$200	$3,000	
	SPMD Processing	40	EA	$250	$10,000	
	Sediment/Surface Water PAH Sample Analysis	40	EA	$130	$5,200	
	Sediment/Surface Water VOC Sample Analysis	40	EA	$130	$5,200	
	Lab Support (Up to 40 Samples)	1	LS	$50,000	$50,000	
	Reporting	1	LS	$25,000	$25,000	
	Total SPME Portwater Monitoring/Surface Water Monitoring				**$127,000**	
TarGOST Monitoring						
	TarGOST Monitoring	1	LS	$125,000	$125,000	
	Reporting	1	LS	$10,000	$10,000	
	Total TarGOST Monitoring				**$135,000**	

LTOM ANNUAL INSPECTION	DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Inspections						Visual cap integrity and seep inspections
	Field Technician	32	HR	$85	$2,720	
	Travel/Per Diem	4	Day	$200	$800	
	Reporting	1	LS	$2,500	$2,500	
	Total Inspections				**$6,020**	

FIVE-YEAR REVIEWS	DESCRIPTION	QTY	UNIT	COST	TOTAL	NOTES
Input to EPA Five-Year Report						
	Project Engineer	80	HR	$105	$8,400	
	Reporting	1	LS	$20,000	$20,000	
	Total Input to EPA Five-Year Report				**$28,400**	

PRESENT VALUE ANALYSIS (30-year) Discount Rate = 7.0%

End Year	COST TYPE	TOTAL COST/YEAR	DISCOUNT FACTOR	PRESENT VALUE	All O&M items include 30% contingency
0	CAPITAL COST	$0	100.00%	$0	
1	PERIODIC COST - O&M	$21,000	93.46%	$20,000	
2	PERIODIC COST - O&M	$21,000	87.34%	$18,000	
3	PERIODIC COST - O&M	$82,000	81.63%	$67,000	
4	PERIODIC COST - O&M	$8,000	76.29%	$6,000	
5	PERIODIC COST - O&M	$45,000	71.30%	$32,000	
6	PERIODIC COST - O&M	$69,000	66.63%	$46,000	
7	PERIODIC COST - O&M	$8,000	62.27%	$5,000	
8	PERIODIC COST - O&M	$8,000	58.20%	$5,000	
9	PERIODIC COST - O&M	$69,000	54.39%	$38,000	
10	PERIODIC COST - O&M	$45,000	50.83%	$23,000	
11	PERIODIC COST - O&M	$8,000	47.51%	$4,000	
12	PERIODIC COST - O&M	$8,000	44.40%	$4,000	
13	PERIODIC COST - O&M	$8,000	41.50%	$3,000	
14	PERIODIC COST - O&M	$8,000	38.78%	$3,000	
15	PERIODIC COST - O&M	$106,000	36.24%	$38,000	
16	PERIODIC COST - O&M	$8,000	33.87%	$3,000	
17	PERIODIC COST - O&M	$8,000	31.66%	$3,000	
18	PERIODIC COST - O&M	$8,000	29.59%	$2,000	
19	PERIODIC COST - O&M	$8,000	27.65%	$2,000	
20	PERIODIC COST - O&M	$106,000	25.84%	$27,000	
21	PERIODIC COST - O&M	$8,000	24.15%	$2,000	
22	PERIODIC COST - O&M	$8,000	22.57%	$2,000	
23	PERIODIC COST - O&M	$8,000	21.09%	$2,000	
24	PERIODIC COST - O&M	$8,000	19.71%	$2,000	
25	PERIODIC COST - O&M	$106,000	18.42%	$20,000	
26	PERIODIC COST - O&M	$8,000	17.22%	$1,000	
27	PERIODIC COST - O&M	$8,000	16.09%	$1,000	
28	PERIODIC COST - O&M	$8,000	15.04%	$1,000	
29	PERIODIC COST - O&M	$8,000	14.06%	$1,000	
30	PERIODIC COST - O&M	$106,000	13.14%	$14,000	
35	PERIODIC COST - O&M	$45,000	9.37%	$4,000	
40	PERIODIC COST - O&M	$106,000	6.68%	$7,000	
45	PERIODIC COST - O&M	$45,000	4.76%	$2,000	
50	PERIODIC COST - O&M	$106,000	3.39%	$4,000	
55	PERIODIC COST - O&M	$45,000	2.42%	$1,000	
60	PERIODIC COST - O&M	$106,000	1.73%	$2,000	
65	PERIODIC COST - O&M	$45,000	1.23%	$1,000	
70	PERIODIC COST - O&M	$106,000	0.88%	$1,000	
75	PERIODIC COST - O&M	$45,000	0.63%	$0	

Table F-8 Long-Term Operation and Maintenance (O&M) Costs for Alternative 5:Dredging

Wyckoff OU-1 Focused Feasibility Study

Site:	Wyckoff OU1	**Description:** Operations and Maintenance Detailed Costing		
Location:	Washington			
80	PERIODIC COST - O&M	$106,000	0.45%	$0
85	PERIODIC COST - O&M	$45,000	0.32%	$0
90	PERIODIC COST - O&M	$106,000	0.23%	$0
95	PERIODIC COST - O&M	$45,000	0.16%	$0
100	PERIODIC COST - O&M	$106,000	0.12%	$0
			TOTAL O&M VALUE (non-discounted)	**$1,985,000**
			TOTAL PRESENT VALUE OF O&M (discounted)	**$417,000**

Table F-9 Long-Term Operation and Maintenance (O&M) Summary By Year

Wyckoff OU-1 Focused Feasibility Study

	YEAR																					
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
ALTERNATIVE 2																						
																				#REF!		
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring	$0	$0	#REF!	$0	$0	#REF!	$0	$0	#REF!	$0	$0	$0	$0	$0	#REF!	$0	$0	$0	$0	#REF!	$0	$0
Bathymetric/Topogrpahic Survey	#REF!	#REF!	#REF!	$0	#REF!	$0	$0	$0	$0	#REF!	$0	$0	$0	$0	#REF!	$0	$0	$0	$0	#REF!	$0	$0
TarGOST Monitoring	$0	$0	$0	$0	#REF!	$0	$0	$0	$0	#REF!	$0	$0	$0	$0	#REF!	$0	$0	$0	$0	#REF!	$0	$0
#REF!	**#REF!**	**#REF!**	**#REF!**	**$0**	**#REF!**	**#REF!**	**$0**	**$0**	**#REF!**	**#REF!**	**$0**	**$0**	**$0**	**$0**	**#REF!**	**$0**	**$0**	**$0**	**$0**	**#REF!**	**$0**	**$0**
LTOM ANNUAL INSPECTION																						
Inspections	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!
TOTAL: LTOM ANNUAL INSPECTION	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**
FIVE-YEAR REVIEWS																						
Input to EPA Five-Year Report	$0	$0	$0	$0	#REF!	$0	$0	$0	$0	#REF!	$0	$0	$0	$0	#REF!	$0	$0	$0	$0	#REF!	$0	$0
TOTAL: Input to EPA Five-Year Report	**$0**	**$0**	**$0**	**$0**	**#REF!**	**$0**	**$0**	**$0**	**$0**	**#REF!**	**$0**	**$0**	**$0**	**$0**	**#REF!**	**$0**	**$0**	**$0**	**$0**	**#REF!**	**$0**	**$0**
LONG TERM OPERATIONS AND MAINTENANCE																						
Seep Remediation	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Seep/Cap Replacement	$0	$0	$0	$0	$0	$0	$0	$0	$112,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL: LONG TERM OPERATIONS AND MAINTENANCE	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$112,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
ALTERNATIVE 3																						
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring	$0	$0	$46,750	$0	$0	$46,750	$0	$0	$46,750	$0	$0	$0	$0	$0	$46,750	$0	$0	$0	$0	$46,750	$0	$0
Bathymetric/Topogrpahic Survey	#REF!	#REF!	#REF!	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TarGOST Monitoring	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL: 0	**#REF!**	**#REF!**	**#REF!**	**$0**	**$0**	**$46,750**	**$0**	**$0**	**$46,750**	**$0**	**$0**	**$0**	**$0**	**$0**	**$46,750**	**$0**	**$0**	**$0**	**$0**	**$46,750**	**$0**	**$0**
LTOM ANNUAL INSPECTION																						
Inspections	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020
TOTAL: LTOM ANNUAL INSPECTION	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**
FIVE-YEAR REVIEWS																						
Input to EPA Five-Year Report	$0	$0	$0	$0	$28,400	$0	$0	$0	$0	$28,400	$0	$0	$0	$0	$28,400	$0	$0	$0	$0	$28,400	$0	$0
TOTAL: Input to EPA Five-Year Report	**$0**	**$0**	**$0**	**$0**	**$28,400**	**$0**	**$0**	**$0**	**$0**	**$28,400**	**$0**	**$0**	**$0**	**$0**	**$28,400**	**$0**	**$0**	**$0**	**$0**	**$28,400**	**$0**	**$0**
LONG TERM OPERATIONS AND MAINTENANCE																						
Cap Replacement	$0	$0	$0	$0	$0	$0	$0	$0	$3,990,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL: LONG TERM OPERATIONS AND MAINTENANCE	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$3,990,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
ALTERNATIVE 4																						
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring	$0	$0	$46,750	$0	$0	$46,750	$0	$0	$46,750	$0	$0	$0	$0	$0	$46,750	$0	$0	$0	$0	$46,750	$0	$0
Bathymetric/Topogrpahic Survey	#REF!	#REF!	#REF!	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TarGOST Monitoring	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL: 0	**#REF!**	**#REF!**	**#REF!**	**$0**	**$0**	**$46,750**	**$0**	**$0**	**$46,750**	**$0**	**$0**	**$0**	**$0**	**$0**	**$46,750**	**$0**	**$0**	**$0**	**$0**	**$46,750**	**$0**	**$0**
LTOM ANNUAL INSPECTION																						
Inspections	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020
TOTAL: LTOM ANNUAL INSPECTION	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**
FIVE-YEAR REVIEWS																						
Input to EPA Five-Year Report	$0	$0	$0	$0	$28,400	$0	$0	$0	$0	$28,400	$0	$0	$0	$0	$28,400	$0	$0	$0	$0	$28,400	$0	$0
TOTAL: Input to EPA Five-Year Report	**$0**	**$0**	**$0**	**$0**	**$28,400**	**$0**	**$0**	**$0**	**$0**	**$28,400**	**$0**	**$0**	**$0**	**$0**	**$28,400**	**$0**	**$0**	**$0**	**$0**	**$28,400**	**$0**	**$0**
LONG TERM OPERATIONS AND MAINTENANCE																						
Sheetpile Inspection/Maintenance	$13,580	$13,580	$13,580	$13,580	$13,580	$0	$0	$0	$0	$13,580	$0	$0	$0	$0	$13,580	$0	$0	$0	$0	$13,580	$0	$0
Cap Maintenance	$0	$0	$0	$0	$0	$0	$0	$0	$3,098,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL: LONG TERM OPERATIONS AND MAINTENANCE	**$13,580**	**$13,580**	**$13,580**	**$13,580**	**$13,580**	**$0**	**$0**	**$0**	**$3,098,000**	**$13,580**	**$0**	**$0**	**$0**	**$0**	**$13,580**	**$0**	**$0**	**$0**	**$0**	**$13,580**	**$0**	**$0**
ALTERNATIVE 5																						
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring	$0	$0	$46,750	$0	$0	$46,750	$0	$0	$46,750	$0	$0	$0	$0	$0	$46,750	$0	$0	$0	$0	$46,750	$0	$0
Bathymetric/Topogrpahic Survey	#REF!	#REF!	#REF!	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TarGOST Monitoring	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL: 0	**#REF!**	**#REF!**	**#REF!**	**$0**	**$0**	**$46,750**	**$0**	**$0**	**$46,750**	**$0**	**$0**	**$0**	**$0**	**$0**	**$46,750**	**$0**	**$0**	**$0**	**$0**	**$46,750**	**$0**	**$0**
LTOM ANNUAL INSPECTION																						
Inspections	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020
TOTAL: LTOM ANNUAL INSPECTION	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**
FIVE-YEAR REVIEWS																						
Input to EPA Five-Year Report	$0	$0	$0	$0	$28,400	$0	$0	$0	$0	$28,400	$0	$0	$0	$0	$28,400	$0	$0	$0	$0	$28,400	$0	$0
TOTAL: Input to EPA Five-Year Report	**$0**	**$0**	**$0**	**$0**	**$28,400**	**$0**	**$0**	**$0**	**$0**	**$28,400**	**$0**	**$0**	**$0**	**$0**	**$28,400**	**$0**	**$0**	**$0**	**$0**	**$28,400**	**$0**	**$0**
LONG TERM OPERATIONS AND MAINTENANCE																						
Cap Maintenance	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL: LONG TERM OPERATIONS AND MAINTENANCE	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**

Table F-9 Long-Term Operation and Maintenance (O&M) Summary By Year
Wyckoff OU-1 Focused Feasibility Study

	YEAR																					
	23	24	25	26	27	28	29	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
ALTERNATIVE 2																						
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring	$0	$0	#REF!	$0	$0	$0	$0	#REF!	$0	#REF!	$0	#REF!	$0	#REF!	$0	#REF!	$0	#REF!	$0	#REF!	$0	#REF!
Bathymetric/Topogrpahic Survey	$0	$0	#REF!	$0	$0	$0	$0	#REF!	#REF!	#REF!	$0	#REF!	$0	#REF!	$0	#REF!	$0	#REF!	$0	#REF!	$0	#REF!
TarGOST Monitoring	$0	$0	#REF!	$0	$0	$0	$0	#REF!	#REF!	#REF!	$0	#REF!	$0	#REF!	$0	#REF!	$0	#REF!	$0	#REF!	$0	#REF!
#REF!	**$0**	**$0**	**#REF!**	**$0**	**$0**	**$0**	**$0**	**#REF!**	**#REF!**	**#REF!**	**$0**	**#REF!**	**$0**	**#REF!**	**$0**	**#REF!**	**$0**	**#REF!**	**$0**	**#REF!**	**$0**	**#REF!**
LTOM ANNUAL INSPECTION																						
Inspections	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!
TOTAL: LTOM ANNUAL INSPECTION	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**
FIVE-YEAR REVIEWS																						
Input to EPA Five-Year Report	$0	$0	#REF!	$0	$0	$0	$0	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!
TOTAL: Input to EPA Five-Year Report	**$0**	**$0**	**#REF!**	**$0**	**$0**	**$0**	**$0**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**	**#REF!**
LONG TERM OPERATIONS AND MAINTENANCE																						
Seep Remediation	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Seep/Cap Replacement	$0	$0	$0	$0	$0	$0	$0	$56,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL: LONG TERM OPERATIONS AND MAINTENANCE	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$56,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
ALTERNATIVE 3																						
																						0
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring	$0	$0	$46,750	$0	$0	$0	$0	$46,750	$0	$46,750	$0	$46,750	$0	$46,750	$0	$46,750	$0	$46,750	$0	$46,750	$0	$46,750
Bathymetric/Topogrpahic Survey	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TarGOST Monitoring	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL: 0	**$0**	**$0**	**$46,750**	**$0**	**$0**	**$0**	**$0**	**$46,750**	**$0**	**$46,750**	**$0**	**$46,750**	**$0**	**$46,750**	**$0**	**$46,750**	**$0**	**$46,750**	**$0**	**$46,750**	**$0**	**$46,750**
LTOM ANNUAL INSPECTION																						
Inspections	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020
TOTAL: LTOM ANNUAL INSPECTION	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**
FIVE-YEAR REVIEWS																						
Input to EPA Five-Year Report	$0	$0	$28,400	$0	$0	$0	$0	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400
TOTAL: Input to EPA Five-Year Report	**$0**	**$0**	**$28,400**	**$0**	**$0**	**$0**	**$0**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**
LONG TERM OPERATIONS AND MAINTENANCE																						
Cap Replacement	$0	$0	$0	$0	$0	$0	$0	$1,995,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL: LONG TERM OPERATIONS AND MAINTENANCE	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$1,995,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
ALTERNATIVE 4																						
																						0
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring	$0	$0	$46,750	$0	$0	$0	$0	$46,750	$0	$46,750	$0	$46,750	$0	$46,750	$0	$46,750	$0	$46,750	$0	$46,750	$0	$46,750
Bathymetric/Topogrpahic Survey	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TarGOST Monitoring	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL: 0	**$0**	**$0**	**$46,750**	**$0**	**$0**	**$0**	**$0**	**$46,750**	**$0**	**$46,750**	**$0**	**$46,750**	**$0**	**$46,750**	**$0**	**$46,750**	**$0**	**$46,750**	**$0**	**$46,750**	**$0**	**$46,750**
LTOM ANNUAL INSPECTION																						
Inspections	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020
TOTAL: LTOM ANNUAL INSPECTION	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**
FIVE-YEAR REVIEWS																						
Input to EPA Five-Year Report	$0	$0	$28,400	$0	$0	$0	$0	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400
TOTAL: Input to EPA Five-Year Report	**$0**	**$0**	**$28,400**	**$0**	**$0**	**$0**	**$0**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**
LONG TERM OPERATIONS AND MAINTENANCE																						
Sheetpile Inspection/Maintenance	$0	$0	$13,580	$0	$0	$0	$0	$13,580	$13,580	$13,580	$13,580	$13,580	$13,580	$13,580	$13,580	$13,580	$13,580	$13,580	$13,580	$13,580	$13,580	$13,580
Cap Maintenance	$0	$0	$0	$0	$0	$0	$0	$1,549,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL: LONG TERM OPERATIONS AND MAINTENANCE	**$0**	**$0**	**$13,580**	**$0**	**$0**	**$0**	**$0**	**$1,562,580**	**$13,580**	**$13,580**	**$13,580**	**$13,580**	**$13,580**	**$13,580**	**$13,580**	**$13,580**	**$13,580**	**$13,580**	**$13,580**	**$13,580**	**$13,580**	**$13,580**
ALTERNATIVE 5																						
																						0
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring	$0	$0	$46,750	$0	$0	$0	$0	$46,750	$0	$46,750	$0	$46,750	$0	$46,750	$0	$46,750	$0	$46,750	$0	$46,750	$0	$46,750
Bathymetric/Topogrpahic Survey	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TarGOST Monitoring	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL: 0	**$0**	**$0**	**$46,750**	**$0**	**$0**	**$0**	**$0**	**$46,750**	**$0**	**$46,750**	**$0**	**$46,750**	**$0**	**$46,750**	**$0**	**$46,750**	**$0**	**$46,750**	**$0**	**$46,750**	**$0**	**$46,750**
LTOM ANNUAL INSPECTION																						
Inspections	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020
TOTAL: LTOM ANNUAL INSPECTION	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**	**$6,020**
FIVE-YEAR REVIEWS																						
Input to EPA Five-Year Report	$0	$0	$28,400	$0	$0	$0	$0	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400	$28,400
TOTAL: Input to EPA Five-Year Report	**$0**	**$0**	**$28,400**	**$0**	**$0**	**$0**	**$0**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**	**$28,400**
LONG TERM OPERATIONS AND MAINTENANCE																						
Cap Maintenance	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL: LONG TERM OPERATIONS AND MAINTENANCE	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**							**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**

Table F-10 Long-Term Operation and Maintenance (O&M) Summary
By Year
Wyckoff OU-1 Focused Feasibility Study

	YEAR																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
ALTERNATIVE 2																		
PERFORMANCE MONITORING																		
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring	$0.00	$0.00	$0.00	$0.00	$54,000.00	$0.00	$0.00	$0.00	$0.00	$54,000.00	$0.00	$0.00	$0.00	$0.00	$54,000.00	$0.00	$0.00	$0.00
SPME Portwater Monitoring/Surface Water Monitoring	$0.00	$0.00	$0.00	$0.00	$127,000.00	$0.00	$0.00	$0.00	$0.00	$127,000.00	$0.00	$0.00	$0.00	$0.00	$127,000.00	$0.00	$0.00	$0.00
TarGOST Monitoring	$0.00	$0.00	$0.00	$0.00	$135,000.00	$0.00	$0.00	$0.00	$0.00	$135,000.00	$0.00	$0.00	$0.00	$0.00	$135,000.00	$0.00	$0.00	$0.00
TOTAL: PERFORMANCE MONITORING	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$316,000.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$316,000.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$316,000.00**	**$0.00**	**$0.00**	**$0.00**
LTOM ANNUAL INSPECTION																		
Inspections	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020
TOTAL: LTOM ANNUAL INSPECTION	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**
FIVE-YEAR REVIEWS																		
Input to EPA Five-Year Report	$0.00	$0.00	$0.00	$0.00	$24,200.00	$0.00	$0.00	$0.00	$0.00	$24,200.00	$0.00	$0.00	$0.00	$0.00	$24,200.00	$0.00	$0.00	$0.00
TOTAL: Input to EPA Five-Year Report	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$24,200.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$24,200.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$24,200.00**	**$0.00**	**$0.00**	**$0.00**
LONG TERM OPERATIONS AND MAINTENANCE																		
Seep Remediation	$0.00	$0.00	$0.00	$0.00	$1,665,000.00	$0.00	$0.00	$0.00	$0.00	$1,665,000.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Seep/Cap Replacement	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$666,000.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL: LONG TERM OPERATIONS AND MAINTENANCE	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$1,665,000.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$2,331,000.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
TOTAL LTOM YEARLY COST	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$2,115,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$2,781,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$450,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**
ALTERNATIVE 3																		
PERFORMANCE MONITORING																		
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring	$0.00	$0.00	$0.00	$0.00	$46,750.00	$0.00	$0.00	$0.00	$0.00	$46,750.00	$0.00	$0.00	$0.00	$0.00	$46,750.00	$0.00	$0.00	$0.00
SPME Portwater Monitoring/Surface Water Monitoring	$0.00	$0.00	$0.00	$0.00	$127,000.00	$0.00	$0.00	$0.00	$0.00	$127,000.00	$0.00	$0.00	$0.00	$0.00	$127,000.00	$0.00	$0.00	$0.00
TarGOST Monitoring	$0.00	$0.00	$0.00	$0.00	$135,000.00	$0.00	$0.00	$0.00	$0.00	$135,000.00	$0.00	$0.00	$0.00	$0.00	$135,000.00	$0.00	$0.00	$0.00
TOTAL: PERFORMANCE MONITORING	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$308,750.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$308,750.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$308,750.00**	**$0.00**	**$0.00**	**$0.00**
LTOM ANNUAL INSPECTION																		
Inspections	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020
TOTAL: LTOM ANNUAL INSPECTION	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**
FIVE-YEAR REVIEWS																		
Input to EPA Five-Year Report	$0.00	$0.00	$0.00	$0.00	$28,400.00	$0.00	$0.00	$0.00	$0.00	$28,400.00	$0.00	$0.00	$0.00	$0.00	$28,400.00	$0.00	$0.00	$0.00
TOTAL: Input to EPA Five-Year Report	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$28,400.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$28,400.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$28,400.00**	**$0.00**	**$0.00**	**$0.00**
LONG TERM OPERATIONS AND MAINTENANCE																		
Cap Replacement	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$1,371,000.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL: LONG TERM OPERATIONS AND MAINTENANCE	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$1,371,000.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
TOTAL LTOM YEARLY COST	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$446,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$1,817,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$446,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**
ALTERNATIVE 4																		
PERFORMANCE MONITORING																		
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring	$0.00	$0.00	$0.00	$0.00	$46,750.00	$0.00	$0.00	$0.00	$0.00	$46,750.00	$0.00	$0.00	$0.00	$0.00	$46,750.00	$0.00	$0.00	$0.00
SPME Portwater Monitoring/Surface Water Monitoring	$0.00	$0.00	$0.00	$0.00	$127,000.00	$0.00	$0.00	$0.00	$0.00	$127,000.00	$0.00	$0.00	$0.00	$0.00	$127,000.00	$0.00	$0.00	$0.00
TarGOST Monitoring	$0.00	$0.00	$0.00	$0.00	$135,000.00	$0.00	$0.00	$0.00	$0.00	$135,000.00	$0.00	$0.00	$0.00	$0.00	$135,000.00	$0.00	$0.00	$0.00
TOTAL: PERFORMANCE MONITORING	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$308,750.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$308,750.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$308,750.00**	**$0.00**	**$0.00**	**$0.00**
LTOM ANNUAL INSPECTION																		
Inspections	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020
TOTAL: LTOM ANNUAL INSPECTION	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**
FIVE-YEAR REVIEWS																		
Input to EPA Five-Year Report	$0.00	$0.00	$0.00	$0.00	$28,400.00	$0.00	$0.00	$0.00	$0.00	$28,400.00	$0.00	$0.00	$0.00	$0.00	$28,400.00	$0.00	$0.00	$0.00
TOTAL: Input to EPA Five-Year Report	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$28,400.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$28,400.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$28,400.00**	**$0.00**	**$0.00**	**$0.00**
LONG TERM OPERATIONS AND MAINTENANCE																		
Sheetpile Inspection/Maintenance	$13,580.00	$13,580.00	$13,580.00	$13,580.00	$13,580.00	$0.00	$0.00	$0.00	$0.00	$13,580.00	$0.00	$0.00	$0.00	$0.00	$13,580.00	$0.00	$0.00	$0.00
Cap Maintenance	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$844,000.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL: LONG TERM OPERATIONS AND MAINTENANCE	**$13,580.00**	**$13,580.00**	**$13,580.00**	**$13,580.00**	**$13,580.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$857,580.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$13,580.00**	**$0.00**	**$0.00**	**$0.00**
TOTAL LTOM YEARLY COST	**$21,000.00**	**$21,000.00**	**$21,000.00**	**$21,000.00**	**$460,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$1,304,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$460,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**
ALTERNATIVE 5																		
PERFORMANCE MONITORING																		
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring	$0.00	$0.00	$0.00	$0.00	$46,750.00	$0.00	$0.00	$0.00	$0.00	$46,750.00	$0.00	$0.00	$0.00	$0.00	$46,750.00	$0.00	$0.00	$0.00
SPME Portwater Monitoring/Surface Water Monitoring	$0.00	$0.00	$0.00	$0.00	$127,000.00	$0.00	$0.00	$0.00	$0.00	$127,000.00	$0.00	$0.00	$0.00	$0.00	$127,000.00	$0.00	$0.00	$0.00
TarGOST Monitoring	$0.00	$0.00	$0.00	$0.00	$135,000.00	$0.00	$0.00	$0.00	$0.00	$135,000.00	$0.00	$0.00	$0.00	$0.00	$135,000.00	$0.00	$0.00	$0.00
TOTAL: PERFORMANCE MONITORING	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$308,750.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$308,750.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$308,750.00**	**$0.00**	**$0.00**	**$0.00**
LTOM ANNUAL INSPECTION																		
Inspections	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020
TOTAL: LTOM ANNUAL INSPECTION	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**
FIVE-YEAR REVIEWS																		
Input to EPA Five-Year Report	$0.00	$0.00	$0.00	$0.00	$28,400.00	$0.00	$0.00	$0.00	$0.00	$28,400.00	$0.00	$0.00	$0.00	$0.00	$28,400.00	$0.00	$0.00	$0.00
TOTAL: Input to EPA Five-Year Report	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$28,400.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$28,400.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$28,400.00**	**$0.00**	**$0.00**	**$0.00**
LONG TERM OPERATIONS AND MAINTENANCE																		
Cap Maintenance	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL: LONG TERM OPERATIONS AND MAINTENANCE	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
TOTAL LTOM YEARLY COST	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$446,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$446,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$446,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**

Table F-10 Long-Term Operation and Maintenance (O&M) Summary
By Year
Wyckoff OU-1 Focused Feasibility Study

	YEAR																			
	19	20	21	22	23	24	25	26	27	28	29	30	35	40	45	50	55	60	65	70
ALTERNATIVE 2																				
PERFORMANCE MONITORING																				
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring	$0.00	$54,000.00	$0.00	$0.00	$0.00	$0.00	$54,000.00	$0.00	$0.00	$0.00	$0.00	$54,000.00	$0.00	$54,000.00	$0.00	$54,000.00	$0.00	$54,000.00	$0.00	$54,000.00
SPME Portwater Monitoring/Surface Water Monitoring	$0.00	$127,000.00	$0.00	$0.00	$0.00	$0.00	$127,000.00	$0.00	$0.00	$0.00	$0.00	$127,000.00	$127,000.00	$127,000.00	$0.00	$127,000.00	$0.00	$127,000.00	$0.00	$127,000.00
TarGOST Monitoring	$0.00	$135,000.00	$0.00	$0.00	$0.00	$0.00	$135,000.00	$0.00	$0.00	$0.00	$0.00	$135,000.00	$135,000.00	$135,000.00	$0.00	$135,000.00	$0.00	$135,000.00	$0.00	$135,000.00
TOTAL: PERFORMANCE MONITORING	**$0.00**	**$316,000.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$316,000.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$316,000.00**	**$262,000.00**	**$316,000.00**	**$0.00**	**$316,000.00**	**$0.00**	**$316,000.00**	**$0.00**	**$316,000.00**
LTOM ANNUAL INSPECTION																				
Inspections	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020
TOTAL: LTOM ANNUAL INSPECTION	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**
FIVE-YEAR REVIEWS																				
Input to EPA Five-Year Report	$0.00	$24,200.00	$0.00	$0.00	$0.00	$0.00	$24,200.00	$0.00	$0.00	$0.00	$0.00	$24,200.00	$24,200.00	$24,200.00	$24,200.00	$24,200.00	$24,200.00	$24,200.00	$24,200.00	$24,200.00
TOTAL: Input to EPA Five-Year Report	**$0.00**	**$24,200.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$24,200.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$24,200.00**	**$24,200.00**	**$24,200.00**	**$24,200.00**	**$24,200.00**	**$24,200.00**	**$24,200.00**	**$24,200.00**	**$24,200.00**
LONG TERM OPERATIONS AND MAINTENANCE																				
Seep Remediation	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Seep/Cap Replacement	$0.00	$666,000.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$666,000.00	$0.00	$666,000.00	$0.00	$333,000.00	$0.00	$333,000.00	$0.00	$0.00
TOTAL: LONG TERM OPERATIONS AND MAINTENANCE	**$0.00**	**$666,000.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$666,000.00**	**$0.00**	**$666,000.00**	**$0.00**	**$333,000.00**	**$0.00**	**$333,000.00**	**$0.00**	**$0.00**
TOTAL LTOM YEARLY COST	**$8,000.00**	**$1,116,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$450,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$1,116,000.00**	**$380,000.00**	**$1,116,000.00**	**$39,000.00**	**$783,000.00**	**$39,000.00**	**$783,000.00**	**$39,000.00**	**$450,000.00**
ALTERNATIVE 3																				
PERFORMANCE MONITORING																				
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring	$0.00	$46,750.00	$0.00	$0.00	$0.00	$0.00	$46,750.00	$0.00	$0.00	$0.00	$0.00	$46,750.00	$0.00	$46,750.00	$0.00	$46,750.00	$0.00	$46,750.00	$0.00	$46,750.00
SPME Portwater Monitoring/Surface Water Monitoring	$0.00	$127,000.00	$0.00	$0.00	$0.00	$0.00	$127,000.00	$0.00	$0.00	$0.00	$0.00	$127,000.00	$127,000.00	$127,000.00	$0.00	$127,000.00	$0.00	$127,000.00	$0.00	$127,000.00
TarGOST Monitoring	$0.00	$135,000.00	$0.00	$0.00	$0.00	$0.00	$135,000.00	$0.00	$0.00	$0.00	$0.00	$135,000.00	$135,000.00	$135,000.00	$0.00	$135,000.00	$0.00	$135,000.00	$0.00	$135,000.00
TOTAL: PERFORMANCE MONITORING	**$0.00**	**$308,750.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$308,750.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$308,750.00**	**$262,000.00**	**$308,750.00**	**$0.00**	**$308,750.00**	**$0.00**	**$308,750.00**	**$0.00**	**$308,750.00**
LTOM ANNUAL INSPECTION																				
Inspections	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020
TOTAL: LTOM ANNUAL INSPECTION	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**
FIVE-YEAR REVIEWS																				
Input to EPA Five-Year Report	$0.00	$28,400.00	$0.00	$0.00	$0.00	$0.00	$28,400.00	$0.00	$0.00	$0.00	$0.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00
TOTAL: Input to EPA Five-Year Report	**$0.00**	**$28,400.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$28,400.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**
LONG TERM OPERATIONS AND MAINTENANCE																				
Cap Replacement	$0.00	$1,371,000.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$1,371,000.00	$0.00	$1,371,000.00	$0.00	$1,371,000.00	$0.00	$0.00	$0.00	$0.00
TOTAL: LONG TERM OPERATIONS AND MAINTENANCE	**$0.00**	**$1,371,000.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$1,371,000.00**	**$0.00**	**$1,371,000.00**	**$0.00**	**$1,371,000.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
TOTAL LTOM YEARLY COST	**$8,000.00**	**$1,817,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$446,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$1,817,000.00**	**$385,000.00**	**$1,817,000.00**	**$45,000.00**	**$1,817,000.00**	**$45,000.00**	**$446,000.00**	**$45,000.00**	**$446,000.00**
ALTERNATIVE 4																				
PERFORMANCE MONITORING																				
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring	$0.00	$46,750.00	$0.00	$0.00	$0.00	$0.00	$46,750.00	$0.00	$0.00	$0.00	$0.00	$46,750.00	$0.00	$46,750.00	$0.00	$46,750.00	$0.00	$46,750.00	$0.00	$46,750.00
SPME Portwater Monitoring/Surface Water Monitoring	$0.00	$127,000.00	$0.00	$0.00	$0.00	$0.00	$127,000.00	$0.00	$0.00	$0.00	$0.00	$127,000.00	$127,000.00	$127,000.00	$0.00	$127,000.00	$0.00	$127,000.00	$0.00	$127,000.00
TarGOST Monitoring	$0.00	$135,000.00	$0.00	$0.00	$0.00	$0.00	$135,000.00	$0.00	$0.00	$0.00	$0.00	$135,000.00	$135,000.00	$135,000.00	$0.00	$135,000.00	$0.00	$135,000.00	$0.00	$135,000.00
TOTAL: PERFORMANCE MONITORING	**$0.00**	**$308,750.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$308,750.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$308,750.00**	**$262,000.00**	**$308,750.00**	**$0.00**	**$308,750.00**	**$0.00**	**$308,750.00**	**$0.00**	**$308,750.00**
LTOM ANNUAL INSPECTION																				
Inspections	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020
TOTAL: LTOM ANNUAL INSPECTION	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**
FIVE-YEAR REVIEWS																				
Input to EPA Five-Year Report	$0.00	$28,400.00	$0.00	$0.00	$0.00	$0.00	$28,400.00	$0.00	$0.00	$0.00	$0.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00
TOTAL: Input to EPA Five-Year Report	**$0.00**	**$28,400.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$28,400.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**
LONG TERM OPERATIONS AND MAINTENANCE																				
Sheetpile Inspection/Maintenance	$0.00	$13,580.00	$0.00	$0.00	$0.00	$0.00	$13,580.00	$0.00	$0.00	$0.00	$0.00	$13,580.00	$13,580.00	$13,580.00	$13,580.00	$13,580.00	$13,580.00	$13,580.00	$13,580.00	$13,580.00
Cap Maintenance	$0.00	$844,000.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$844,000.00	$0.00	$844,000.00	$0.00	$844,000.00	$0.00	$0.00	$0.00	$0.00
TOTAL: LONG TERM OPERATIONS AND MAINTENANCE	**$0.00**	**$857,580.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$13,580.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$857,580.00**	**$13,580.00**	**$857,580.00**	**$13,580.00**	**$857,580.00**	**$13,580.00**	**$13,580.00**	**$13,580.00**	**$13,580.00**
TOTAL LTOM YEARLY COST	**$8,000.00**	**$1,304,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$460,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$1,304,000.00**	**$399,000.00**	**$1,304,000.00**	**$58,000.00**	**$1,304,000.00**	**$58,000.00**	**$460,000.00**	**$58,000.00**	**$460,000.00**
ALTERNATIVE 5																				
PERFORMANCE MONITORING																				
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring	$0.00	$46,750.00	$0.00	$0.00	$0.00	$0.00	$46,750.00	$0.00	$0.00	$0.00	$0.00	$46,750.00	$0.00	$46,750.00	$0.00	$46,750.00	$0.00	$46,750.00	$0.00	$46,750.00
SPME Portwater Monitoring/Surface Water Monitoring	$0.00	$127,000.00	$0.00	$0.00	$0.00	$0.00	$127,000.00	$0.00	$0.00	$0.00	$0.00	$127,000.00	$127,000.00	$127,000.00	$0.00	$127,000.00	$0.00	$127,000.00	$0.00	$127,000.00
TarGOST Monitoring	$0.00	$135,000.00	$0.00	$0.00	$0.00	$0.00	$135,000.00	$0.00	$0.00	$0.00	$0.00	$135,000.00	$135,000.00	$135,000.00	$0.00	$135,000.00	$0.00	$135,000.00	$0.00	$135,000.00
TOTAL: PERFORMANCE MONITORING	**$0.00**	**$308,750.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$308,750.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$308,750.00**	**$262,000.00**	**$308,750.00**	**$0.00**	**$308,750.00**	**$0.00**	**$308,750.00**	**$0.00**	**$308,750.00**
LTOM ANNUAL INSPECTION																				
Inspections	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020
TOTAL: LTOM ANNUAL INSPECTION	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**
FIVE-YEAR REVIEWS																				
Input to EPA Five-Year Report	$0.00	$28,400.00	$0.00	$0.00	$0.00	$0.00	$28,400.00	$0.00	$0.00	$0.00	$0.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00
TOTAL: Input to EPA Five-Year Report	**$0.00**	**$28,400.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$28,400.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**
LONG TERM OPERATIONS AND MAINTENANCE																				
Cap Maintenance	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL: LONG TERM OPERATIONS AND MAINTENANCE	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**							**$0.00**
TOTAL LTOM YEARLY COST	**$8,000.00**	**$446,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$446,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$8,000.00**	**$446,000.00**	**$385,000.00**	**$446,000.00**	**$45,000.00**	**$446,000.00**	**$45,000.00**	**$446,000.00**	**$45,000.00**	**$446,000.00**

Table F-10 Long-Term Operation and Maintenance (O&M) Summary
By Year
Wyckoff OU-1 Focused Feasibility Study

	YEAR					
	75	80	85	90	95	100
ALTERNATIVE 2						
PERFORMANCE MONITORING						
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring	$0.00	$54,000.00	$0.00	$54,000.00	$0.00	$54,000.00
SPME Portwater Monitoring/Surface Water Monitoring	$0.00	$127,000.00	$0.00	$127,000.00	$0.00	$127,000.00
TarGOST Monitoring	$0.00	$135,000.00	$0.00	$135,000.00	$0.00	$135,000.00
TOTAL: PERFORMANCE MONITORING	**$0.00**	**$316,000.00**	**$0.00**	**$316,000.00**	**$0.00**	**$316,000.00**
LTOM ANNUAL INSPECTION						
Inspections	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020
TOTAL: LTOM ANNUAL INSPECTION	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**
FIVE-YEAR REVIEWS						
Input to EPA Five-Year Report	$24,200.00	$24,200.00	$24,200.00	$24,200.00	$24,200.00	$24,200.00
TOTAL: Input to EPA Five-Year Report	**$24,200.00**	**$24,200.00**	**$24,200.00**	**$24,200.00**	**$24,200.00**	**$24,200.00**
LONG TERM OPERATIONS AND MAINTENANCE						
Seep Remediation	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Seep/Cap Replacement	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL: LONG TERM OPERATIONS AND MAINTENANCE	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
TOTAL LTOM YEARLY COST	**$39,000.00**	**$450,000.00**	**$39,000.00**	**$450,000.00**	**$39,000.00**	**$450,000.00**
ALTERNATIVE 3						
PERFORMANCE MONITORING						
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring	$0.00	$46,750.00	$0.00	$46,750.00	$0.00	$46,750.00
SPME Portwater Monitoring/Surface Water Monitoring	$0.00	$127,000.00	$0.00	$127,000.00	$0.00	$127,000.00
TarGOST Monitoring	$0.00	$135,000.00	$0.00	$135,000.00	$0.00	$135,000.00
TOTAL: PERFORMANCE MONITORING	**$0.00**	**$308,750.00**	**$0.00**	**$308,750.00**	**$0.00**	**$308,750.00**
LTOM ANNUAL INSPECTION						
Inspections	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020
TOTAL: LTOM ANNUAL INSPECTION	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**
FIVE-YEAR REVIEWS						
Input to EPA Five-Year Report	$28,400.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00
TOTAL: Input to EPA Five-Year Report	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**
LONG TERM OPERATIONS AND MAINTENANCE						
Cap Replacement	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL: LONG TERM OPERATIONS AND MAINTENANCE	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
TOTAL LTOM YEARLY COST	**$45,000.00**	**$446,000.00**	**$45,000.00**	**$446,000.00**	**$45,000.00**	**$446,000.00**
ALTERNATIVE 4						
PERFORMANCE MONITORING						
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring	$0.00	$46,750.00	$0.00	$46,750.00	$0.00	$46,750.00
SPME Portwater Monitoring/Surface Water Monitoring	$0.00	$127,000.00	$0.00	$127,000.00	$0.00	$127,000.00
TarGOST Monitoring	$0.00	$135,000.00	$0.00	$135,000.00	$0.00	$135,000.00
TOTAL: PERFORMANCE MONITORING	**$0.00**	**$308,750.00**	**$0.00**	**$308,750.00**	**$0.00**	**$308,750.00**
LTOM ANNUAL INSPECTION						
Inspections	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020
TOTAL: LTOM ANNUAL INSPECTION	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**
FIVE-YEAR REVIEWS						
Input to EPA Five-Year Report	$28,400.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00
TOTAL: Input to EPA Five-Year Report	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**
LONG TERM OPERATIONS AND MAINTENANCE						
Sheetpile Inspection/Maintenance	$13,580.00	$13,580.00	$13,580.00	$13,580.00	$13,580.00	$13,580.00
Cap Maintenance	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL: LONG TERM OPERATIONS AND MAINTENANCE	**$13,580.00**	**$13,580.00**	**$13,580.00**	**$13,580.00**	**$13,580.00**	**$13,580.00**
TOTAL LTOM YEARLY COST	**$58,000.00**	**$460,000.00**	**$58,000.00**	**$460,000.00**	**$58,000.00**	**$460,000.00**
ALTERNATIVE 5						
PERFORMANCE MONITORING						
Physical Stability/Visual Seep/Chemical Quality/Clam Tissue Monitoring	$0.00	$46,750.00	$0.00	$46,750.00	$0.00	$46,750.00
SPME Portwater Monitoring/Surface Water Monitoring	$0.00	$127,000.00	$0.00	$127,000.00	$0.00	$127,000.00
TarGOST Monitoring	$0.00	$135,000.00	$0.00	$135,000.00	$0.00	$135,000.00
TOTAL: PERFORMANCE MONITORING	**$0.00**	**$308,750.00**	**$0.00**	**$308,750.00**	**$0.00**	**$308,750.00**
LTOM ANNUAL INSPECTION						
Inspections	$6,020	$6,020	$6,020	$6,020	$6,020	$6,020
TOTAL: LTOM ANNUAL INSPECTION	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**	**$6,020.00**
FIVE-YEAR REVIEWS						
Input to EPA Five-Year Report	$28,400.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00	$28,400.00
TOTAL: Input to EPA Five-Year Report	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**	**$28,400.00**
LONG TERM OPERATIONS AND MAINTENANCE						
Cap Maintenance	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL: LONG TERM OPERATIONS AND MAINTENANCE	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
TOTAL LTOM YEARLY COST	**$45,000.00**	**$446,000.00**	**$45,000.00**	**$446,000.00**	**$45,000.00**	**$446,000.00**

Table F-11 Quantities
Wyckoff OU-1 Focused Feasibility Study

SEEP AREAS AND DREDGED MATERIAL STABILIZATION CEMENT QUANTITIES													
ALTERNATIVE	NUMBER OF SEEPS	LENGTH	WIDTH	DEPTH	CUBIC FEET/SEEP	TOTAL CUBIC FEET	CUBIC YARDS/SEEP	TOTAL CUBIC YARDS	WEIGHT/CY	TONS	% PORTLAND CEMENT	TONS PORTLAND CEMENT	T&D TONS
ALT 2	6	40	40	2.50	4,000.00	24,000	148.15	888.89	3,200	1,422.22	5.00%	71.11	1,493.33
ALT 3	0	40	40	2.50	4,000.00	0.00	148.15	0.00	3,200	0.00	5.00%	0.00	0.00
TOTALS						**24,000.00**		**888.89**		**1,422.22**		**71.11**	**1,493.33**

EXCAVATION & CAPPING AREAS AND DREDGED MATERIAL STABILIZATION CEMENT QUANTITIES									
ALTERNATIVE	SF AREA	DEPTH	CUBIC FEET	CUBIC YARDS	WEIGHT/CY	TONS	% PORTLAND CEMENT	TONS PORTLAND CEMENT	T&D TONS
ALT 3	71,150	2.50	177,875.00	6,587.96	3,200	10,540.74	5.00%	527.04	11,067.78
ALT 4 EB	35,575	2.50	88,937.50	3,293.98	3,200	5,270.37	5.00%	263.52	5,533.89
ALT 4 NS	35,575	2.50	88,937.50	3,293.98	3,200	5,270.37	5.00%	263.52	5,533.89
ALT 5 - EB	35,575	10.00	355,750.00	13,175.93	3,200	21,081.48	5.00%	1,054.07	22,135.56
ALT 5 - NS	35,575	10.00	355,750.00	13,175.93	3,200	21,081.48	5.00%	1,054.07	22,135.56
TOTALS			**1,067,250.00**	**39,527.78**		**63,244.44**		**3,162.22**	**66,406.67**

SKIRT TRENCH FOR EXCAVATION AREAS AND DREDGED MATERIAL STABILIZATION CEMENT QUANTITIES										
ALTERNATIVE	LENGTH	WIDTH	DEPTH	TOTAL CUBIC FEET	TOTAL CUBIC YARDS	WEIGHT/CY	TONS	% PORTLAND CEMENT	TONS PORTLAND CEMENT	T&D TONS
ALT 2	1018	3	0.00	0.00	0.00	3,200	0.00	5.00%	0.00	0.00
ALT 3	1640	3	0.00	0.00	0.00	3,200	0.00	5.00%	0.00	0.00
ALT 4	1350	3	0.00	0.00	0.00	3,200	0.00	5.00%	0.00	0.00
TOTALS				**0.00**	**0.00**		**0.00**		**0.00**	**0.00**