Wyckoff/Eagle Harbor Soil and Groundwater Operable Units Focused Feasibility Study - Remedial Technology Screening and Preliminary Remedial Action Alternatives – FINAL

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This technical memorandum (TM) presents the technology screening and proposed remedial action alternatives in support of the Wyckoff/Eagle Harbor Superfund Site (Wyckoff Site, or Site) Soil and Groundwater Operable Units (OU) Focused Feasibility Study (FFS). This TM was prepared as part of work scope items included under Region 10 Architecture and Engineering Services (AES) Contract No. 68-S7-04-01, Task Order 079-RI-FS-10S1.

As described in *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA/540/G-89/004, EPA, 1988), the feasibility study (FS) consists of three phases: a screening of remedial technologies, development of remedial action alternatives, and a detailed analysis of the alternatives. This TM presents the results of the first two phases. The detailed analysis of alternatives will be presented in the Soil and Groundwater OU FFS Report.

This TM is designed to develop U.S. Environmental Protection Agency (EPA) and stakeholder concurrence on the proposed remedial action alternatives, and their technology groupings, prior to preparing the Soil and Groundwater OU FFS report. A majority of the information contained in this TM will also be presented in the FFS report.

Remedial Action Target Area

The area and volume of non-aqueous phase liquid (NAPL)-contaminated source material to be addressed in the FFS was defined using information obtained from a Tar-Specific Green Optical Scanning Tool (TarGOST) field investigation conducted in 2013. The objective for the TarGOST investigation was to define the distribution of NAPL within the Upper Aquifer underlying the Former Process Area. Based on evaluation of the field investigation results (*2014 Conceptual Site Model Update for the OU2 and OU4 Former Process Area*, CH2M HILL, 2014) a TarGOST response of 10 percent reference emitter (%RE) was identified as signifying the presence of NAPL. Because the TarGOST measurements do not specifically indicate the presence of mobile or immobile (residual) NAPL, all locations and depths with a TarGOST response of 10 %RE or greater were identified as potential NAPL source material.

The TarGOST results were used to define five remedial action target zones identified in this TM as the: 1) Core Area, 2) North Shallow (Light NAPL [LNAPL]), 3) East Shallow (LNAPL), 4) North Deep (Dense NAPL [DNAPL]), and 5) Other Periphery. Based on evaluation of the TarGOST data, 91 percent of the Upper Aquifer underlying the Former Process Areas by soil volume was identified for remedial action. Additional information on the approach used to define the remedial action target area is presented in Section 3 of this TM.

Technology Screening Summary

An array of technologies applicable to wood treater site, NAPL source material, was screened to identify a subset of technologies for use in assembling remedial action alternatives. Each technology was screened against the Comprehensive Environmental Response and Liability Act (CERCLA) criteria of effectiveness, implementability, and relative cost as defined in the National Contingency Plan (NCP) under 40 Code of Federal Regulations (CFR) 300.430(e)(7). Additional information on the technology screening is presented in Section 4 of this TM. A list of the retained technologies is presented in Table 4-1 provided in the Tables section at the end of this TM.

Proposed Remedial Action Alternatives

The technologies retained from the screening were assembled into a range of source control alternatives in accordance with the NCP under 40 CFR 300.430(e)(3). Technology and technology combinations identified for each target zone included the following:

- Core Area: In situ Solidification/Stabilization (ISS), Excavation and Thermal Desorption, and Thermal Enhanced Extraction
- North Shallow (LNAPL): ISS, Excavation and Thermal Desorption, Thermal Enhanced Extraction, and In Situ Chemical Oxidation (ISCO)
- East Shallow (LNAPL): ISS, Excavation and Thermal Desorption, and Thermal Enhanced Extraction
- North Deep (DNAPL): ISS, ISCO, and Thermal Enhanced Extraction
- Other Periphery: ISS, ISCO, and Thermal Enhanced Extraction

Enhanced aerobic biodegradation (EAB) is included as a “polishing” technology for deployment in areas with sparse NAPL occurrences and/or for implementation in target zones following completion of more aggressive remedial actions.

Based on the above considerations, a range of source control alternatives were assembled as proposed in Table ES-1 (all tables are provided in a separate section at the end of the main text of the report). In addition to the technologies named in each alternative title, an array of common elements are also required to fully implement each alternative. Additional information on the development and scope of the remedial action alternatives is presented in Section 5 and Appendices D through I of this TM.

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Acronyms and Abbreviations

%RE	percent reference emitter
°F	degrees Fahrenheit
ARAR	applicable or relevant and appropriate requirements
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	contaminant of concern
CSM	conceptual site model
CY	cubic yards
DNAPL	dense non-aqueous phase liquid
EAB	enhance aerobic biodegradation
EC	engineering control
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FFS	focused feasibility study
FRTR	Federal Remediation Technologies Roundtable
FS	feasibility study
gpm	gallon(s) per minute
GRA	general response action
GWTP	groundwater treatment plant
HCl	hydrochloric acid
IC	institutional control
ISCO	in situ chemical oxidation
ISS	in situ solidification/stabilization
ITRC	Interstate Technology and Regulatory Council
kg	kilogram
LNAPL	light non-aqueous phase liquid
MLLW	mean low-low water
MNA	monitored natural attenuation
MTTD	medium temperature thermal desorption
NAPL	non-aqueous phase liquid
NCP	National Contingency Plan
O&M	operations and maintenance
OU	Operable Unit
PAH	polycyclic aromatic hydrocarbon
PCP	pentachlorophenol
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
ROD	Record of Decision
Site	Wyckoff/Eagle Harbor Superfund Site
TarGOST	Tar-Specific Green Optical Scanning Tool
TM	technical memorandum
TOD	total oxidant demand
Wyckoff Site	Wyckoff/Eagle Harbor Superfund Site

1.0 Introduction

The primary objective for the feasibility study (FS) and focused feasibility study (FFS) is to ensure that appropriate remedial alternatives are developed and evaluated such that relevant information concerning the remedial action options can be presented and an appropriate remedy selected.

The purpose of this technical memorandum (TM) is to screen remedial technologies and process options for addressing non-aqueous phase liquid (NAPL) source material present in the Soil and Groundwater Operable Unit (OU) beneath the Wyckoff/Eagle Harbor Superfund Site's (Wyckoff Site, or Site) Former Process Area, and to assemble the retained technologies into a range of remedial action alternatives. The detailed evaluation of remedial alternatives will be presented in the Soil and Groundwater OU FFS report.

1.1 Approach

Remedial action alternatives were developed by assembling combinations of technologies, and the media to which they are applied, into alternatives that address NAPL-contaminated source material. The overall approach included the following steps:

- Step 1 – Identify the remedial action objectives (RAO) specifying the contaminants of concern (COC) and their corresponding remedial goals, the environmental media, and the exposure pathways to be addressed. Most of the information required for this step, which is discussed in Section 2 of this TM, was obtained from *Wyckoff Eagle Harbor Superfund Site – OUs 2 and 4 Draft Remedial Action Objective Meeting Minutes* (Snider, 2013).
- Step 2 - Identify the areas and volumes (e.g., remedial action target area or target zones) of contaminated media to be addressed. This is a key element of the FFS that is discussed in Section 3 of this TM. The remedial action target area was identified as summarized in the *Groundwater Conceptual Site Model Update Report for the Former Process Area, Wyckoff/Eagle Harbor Superfund Site, Soil and Groundwater Operable Units* (Draft CSM Update Report; CH2M HILL, 2013a).
- Step 3 – Identify the general response actions (GRA) for environmental media to be addressed, singly or in combination, which may be taken to achieve the RAOs. GRA categories applicable to the Soil and Groundwater OU included no action, access controls, containment, removal and disposal, ex situ treatment, and in situ treatment.
- Step 4 – Within each GRA category, identify the applicable technologies and their associated process options and screen them based on effectiveness, implementability, and relative cost to eliminate those that are not viable for the Soil and Groundwater OU. The screening, which is presented in Section 4 of this TM, was performed as generally described in *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final* (U.S. Environmental Protection Agency [EPA], 1988).
- Step 5 – Technologies retained from the screening performed in Step 4 were assembled into a range of source control remedial action alternatives, in accordance with the National Contingency Plan (NCP; 40 Code of Federal Regulations [CFR] 300.430(e)(3), because NAPL is the primary contaminant source present in the Soil and Groundwater OU. While assembling alternatives containing multiple technologies, consideration was given to technologies that are compatible and complementary. The results from this step are presented in Section 5 of this TM.

1.2 Current Remedy Status

In February 2000, EPA issued the *Record of Decision, Wyckoff/Eagle Harbor Superfund Site, Soil and Groundwater Operable Units, Bainbridge Island, Washington*; hereafter referred to as the "2000 ROD") for the upland portion of the Wyckoff Site addressing contaminated soil (OU2) and groundwater (OU4). The selected remedy – Thermal Remediation – included a number of components designed to achieve substantial risk reduction by cutting off subsurface contaminant migration pathways with a sheet pile wall and treating the principal threat at the Site using thermal technology. The 2000 ROD also identified a contingent remedy to be implemented in the event the thermal remediation pilot test did not achieve its performance objectives.

A substantial amount of work has been completed since issuance of the 2000 ROD. Major activities have included the following:

1. Installation of 2,300 lineal feet of sheet pile wall around the most heavily contaminated portion of the Site. This includes a 1,870-foot-long outer wall encompassing the north and east perimeter of the Former Process Area, and a 536-foot-long inner wall encompassing the north and east perimeter of the thermal (steam extraction) pilot test area. A shoreline protection system to protect the outer wall has not been constructed.
2. Completion of a steam extraction pilot test. Although the pilot test experienced design and implementation challenges, and did not necessarily achieve its performance objectives, the pilot test demonstrated that steam injection can significantly accelerate contaminant removal from subsurface soil and groundwater.
3. Construction of a new 80 gallon-per-minute (gpm) groundwater treatment plant (GWTP) and demolition of the old GWTP.
4. Upgrading the existing groundwater extraction system and water level monitoring system. The groundwater extraction system consists of groundwater and NAPL pumping from nine Upper Aquifer extraction wells.
5. Routine water level measurements to assess hydraulic containment, and periodic groundwater sampling to assess contaminant concentration trends in the Lower Aquifer.

2.0 Remedial Action Objectives

Prior to identifying and screening remedial technologies, the objectives that the remedial action is intended to achieve must be identified. This section summarizes existing information that forms the basis for the RAOs that guide the technology screening presented in this TM, and the evaluation of remedial action alternatives to be presented in the Soil and Groundwater OU FFS Report.

2.1 Former Process Area Performance Objectives

The following performance objectives were defined for the Former Process Area:

1. Performance Objective #1 - Remove or treat mobile NAPL in the Upper Aquifer to the maximum extent practicable such that migration and leaching of contaminants is significantly reduced. This will remove principal threat materials, which allows for consideration of monitored natural attenuation (MNA) as a remedial action technology for residual concentrations, and allows for implementation of Performance Objective #2.
2. Performance Objective #2 - Implement a remedial action that does not require active hydraulic control as a long-term component of O&M following completion of source removal action.

Relative to Performance Objective #1, remedial action alternatives will be evaluated based on their ability to reduce NAPL mobility and thickness. Multiple lines of evidence will be evaluated in the FFS regarding whether an alternative meets this objective. Relative to Performance Objective #2, hydraulic control may be used during the active remediation phase, but not long term. Performance Objective #2 is only possible if Performance Objective #1 is met.

2.2 Former Process Area RAOs

The RAOs established for OU2/OU4 at the Wyckoff Site through the EPA and Ecology meetings described above are presented in Table 2-1 (all tables are provided in a separate section at the end of the main text). To achieve RAOs #1 to #4, the selected remedial action will have to address Performance Objective #1.

2.3 Contaminants of Concern and Remedial Goals

The primary COCs in soil and groundwater identified in the 2000 ROD include:

- Polycyclic aromatic hydrocarbons (PAHs)
- Pentachlorophenol (PCP)
- Dioxins/Furans (soil)

A list of the individual PAH and dioxin/furan congeners comprising the above COCs is provided in the 2000 ROD. No additional COCs were identified based on the findings of post-ROD investigations.

Remedial goals (RGs) or medium-specific cleanup levels are a core component of the FFS technology screening and remedial alternative development and evaluation process. RGs represent the allowable concentration of chemicals in environmental media that are protective of human health and the environment.

RGs are generally used to identify the area and volume of environmental media to be addressed by a remedial action. For the technology screening and remedial action alternative development presented in this TM, areas and volumes of contaminated media were defined as described in Section 3.0 of this TM. Final remedial goals will be developed by EPA and presented in the ROD amendment.

2.4 Principal and Low-Level Threat Waste

The NCP establishes an expectation that EPA will use treatment to address the principal threats posed by a site wherever practicable (NCP CFR 300.430(a)(l)(iii)(A)). Identifying principal threat wastes combines concepts of both hazard and risk. The manner in which principal threats are addressed generally determines whether the statutory preference for treatment as a principal element of the remedial alternative is satisfied in the ROD.

Principal threat wastes are those source materials considered to be highly toxic or highly mobile that generally cannot be reliably contained, or would present a significant risk to public health or the environment should exposure occur. The decision to treat these wastes is made on a site-specific basis through a detailed analysis of remedial alternatives, using the nine remedy selection criteria specified in the NCP. This analysis provides the basis for making a statutory finding that the selected remedy uses a proven treatment technology as a principal element.

For the purposes of the Wyckoff Soil and Groundwater OU FFS, NAPL source material meets the definition of a principal threat waste. Contaminated groundwater is not considered a principal threat or low-level threat waste because it is not source material (EPA, 1991).

3.0 Remedial Action Target Zones

This section describes the area and volume of contaminated media (remedial action target zones) to be addressed in the Soil and Groundwater OU FFS Report. The general areas (Figure 3-1) identified for remedial action in the Draft CSM Update Report (CH2M HILL, 2013a) included the following:

- Upper Aquifer – Subsurface portion of the Former Process Area upland area with a Tar-Specific Green Optical Scanning Tool (TarGOST) response of 10 percent reference emitter (%RE) or greater. This area (Figure 3-1) corresponds to the footprint where NAPL occurs.
- Lower Aquifer – That portion lying in the northern and southwestern portions of the Former Process Area. In this area, groundwater monitoring results indicate the presence of acenaphthene and other PAHs at concentrations above the groundwater cleanup levels identified in the 2000 ROD (Table 13, EPA, 2000). The potential for saltwater intrusion in the northern area will need to be assessed further in the Soil and Groundwater OU FFS Report in accordance with RAO #4.
- Aquitard – Same northern footprint as defined for the Lower Aquifer.

The Upper Aquifer represents the primary remedial action target area for the FFS because remedial action in this area is necessary to address NAPL source material per Performance Objective #1. Owing to the complexity of the NAPL architecture at the Site, where thinner branches of NAPL extend outward from a thicker NAPL core located near the center of the Former Process Area (associated with primary NAPL sources), the Upper Aquifer was divided into five target zones.

Partitioning of the Upper Aquifer remedial action target area into five target zones was conducted iteratively with feedback from EPA and project stakeholders. EPA concurrence on the horizontal and vertical boundaries of contaminated media is an important early step in the FFS process. The target zone approach allows treatment areas and volumes to be better correlated with specific technologies.

3.1 Approach for Identifying NAPL Presence

During the 2013 Upland NAPL field investigation, 141 primary and 7 replicate TarGOST borings, and 20 confirmation soil core borings were advanced in the Upper Aquifer to characterize NAPL distribution. The high ratio of vertical-to-horizontal TarGOST measurements generated a large dataset containing 198,992 data points. In raw form, the TarGOST data do not explicitly indicate the presence or absence of NAPL. Interpretation is needed to select a minimum TarGOST %RE value that defines the transition or cutoff between NAPL present and NAPL absent.

To accomplish this, a robust evaluation of the TarGOST dataset, using multiple lines of evidence, was conducted to define the %RE cutoff value. Details of this evaluation are presented in the *Wyckoff Upland NAPL Field Investigation Technical Memorandum Field Summary Report* (CH2M HILL, 2013b). The evaluation findings indicate that a value between 5 %RE and 10 %RE can be justifiably selected as the minimum value signifying NAPL presence. Based on EPA and Ecology review and approval, TarGOST responses of 10 %RE and greater are inferred to indicate that NAPL source material is present in the Upper Aquifer.

3.2 Methodology for Upper Aquifer Target Area Definition

Refinement of the Upper Aquifer remedial action target area into smaller target zones allows treatment areas and volumes to be better correlated with specific technologies. This also permits application of multiple and complementary treatment technologies that capitalize on specific technology strengths.

Based on the geographic distribution of NAPL observed, the Upper Aquifer remedial action target area was partitioned into two primary treatment zones: a core area where thick sequences of NAPL are present, and a periphery area where thinner lenses of NAPL occur. The periphery area was further divided into four smaller target zones. The overall partitioning of the Former Process Area into multiple target zones is consistent with the Performance Objectives described in Section 2.1, which focus on developing and evaluating remedial action alternatives that reduce NAPL mobility and thickness, and the overall approach described in the Task Order Work Plan (CH2M HILL, 2012).

In addition to identifying target zones in two-dimensional plan view, each target zone was segregated vertically into three compartments. Additional information on delineation of the target zones and their associated compartments is provided in the following subsections.

3.2.1 Core Area

The Core Area is characterized by thick lenses of NAPL that in aggregate account for the majority of the NAPL mass present in the Former Process Area. The Core Area will require application of aggressive remedial technologies if the Performance Objectives and RAOs for the Former Process Area are to be achieved.

The methodology used to identify the Core Area target zone was initially presented in the *Wyckoff Upland NAPL Field Investigation Technical Memorandum Field Summary Report* (Field Summary Report; CH2M HILL, 2013b). The methodology plots the volume of NAPL-contaminated material against the total soil volume on a chart to generate a curve. The curve is inspected to identify the point, informally referred to as the "breakpoint," where it first begins to flatten. Above the breakpoint, the total volume of soil that must be treated, per each unit volume increase of NAPL-contaminated soil, is much greater.

The evaluation was performed by subdividing the Former Process Area into a two-dimensional array of Thiessen polygons and calculating the volume of NAPL-contaminated material present in each polygon. The breakpoint was identified by ranking the TarGOST borings by percent of NAPL-contaminated volume and then plotting the cumulative NAPL-contaminated soil volume versus cumulative total volume. The breakpoint was selected (see Appendix A) as the point where the NAPL-contaminated soil volume increases at a slower rate than the total soil volume. An illustrative example of the methodology (Figure 3-2) shows the resulting breakpoint graph for the Core Area - Compartments 2 and 3 (combined). Figure 3-3 shows the location of the Core Area target zone.

3.2.2 Periphery Area

The Periphery Area by definition corresponds to the remaining portions of the Former Process Area that lie outside the Core Area and have TarGOST response of 10 %RE and greater.

While evaluating TarGOST information for the Periphery Area, in conjunction with initial technology discussions, it became apparent that the distribution of NAPL in the Periphery Area warranted further subdivision based on considerations of NAPL architecture, geology, depth, and potential technology application. Therefore, the Periphery Area was partitioned into four different target zones identified as the North Shallow (Light NAPL [LNAPL]), East Shallow (LNAPL), North Deep (Dense NAPL [DNAPL]), and Other Periphery areas. These target zones were identified for more discrete application of aggressive remedial technologies because the mobility and thickness of NAPL present is less than present in the Core Area. Additionally, NAPL characteristics vary among these target zones (e.g., LNAPL versus DNAPL).

The NAPL distribution fence diagrams (see Appendix B) presented in the Field Summary Report (CH2M HILL, 2013b) were the primary tool used for visually depicting and selecting the Periphery Area target zones. The methodology used to define the Periphery Area target zones included the following steps:

- The Core Area was marked on each of the fence diagrams and then the Periphery Area was identified.
- Using the TarGOST logs and professional judgment, target zones were identified focusing on continuous NAPL thickness and relative TarGOST response.
- Polygons with similar NAPL characteristics (inferred as LNAPL, DNAPL, or LNAPL and DNAPL based on NAPL architecture) were grouped into discrete target zones.

- The partitioning process was completed by combining the Thiessen polygon areas with the thickness of NAPL-contaminated soil observed to estimate target zone volumes.
- TarGOST borings and their associated polygons with an aggregate NAPL thickness of less than 1 foot were not identified for active remediation. It is expected that NAPL present at these locations will be addressed incidentally by active remediation of adjacent target zones.

Because a number of TarGOST logs are not depicted on the fence diagrams, another tool referred to as a cluster diagram was also used to support identification of Periphery Area target zones. Four cluster diagrams, which grouped the remaining TarGOST logs, not depicted on the fence diagrams, were prepared (see Appendix B) for different areas of the Site. As with the fence diagrams, the Core Area was demarcated first, where present, and then the Periphery Area target zones were identified using professional judgment; again focusing on NAPL thickness and %RE. Figure 3-3 shows the boundaries of the Core Area, each of the Periphery Area target zones, and the Thiessen polygons within the Periphery Area that were not assigned to a target zone (e.g., not identified for remedial action).

3.2.3 Compartments

Based on interpretation of the TarGOST data and knowledge of wood-treating formulations, there are distinct areas where NAPL occurs as: 1) LNAPL that has spread horizontally and smeared along a variable water table surface, and 2) DNAPL that has migrated vertically downward to the Aquitard and then spread laterally on the top of the Aquitard. Based on these occurrences, the Upper Aquifer was segregated into three vertical compartments (Figure 3-4), as follows:

- Compartment 1 – Extends from the ground surface to just below the water table elevation (-5 feet mean low-low water [MLLW]).
- Compartment 2 – Extends from -5 MLLW to 10 feet above the Aquitard, and
- Compartment 3 – Extends from 10 feet above the Aquitard to the TarGOST boring refusal depth, which is generally at or just below the top of the Aquitard.

3.3 Description of Target Zones by Core and Periphery Areas

The five remedial action target zones shown on Figure 3-5 are described briefly in the following subsections. The areas where remedial action is not proposed are also shown on Figure 3-5. As indicated previously, it is expected that residual NAPL present in areas (e.g., polygons) not proposed for remedial action will be addressed incidentally through remedial action of adjacent target zones and MNA. The volume of soil, volume of NAPL-contaminated soil, and estimated volume of NAPL present in each target zone are summarized in Table 3-1.

3.3.1 Core Area

The Core Area target zone was identified by the combined Upper Aquifer breakpoint graph results for NAPL-contaminated material. Potential remedial action technologies for the Core Area will address NAPL present in Compartments 1, 2, and 3, which extends from the ground surface to the top of the Aquitard. The volume of NAPL-contaminated soil captured in this target zone is estimated at 38,700 cubic yards (CY) or 100 percent of the NAPL-contaminated volume (Table 3-2).

3.3.2 Periphery - North Deep (DNAPL) Area

The North Deep (DNAPL) Periphery target zone is located on the north end of the Former Process Area. This zone is characterized by DNAPL present in Compartment 3 (Upper Aquifer-Aquitard interface).The volume of NAPL-contaminated soil captured in this target zone is estimated at 11,800 CY or 83 percent of the NAPL-contaminated volume (Table 3-2).

3.3.3 Periphery - North Shallow (LNAPL) Area

The North Shallow (LNAPL) Periphery target zone is located on the north end of the Former Process Area and is characterized by LNAPL present in Compartment 1 (capillary fringe). The volume of NAPL-contaminated soil captured in this target zone is estimated at 4,200 CY or 88 percent of the NAPL-contaminated volume (Table 3-2).

3.3.4 Periphery – North Shallow and Deep (Overlap of LNAPL and DNAPL Areas)

This is an overlap of the North Shallow and North Deep Periphery target zones located on the north end of the Former Process Area. This zone is characterized by NAPL present in Compartment 2. The volume of NAPL-contaminated soil captured in this target zone is estimated at 2,900 CY or 84 percent of the NAPL-contaminated volume (Table 3-2).

3.3.5 Periphery - East Shallow (LNAPL) Area

The East Shallow (LNAPL) Periphery target zone is located along the east side of the Former Process Area and is characterized by LNAPL present in Compartment 1, and sporadic NAPL present in Compartment 2. The volume of NAPL-contaminated soil captured in this target zone is estimated at 39,200 CY or 91 percent of the NAPL-contaminated volume (Table 3-2).

3.3.6 Periphery – Other Areas

The Other Periphery target zones represent areas with discontinuous NAPL that are located near the south and southwest portions of the Former Process Area. This target zone is characterized by NAPL present in isolated pockets. The volume of NAPL-contaminated soil captured in this target zone is estimated at 3,500 CY or 82 percent of the NAPL-contaminated volume (Table 3-2).

3.4 Summary of Areas and Volumes of Media to Be Addressed

The Upper Aquifer remedial action target area includes those portions of the Former Process Area where NAPL occurs as defined by a TarGOST response of 10 %RE and greater. Owing to the complexity of the NAPL architecture, where thinner branches of NAPL extend outward from a thicker NAPL core located near the center of the Former Process Area, the Upper Aquifer remedial action target area was divided into five smaller target zones. Refinement of the Upper Aquifer remedial action target area into distinct target zones allows for application of multiple and complementary treatment technologies within a single remedial action alternative.

Within the Upper Aquifer, a Core Area and Periphery Area were identified. The Core Area is characterized by thick NAPL occurrences, and the Periphery Area by thinner NAPL lenses. The Periphery Area was further partitioned into four smaller target zones to allow for focused application of specific treatment technologies.

Volume estimates of NAPL-contaminated soil were developed using a Thiessen polygon approach, as summarized in the Conceptual Site Model Update Report (CH2M HILL, 2013a). The estimated volumes of NAPL-contaminated soil and NAPL present in the target zones are shown in Table 3-2. Based on evaluation of the TarGOST data, 91 percent of the Upper Aquifer underlying the Former Process Areas by soil volume was identified for remedial action.

4.0 Technology Screening

This section identifies and screens remedial technologies, and their associated process options, potentially capable of achieving the Performance Objectives and RAOs identified in Section 2. The remedial technologies were screened for their ability to achieve the Performance Objectives and RAOs based on the CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act) criteria of effectiveness; implementability; and relative cost. The technologies retained from the screening are combined into a range of remedial action alternatives in Section 5 of this TM.

4.1 Remedial Technologies Considered

The technology screening step included a broad range of technologies applicable to wood treater sites with an emphasis on treatment technologies that address NAPL source material. Additionally, because the remedial action timeframe is expected to span several to tens of years, technologies that protect human health and the environment during the remedial action were also emphasized. Factors considered in this evaluation include the state of technology development, site conditions, NAPL characteristics and distribution, and specific COCs that could limit the effectiveness or implementability of a technology.

Sources of information considered for the technology screening included:

- Presumptive Remedies for Soils, Sediment, and Sludges at Wood Treater Sites (EPA, 1995)
- 1997 OU2/OU4 FS Report (CH2M HILL, 1997)
- Previous bench-scale and field-scale pilot studies
- CH2M HILL project experience on other wood treater sites
- Federal Remediation Technologies Roundtable (FRTR, 2010)
- Interstate Technology and Regulatory Council (ITRC, 2009)
- Vendor information, case studies, and technical journal articles
- Information presented in the *Generational Remedy Evaluation* (Ecology, 2010)

The technology screening includes many of the technologies retained in the OU2/OU4 FS Report (CH2M HILL, 1997) and technologies used under the current containment remedy.

4.2 Technology Screening Criteria and Methodology

The technology screening qualitatively assesses each technology's ability to achieve the Performance Objectives and RAOs using the CERCLA criteria of effectiveness, implementability, and cost as defined in the NCP (40 CFR 300.430 (e) (7)). Technologies that are not viable based on these considerations were eliminated from further consideration.

4.2.1 Effectiveness

Effectiveness refers to the ability of a technology and its associated process option(s) to perform as a stand-alone or component of a broader alternative to meet RAOs under the conditions and limitations present at a site. Additionally, the NCP (40 CFR 300) defines effectiveness as the "degree to which an alternative reduces toxicity, mobility, or volume through treatment; minimizes residual risk; affords long-term protection; complies with Applicable or Relevant and Appropriate Requirements (ARARs); minimizes short-term effects; and how quickly it achieves protection." Section 4.2.5 of CERCLA RI/FS Guidance (EPA/540/G-89/004) states that the evaluation of remedial technologies and process options with respect to effectiveness should focus on: "(1) the potential effectiveness of process options in handling the estimated areas or volumes of media and meeting the remediation goals identified in the RAOs; (2) the potential impacts to human health and the environment (HHE) during the construction and implementation phase; and (3) how proven and reliable the process is with respect to the contaminants and conditions at the site."

4.2.2 Implementability

Implementability refers to the relative degree of difficulty anticipated in implementing a particular remedial technology and process option under technical, regulatory, and schedule (administrative) constraints posed by a site. As suggested by CERCLA RI/FS Guidance (EPA/540/G-89/004), process options and entire technology types can be eliminated from further consideration if a technology or process option cannot be effectively implemented at a site. As discussed in Section 4.2.5 of CERCLA RI/FS Guidance (EPA/540/G-89/004), "technical implementability is used as an initial screening of technology types and process options to eliminate those that are clearly ineffective or unworkable at a site." Administrative implementability, which includes "the ability to obtain necessary permits for offsite actions, the availability of treatment, storage, and disposal services (including capacity), and the availability of necessary equipment and skilled workers to implement the technology," is also considered in the initial screening.

4.2.3 Relative Cost

For the initial screening of technology types and process options, the cost criterion is relative; meaning quantitative cost estimates are not prepared. Rather it compares remedial technology and process option costs using narrative terms. Section 4.2.5 of CERCLA RI/FS Guidance (EPA/540/G-89/004) states that "cost plays a limited role in the screening of process options. Relative capital and O&M costs are used rather than detailed estimates. At this stage in the process, the cost analysis is made on the basis of engineering judgment, and each process is evaluated as to whether costs are high, low, or medium relative to other process options in the same technology type." For this evaluation, relative cost is used to screen out process options that have a high capital cost if there are other choices that perform similar functions with similar effectiveness. Technology screening based on relative O&M costs was not specifically performed but was considered as part of the overall cost evaluation.

4.2.4 Assessment Methodology

The assessment of individual technologies and their associated process options was performed based on the criteria described above using a relative grading scale employing a "Good," "Moderate," or "Poor" rating. To create greater separation, or where a technology's performance could vary within the different target zones at the Site, a blended rating such as Poor to Moderate or Moderate to Good was used. Once the assessment against each of the three criteria was completed, a "Retained" or "Not Retained" determination was made. The assessment is subjective, and the initial assessment presented in this TM may be revised following EPA review and comment on this TM.

4.3 General Response Actions

GRAs are typically 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 - includes institutional controls (ICs) and engineering controls (ECs)
- Containment
- Removal and Disposal (onsite and offsite)
- Ex Situ Treatment (onsite and offsite)
- In Situ Treatment

Because this FFS focuses on NAPL source material, the GRAs were not segregated by soil and groundwater. The following Sections 4.3.1 through 4.3.5 provide a general description of each GRA.

4.3.1 No Action

This GRA is required as a baseline for comparison against other technologies 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 ROD or ROD amendment signature.

4.3.2 Access Restrictions

This GRA includes ICs and ECs. ICs are administrative controls or legal restrictions placed on land and groundwater use to protect the public against inadvertent exposure to hazardous constituents and/or to protect the integrity of a functioning or completed remedy. ICs may include land use restrictions, natural resource use restrictions, groundwater use restriction or management areas, property deed notices, declaration of environmental restrictions, access controls (digging/drilling permits), surveillance, information posting or distribution, restrictive covenants, and federal/state/county/local registries.

ECs generally include fences or manned security to protect against trespasser exposure to contaminated soils or groundwater (seeps/springs) until RAOs are achieved. For groundwater, ECs may include provision of an alternate water supply for current or future users when contaminated groundwater is identified as a current drinking water source.

The existing containment remedy for the Site uses access restrictions to reduce the potential for human exposure to contaminated media present in the Former Process Area.

4.3.3 Removal and Disposal

These GRAs include excavation to remove contaminated media with long-term containment and management provided by disposing of the material at a secure onsite or a permitted offsite Resource Conservation and Recovery Act (RCRA) Subtitle D or Subtitle C facility. Depending on the concentration of contaminants present, disposal may be combined with ex situ treatment to comply with RCRA land disposal restrictions.

4.3.4 Ex Situ Treatment

This GRA includes technologies employed at an onsite or offsite treatment facility that treat contaminated media in aboveground treatment units. The current containment remedy uses ex situ physical treatment technologies (NAPL separation and granular activated carbon filtration) to treat NAPL, PAH, and PCP contamination in groundwater.

4.3.5 In Situ Treatment

This GRA includes various technologies (biological, chemical, thermal, physical) to treat contaminated media below the ground surface or in situ. MNA is also included within the scope of this GRA.

4.4 Technology Screening Results

As described in Section 4.2, individual remedial technologies and their associated process options were screened based on considerations of effectiveness, implementability, and relative cost. The screening step narrows the list of remedial technologies to identify the most viable candidates for use in assembling remedial action alternatives. The technology screening and screening results are summarized in Appendix C, Table C-1. Where appropriate, the technology screening also provides the justification for retaining or not retaining a technology for further consideration. The technology screening may be updated following EPA review and comment on this TM. The remedial technologies and process options retained from the screening are summarized in Table 4-1.

Based on the list of retained technologies, individual technology and technology combinations identified for each target zone included the following:

- Core Area
  - In Situ Solidification/Stabilization (ISS)

  - Excavation and Thermal Desorption
  - Thermal Enhanced Extraction

- North Shallow (LNAPL)
  - ISS
  - Excavation and Thermal Desorption
  - In Situ Chemical Oxidation (ISCO)
  - Thermal Enhanced Extraction

- East Shallow (LNAPL)
  - ISS
  - Excavation and Thermal Desorption
  - Thermal Enhanced Extraction

- North Deep (DNAPL)
  - ISS
  - ISCO
  - Thermal Enhanced Extraction

- Other Periphery
  - ISS
  - ISCO
  - Thermal Enhanced Extraction

Enhanced aerobic biodegradation (EAB) was identified as a polishing technology for implementation following application of more aggressive technologies, and for application in the Other Periphery target zone where dispersed NAPL occurs.

5.0 Preliminary Remedial Action 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.*

Per the above expectations, and the retained technology and target zone correlations identified in Section 4.4, a range of source control alternatives were assembled. While other technology and process option combinations are possible, consideration was given to technology combinations that appear most viable based on the Performance Objectives and RAOs. This list of alternatives is preliminary and must be fully vetted with EPA and stakeholder representatives prior to preparation of the Soil and Groundwater OU FFS Report.

The proposed alternatives include:

- Alternative 1 – No Action (required per the NCP)
- Alternative 2 - Containment (this is the current remedy)
- Alternative 3 – Excavation, Thermal Desorption, and ISCO
- Alternative 4 – ISS
- Alternative 5 – Thermal Enhanced Extraction and ISCO
- Alternative 6 – Excavation, Thermal Desorption, and Thermal Enhanced Extraction

A general description of the unique attributes of each alternative is presented in Sections 5.2 through 5.7. All of the remedial action alternatives, with the exception of Alternative 1 – No Action, require additional technologies, not inherent in the alternative title, that are needed to fully implement the alternative. These additional technologies, identified as common elements, are discussed in Section 5.1 before the remedial alternatives are described. The proposed remedial action alternatives are also listed in Table ES-1.

5.1 Common Elements

Many of the alternatives described in Sections 5.2 through 5.7 have one or more common elements (Table 5-1) including several of the key technologies inherent in each alternative name. The following subsections provide a brief description of the key technologies and common elements comprising each alternative. More detailed discussion of the common elements is also provided in Appendix D.

5.1.1 Access Improvements (Alternatives 3, 4, and 6)

Several remedial alternatives require heavy equipment that will need to be delivered by barge. Anticipated access improvements include the following:

- Temporary dock and ramp for offloading heavy equipment from barges
- Temporary anchoring systems for barges
- New road access to the Site for general truck delivery
- New outfall pipe to replace the deteriorated outfall

Additional discussion and details are provided in Appendix D, Section D1.

5.1.2 Demolition, Decontamination/Reuse, and Disposal (Alternatives 3 to 6)

Demolition and removal of existing structures, underground utilities, and buried debris will be required to prepare the Site for remedial action implementation. Demolition includes the following work:

- Removal of concrete foundations and other structures
- Removal of buried utilities (pipes and conduit) and debris
- Decontamination of concrete, buried utilities, and debris
- Processing decontaminated concrete into reusable material
- Transport to and disposal of hazardous demolition debris, that cannot be decontaminated, at a RCRA Subtitle C facility

The estimated volume of demolition debris is 14,300 CY. The FFS assumes that 50 percent of this material can be decontaminated and reused onsite, while the other 50 percent will require disposal at a RCRA Subtitle C facility. However, further evaluation will be performed during preparation of the FFS to determine if it is technically feasible to decontaminate and reuse the 50 percent of the material currently assumed to be hazardous. Decontamination would be performed through sizing and treatment using thermal desorption or solidification/stabilization reagent technology. Additional discussion and details are provided in Appendix D, Section D2.

5.1.3 Groundwater Extraction and Treatment (Alternatives 2 to 6)

In addition to providing treatment of groundwater produced by containment or dewatering, the existing GWTP will also treat groundwater that is produced by thermal treatment.

After the work described for Alternatives 3 through 6 is completed, it is expected that the GWTP will continue to be maintained and potentially operated, as necessary, for up to 10 years. Any remaining contamination present after 10 years of operation would be addressed by passive groundwater treatment (see Section 5.1.11 and MNA (see Section 5.1.12). For Alternative 2 – Containment, the GWTP would operated for a longer timeframe to be determined in the FFS.

For Alternatives 3, 4, and 6 existing groundwater wells may need to be removed as part of the remedial action. Therefore, for these alternatives, new groundwater wells may have to be installed.

5.1.4 Enhanced NAPL Recovery (Alternatives 3 to 6)

Where NAPL is pooled along the water table (LNAPL) or on low permeability layers (DNAPL), inducing NAPL to flow to wells is an effective means of achieving significant contaminant mass reduction, which in turn increases the effectiveness of other treatment technologies. Under this common element, enhanced NAPL recovery would be performed by increasing the horizontal hydraulic gradient across the area where mobile NAPL occurs. The mobile NAPL area is defined by the area where a TarGOST response greater than 50% RE was observed. Gradient control across this area would be achieved through a coordinated injection and total fluids pumping strategy. The boundaries of the enhanced NAPL recovery treatment area will be refined during remedial design to align with other elements of the selected remedy. Pumped fluids would be conveyed to the GWTP were the NAPL would be separated and transferred to a storage tank for offsite treatment, or if possible, the recovered NAPL could be used as a fuel supplement under Alternatives 3, 5, and 6. A portion of the treated water from the GWTP would be pumped to the injection wells. For the purposes of the FFS, it is assumed enhanced NAPL recovery would be performed for up to 5 years.

5.1.5 Dewatering, Treatment, and Discharge (Alternatives 3 to 6)

Dewatering is included as a common element for Alternatives 3 through 6. The dewatering system design will be developed to utilize the available capacity of the existing GWTP, which has a design capacity of 140 gpm, with modifications to the existing plant control systems. During the period between October and April, the GWTP treats groundwater from the containment wells at an average flow rate of 60 gpm. Therefore, during this period, the GWTP's available capacity would be 80 gpm. This common element also includes modification of the existing outfall structure to allow for higher discharge rates and pumped discharge versus the current outfall which only allows for gravity discharge.

5.1.6 Soil Excavation (Alternatives 3 to 6)

Shallow and deep soil excavation is required for implementation of Alternatives 3 and 6, and shallow excavation for Alternatives 4 and 5.

Soil excavation includes the following work:

- Excavate soil as needed for demolition.
- Excavate soil as needed to prepare treatment areas for ISS or thermal treatment.
- Excavate soil that will be treated by thermal desorption.
- Stockpile excavated soil.
- Sample and test stockpiled soil to determine if it is hazardous.
- Onsite treatment of hazardous soil and obtaining a regulatory "contained out" determination for listed hazardous soil following treatment and confirmation sampling to allow for onsite reuse of the soil.
- Use soil designated as non-hazardous for onsite fill material.
- Use excess soil that is non-hazardous to recontour the site topography.

The estimated volumes of material to be excavated by alternative and target zone are summarized in Table 5-3. Additional discussion and details are provided in Appendix D, Section D3.

5.1.7 Propane System (Alternatives 3, 5, and 6)

Alternatives 3, 5, and 6 require a fuel source to power the thermal desorber unit (Alternative 3 and 6) and the steam boiler and thermal oxidizer (Alternatives 3, 5, and 6). Propane would be used as the fuel source. The propane system includes the following components:

- Propane storage tank
- Propane delivery truck offloading facility
- Propane vaporizer

The total estimated propane consumption for Alternative 3 is approximately 3 million gallons. For Alternatives 5 and 6, the total estimated propane consumption is approximately 1.3 million gallons. Additional discussion and details are provided in Appendix D, Section D4.

Non-thermal, low energy demands will be met using renewable sources and electricity obtained from the local grid.

5.1.8 In Situ Chemical Oxidation (Alternatives 3 and 5)

In general, ISCO is an aqueous phase reaction, thus the NAPL must dissolve into water to react with the oxidant, although some evidence exists supporting oxidation at the NAPL surface. The most suitable oxidants for PAHs are hydrogen peroxide, sodium persulfate, and permanganate (Forsey, 2004).

Hydrogen peroxide is a stronger oxidant than persulfate and permanganate; however, persulfate and permanganate remain active much longer in the subsurface, allowing more time for distribution and reaction with contaminants present in low permeability soils such as silts and clays. Persulfate is not compatible with the Former Process Area sheet pile wall and, therefore, is not considered further in this TM. Numerous methods are available to catalyze hydrogen peroxide to increase its oxidizing strength. Aqueous iron, heat, and ozone are examples. NAPL mass and architecture determine whether chemical oxidation is applied initially or after the application of other NAPL treatment technologies.

Application of ISCO technologies for NAPL remediation are relatively straightforward. Under theoretically ideal conditions, the stoichiometric reaction between the oxidant and dissolved contaminant yields the mass of oxidant required for treatment if initial estimates of NAPL mass and composition are known. The stoichiometric requirement on a mass basis for destruction of naphthalene by the most common oxidants is provided in Table 5-2. Naphthalene accounts for the largest mole fraction for the NAPL present at the Wyckoff Site and ISCO treatment for the remaining fraction is expected to respond similarly to that of naphthalene.

Beyond the mass of contaminant, native organic material present in aquifer solids also reacts with the oxidant. This background oxidant demand must also be met in addition to the NAPL requirement. Background oxidant demand is determined by performing total oxidant demand (TOD) tests in the laboratory with soil samples collected from the site (Haselow et al., 2003). Hydrogen peroxide is generally considered to have a low TOD requirement and an initial TOD estimate can assume a zero value. A recent laboratory study (Liao et al., 2011) reports typical TOD values for various soil types ranging from 7 to 50 grams permanganate per kilogram (kg) of soil with higher values needed for increasing clay content. The TOD values for hydrogen peroxide and permanganate were used to develop initial estimates of oxidant mass required for this common element.

Both hydrogen peroxide and permanganate are delivered to the subsurface by injection through direct push technology or through installed vertical wells. The compatibility of these oxidants with injection through direct push wells facilitates their use for targeted applications (i.e., higher doses in more contaminated locations and vice versa).The oxidant and method of subsurface delivery under this common element will vary depending on the target zone being treated. Specific information is provided in the alternative descriptions presented in Sections 5.2 through 5.7.

5.1.9 Enhanced Aerobic Biodegradation (Alternatives 3, 5, and 6)

This common element injects oxygen into the subsurface to accelerate in situ biodegradation of sparse NAPL and dissolved contaminants. The oxygen is delivered via low-level air injection (biosparging), ozone, or an oxygen-release compound. For this common element biosparging is assumed.

Based on the makeup of creosote at the Wyckoff Site, naphthalene is a suitable surrogate to represent the hydrocarbon mixture for degradation. The overall stoichiometry for aerobic biodegradation of naphthalene results in 1 CY of soil, containing 1 gallon of creosote (4.15 kg), being treated for each 53 kg, or 1,530 standard cubic feet of air injected. This estimate provides an initial basis for the minimum cumulative mass of air required for the design of a biosparging system.

The air injection rate in the biosparging system will be estimated from the anticipated half-lives of contaminants in the groundwater and the partitioning of oxygen from air into the groundwater. For naphthalene, observed half-lives under ambient conditions range from 1 to 250 days. For bioventing in the vadose zone, the half-life of naphthalene ranges from 16 to 48 days. The number of air injection points will be determined from pilot testing performed during remedial design. For the FFS, a 20 standard cubic foot per minute flow rate and 30-foot radius of influence are assumed.

5.1.10 Surface Cover/Sheet Pile Wall Maintenance (Alternatives 2 to 6)

The planned final end use of the Wyckoff Site is a park with open areas. To reduce surface water infiltration at the Site and to prevent exposure to potential, low-level residual contaminants, a surface cover with an impervious bottom liner is included as a common element for Alternative 2 and Alternatives 3 to 6. Stormwater would be collected and discharged to surface water using best management practices typical of vegetated areas. Several cover designs are possible for the Former Process Area, including variations on a multi-layer cover or some form of evapotranspiration (ET) cover. Both would allow for a range of recreational uses.

This common element also includes maintenance of the outer sheet pile wall until RAOs are achieved. Maintenance activities include the following:

- Installation of a shoreline protection system to protect the above-grade portion of the sheet pile wall against corrosion and physical damage. The shoreline protection system consists of installing a shallow secondary wall, constructed of corrosion-resistant material, to a depth of up to 30 feet. This activity would be performed for Alternative 2, and potentially Alternatives 3 through 6 if deemed necessary during remedial design.
- Joint sealing. This consists of impregnating the existing sheet pile wall joints with a sealant material to reduce or eliminate groundwater and NAPL seepage. This activity applies to Alternative 2, and potentially Alternatives 3 through 6 if deemed necessary during remedial design.
- Periodic replacement of the sheet pile wall. This activity consists of replacing the outer sheet pile wall every 50 years. This activity only applies to Alternative 2, which has an operations and maintenance timeframe greater than 30 years.

5.1.11 Passive Groundwater Treatment (Alternative 3, 5, and 6)

This common element is proposed as an optional technology to supplement EAB if deemed necessary based on EAB performance monitoring results. It consists of three main components: a collection system, a treatment media such as granular-activated carbon or other reactive media housed in a treatment vessel, and a pipe that conveys the treated water to the outfall described in Section 5.1.5. The passive treatment system collects Upper Aquifer contaminated groundwater, removes dissolved phase COCs, and discharges the treated groundwater. This common element controls contaminant flux through the sheet pile wall, thereby protecting water quality in the intertidal area where groundwater upwells to surface water. The design concept utilizes the hydraulic head difference that occurs due to tidal fluctuations to provide passive groundwater treatment. The design concept minimizes the need for electricity, pumps, and other features common in active treatment systems. The system treats and discharges contaminated groundwater during periods when there is a significant head difference across the sheet pile wall which allows groundwater flow through the treatment system to occur.

5.1.12 Monitored Natural Attenuation (Alternatives 2 to 6)

MNA relies on natural degradation and non-degradation processes to decrease contaminant concentrations. When relying on natural attenuation processes for site remediation, EPA prefers processes that degrade or destroy contaminants (OSWER Directive 9200.4-17P, *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites*, EPA, 1999). The key degradation processes for dissolved phase creosote constituents at the Wyckoff Site include aerobic and anaerobic biodegradation. The key non-degradation processes include dispersion and groundwater-surface water mixing.

Under this common element, a network of Upper Aquifer and Lower Aquifer monitoring wells and intertidal aquifer tubes would be maintained and sampled semiannually for the first 2 years, and annually thereafter, for semivolatile organic compounds to track contaminant concentrations and to develop information on attenuation rates. Periodic sampling (once every 5 years) for geochemical indicator parameters, stable isotope probing, and phospholipid fatty acids would be performed to develop evidence on specific attenuation processes. It is assumed that sampling would be conducted from 10 Upper Aquifer, 5 Lower Aquifer, and 5 multi-level intertidal aquifer tubes.

5.1.13 Access Controls (Alternatives 2 to 6)

For all remedial alternatives (except Alternative 1 – No Action), site fencing would remain until the Site can be converted to a public area. ICs to ensure that the Upper Aquifer groundwater within the Former Process Area remains unused would be implemented. ICs restricting site use to reduce direct exposure to soil would also be instituted.

5.1.14 Five-Year Reviews (Alternatives 2 to 6)

The NCP, under 40 CFR 300.430(f)(4) (ii), requires that periodic reviews be conducted if a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure. These reviews are conducted no less often than every five years after initiation of the selected remedial action. Three five-year reviews have been performed to date, with the third five-year review completed in 2012. This common element provides for continuation of the five-year reviews until the contaminants are no longer present at unrestricted use/unrestricted exposure levels. For the purposes of this FFS, it is assumed that the cost for five-year reviews would be incurred under each alternative.

5.2 Alternative 1 – No Action

CERCLA requires evaluation of a no action alternative to reflect future conditions without any cleanup effort. This alternative is used as a baseline for comparison to other alternatives.

Under Alternative 1, no additional actions would be taken at the Wyckoff Site with respect to soil and groundwater. The existing groundwater extraction wells and GWTP would be shutdown (if operating) and no decommissioning of this equipment would be performed. The outer sheet pile wall would be left in place, and over time, it is expected that the wall would fail at the mudline due to corrosion. The sections of wall present below the mudline may still provide some partial containment of NAPL and dissolved phase contaminants, but these sections are also expected to eventually fail. No additional action would be taken to maintain the integrity of the inner sheet pile wall. Because this wall is only exposed to freshwater with low dissolved oxygen concentrations, it may have much longer integrity than the outer wall.

5.3 Alternative 2 – Containment

Alternative 2 is the contingent remedy implemented under the 2000 ROD. Under this alternative, the existing remedy would continue to be operated and construction of the remaining remedy components completed. The key components of this alternative that have been constructed include:

- An outer sheet pile wall that is 1,870 feet long bounding the north and east sides of the Former Process Area. It is assumed that the wall is replaced approximately every 50 years.
- Upgrades and O&M of a groundwater extraction system comprised of 9 recovery wells and an 80 gpm GWTP. This component also includes optimization of extraction system operations to ensure hydraulic containment is met during all seasons. It is assumed that the recovery wells and the GWTP require replacement approximately every 30 years.
- Groundwater quality sampling at selected Lower Aquifer monitoring wells, and water level measurements in Upper Aquifer and Lower Aquifer well pairs to assess hydraulic containment.
- Maintenance of perimeter fence and signage around the Former Process Area.
- Maintenance of ICs to restrict Upper Aquifer groundwater use.
- Documentation of remedy performance and protectiveness in 5-year reviews.

Remedy components that would need to be implemented include the following:

- Construction and maintenance of a low permeability soil cap over the Former Process Area, and installation of the shoreline protection system to maintain the integrity of the outer sheet pile wall as described under the Soil Cover/Sheet Pile Wall Maintenance Common Element (see Section 5.1.10).
- Establishment of ICs in accordance with planned future land uses.
- Implementation of an Upper Aquifer groundwater quality monitoring program with regularly scheduled sampling events to allow for assessment of hydraulic contaminant and long-term COC concentration trends.

All elements of this alternative would be maintained until RAOs are achieved. An estimate of the timeframe required to achieve RAOs will be presented in the FFS. Additionally, because the operations and maintenance timeframe for this alternative is greater than 30 years, the cost estimate for this alternative will be presented in a discounted (present worth) and non-discounted format.

5.4 Alternative 3 – Excavation, Thermal Desorption, and In Situ Chemical Oxidation

Alternative 4 consists of the following components in addition to the common elements shown in Table 5-1:

- Core Area, North Shallow (LNAPL), and East Shallow (LNAPL) target zones. Excavation and thermal desorption.
- North Deep (DNAPL) target zone. ISCO using permanganate injection. Three separate injection events will be completed with groundwater monitoring conducted following each injection event. The monitoring results will be used to confirm treatment effectiveness and optimize the scope of subsequent injection events.
- Other Periphery target zone. ISCO using hydrogen peroxide will be applied in a manner similar to that described above for the North Deep (DNAPL) target zone.
- Polishing. Enhanced Aerobic Biodegradation (EAB). An array of biosparge wells would be installed and operated following completion of Core Area, North Area (LNAPL), and East Area (LNAPL) treatment.

An initial estimate on the timeframe to complete the remedial action is 6 to 10 years after the remedial action contract has been awarded for implementation. This assumes that funding is available and can be allocated as the demand requires. Excavation, thermal desorption, and ISCO are assumed to occur simultaneously requiring between 4 and 6 years to complete. EAB is expected to require an additional 2 to 4 years to complete following completion of the excavation, thermal desorption, and ISCO treatment steps.

The individual components for Alternative 3 and the target zone where they would be implemented are shown on Figure 5-1. Appendix E provides additional information.

5.4.1 Excavation Methods

In the Core Area, the target depth interval for excavation and thermal desorption includes the ground surface down to the top of the Aquitard (e.g., Compartments 1, 2, and 3). In the North Shallow (LNAPL) and East Shallow (LNAPL) target zones, excavation will extend to an estimated depth of 35 feet below ground surface (bgs). The excavation footprints for each target zone, lying below the water table, will be hydraulically isolated using sheet pile walls, structural shoring walls, or similar techniques. After the sheet pile wall is installed, the excavation cell will be dewatered, the water pumped to the existing GWTP for treatment, and excavation conducted down in vertical lifts and laterally in contiguous cells. Once the Core Area is excavated, treated soil will be used for backfilling, and the excavation work will be moved to the North Shallow (LNAPL) and East Shallow (LNAPL) target zones.

Excavation for the North Shallow (LNAPL) and East Shallow (LNAPL) target zones will also require lowering of the water table, but not to the same degree as required for the Core Area. This will be accomplished using a combination of existing recovery wells, the new Common Elements - Enhanced NAPL recovery wells, new dewatering wells, temporary sheet pile installations (with internal bracing), and excavation sumps and pumps. Water generated from dewatering will be treated in the existing GWTP.

5.4.2 Thermal Desorption Treatment

Excavated soil would be treated through a direct-fired thermal desorption unit that includes a rotary desorber for soil treatment, a baghouse for dust collection, and a thermal oxidizer to destroy organic vapors. Treated soil will be used to backfill the excavation footprint(s). To reduce thermal oxidizer energy requirements, soil moisture contents will be reduced by lowering the water table below the desired excavation depth through dewatering.

Following excavation, the material would be segregated and stockpiled for air drying and loading into the thermal desorber unit. A burner located at the discharge end of the desorber unit will provide the energy to heat the soil, causing organic compounds to volatilize into an air stream and be carried out of the unit. Material processing temperatures will be adjusted and maintained during the remedial action based upon contaminant type, initial concentration, and desired treatment level. A soil temperature of 1,100 degrees Fahrenheit (°F) is assumed. Field-scale trials would be conducted to establish optimum treatment temperatures and contact times. After treatment, the soils will exit the kiln at temperatures of 400 to 900 °F and be staged for cooling and confirmation testing prior to placement as backfill in the excavation.

Air containing water, organic vapors, and particulate matter will exit the desorber unit and be directed to the baghouse, where particulates would be removed. The resulting air flow will be routed to the thermal oxidizer and heated to between 1,400 and 1,800°F, at which point the organics would be combusted to carbon dioxide and water vapor. The creosote present at the Site contains PCP, which will generate hydrochloric acid (HCl) in the thermal oxidizer unit. Therefore, the offgas will undergo additional treatment in an acid scrubber or thermal oxidizer unit operations limited per HCl discharge regulatory limits. Air monitoring of the thermal oxidation unit will be performed routinely to confirm that the stack offgas is in compliance with discharge limits.

The design basis for the FFS assumes a medium temperature thermal desorption (MTTD) unit operating at a treatment rate of 20 tons per hour. Assuming soil excavation is conducted 50 hours per week, and the MTTD unit operates 100 hours per week, it is estimated that 1,500 CY of contaminated soil would be treated per week.

5.4.3 ISCO Treatment

The North Deep (DNAPL) target zone will be treated using ISCO, with treatment occurring primarily in Compartment 3. Permanganate will be used as the oxidant. Permanganate was selected because of the depth of DNAPL contamination lying below the water table, its effectiveness for PAH treatment, the persistence of its oxidizing power, and its relative ease of injection through temporary or fixed wells. The primary disadvantage of permanganate is its potential negative impact on groundwater quality and the conditions required to apply EAB polishing. A lag period will exist before suitable conditions for EAB are re-established.

To reduce the overall oxidant demand and increase ISCO treatment effectiveness, the enhanced NAPL recovery common element described in Section 5.1.10 would precede ISCO injection. Once the enhanced NAPL recovery step is completed, oxidant injection would be performed through the same wells used for enhanced NAPL recovery. Following completion of the initial (Phase 1) permanganate injections, which are expected to require about 6 months, changes in PAH concentration, redox conditions, and other groundwater quality parameters will be monitored for 6 to 12 months. Reductions in hydraulic conductivity from precipitated manganese dioxide, which could decrease future injection rates, will also be assessed.

Following the Phase 1 injection and monitoring period, Phase 2 injections will occur. It is assumed that the Phase 2 injections will require approximately 50 percent of the permanganate mass injected during Phase 1. Following completion of the Phase 2 monitoring period, Phase 3 permanganate injection will occur. It is assumed that Phase 3 injections will require approximately 25 percent of the permanganate mass injected during Phase 1.

In the Other Periphery target zone, ISCO will be implemented with catalyzed hydrogen peroxide injected through direct push technology to provide more focused treatment. It is assumed that up to three ISCO injections, performed in a phased manner, would be required in a similar manner as described above for the permanganate injection in the North Deep (DNAPL) target zone.

For both oxidant types, site-specific, bench-scale testing of oxidant dosage in both Upper Aquifer and Aquitard material will be performed along with field-scale pilot tests during remedial design to confirm treatment effectiveness prior to full-scale field deployment.

5.5 Alternative 4 – In Situ Solidification/Stabilization

Alternative 4 uses ISS for all five target zones to treat NAPL present in subsurface soil. The ISS is performed using 6-foot to 8-foot-diameter vertical augers mounted on a large crane or hydraulic drill rig, and jet injection equipment. The estimated timeframe to complete the remedial action is 2 years. This presumes that two ISS auger rigs are operating at the Site full-time and funding is available and can be allocated as the demand requires. Figure 5-2 shows the footprint where ISS would be implemented. Appendix F provides additional details for this alternative.

Prior to commencing ISS, the Access Improvement, Demolition, and Soil Excavation common elements would be completed to establish a working surface approximately 7 feet below the original ground elevation. This provides a sump to contain the “swell” or material expansion that occurs during ISS soil mixing. This volume expansion is estimated to range from 20 to 25 percent of the original treatment volume. The working surface is first leveled and stabilized with gravel, and, if necessary, wood crane mats are placed over the working surface to create a stable platform for the ISS auger rigs. Dewatering of the excavation sump using portable sump pumps may also be required.

In the Core Area, North Shallow (LNAPL), East Shallow (LNAPL), and Other Periphery target zones, the ISS auger rigs will mechanically mix reagent and NAPL-contaminated soil, creating an array of overlapping, cement-like columns extending from the surface to the bottom of the target zone. Reagent for the ISS would be delivered by truck and mixed onsite in a batch plant.

In the North Deep (DNAPL) target zone, jet grouting equipment will be used to mix the reagent and NAPL-contaminated soil. Due to the high pressures employed for jet grouting, the reagent and NAPL-contaminated soil are fluidized rather than mechanically mixed. Jet grouting ISS also creates an array of overlapping, cement-like columns, but the columns are generally smaller in diameter than those created with vertical augers.

Along the perimeter of the ISS treatment zone, the mix design will be enriched and an allowance for additional column overlap provided to create a “rind” or contiguous ring of overlapping columns with lower leachability and increased durability characteristics.

Bench-scale treatability testing will be performed during remedial design to determine the optimum reagents, mix ratios, and reagent addition rates for the inner and outer columns. The mix design will be defined by measuring the maximum hydraulic conductivity, minimum unconfined compressive strength, and overall leaching reduction in a series tests prepared using NAPL-contaminated soil obtained from the Site. Optimization testing may also be performed to better refine the reagent mix design, establish ranges for reagent and water addition ratios, and evaluate reagent enhancements that can be added to improve performance (e.g., decrease leachability) or lower costs. Based on experience at other wood treater Superfund sites (Mountain Pine, North Cavalcade, and Texarkana), the mix design for Alternative 4 includes up to 10 percent Portland cement and 1 percent bentonite. A field demonstration test would also be performed to verify the bench-scale results, evaluate full-scale equipment options, establish productivity rates, and identify sitewide implementation considerations. Due to logistical limitations associated with mobilizing ISS equipment to the Site for a standalone field demonstration test, a demonstration period will occur at the start of full-scale remediation.

ISS implementation would be sequenced as follows:

- Enhanced NAPL recovery as described in Section 5.1.10.
- Access improvements and soil excavation to remove the top 7 feet of material to create the swell sump.
- Mobilization and set-up of ISS auger rig and reagent batch plant. Large items such as silos and the ISS auger rig(s) will be transported to the Site via barge.
- Given the size of the Wyckoff Site and the volume of soil to be treated, several operations will occur concurrently. As pre-excavation progresses from north to south across the Site, jet grouting ISS will be initiated to treat the North Deep (DNAPL) target zone. A jet grout field demonstration test will be performed initially to evaluate jet grout characteristics and column size.
- As the pre-excavation and jet grout operations proceed south across the Site, ISS auger mixing will commence. The mixing will be done with a 6-foot or 8-foot-diameter auger, depending on the required depth of treatment, and the difficulty of mixing. ISS columns will be overlapped to treat 100 percent of the NAPL-contaminated soil in each target zone. Full-scale ISS operations will commence after completion of the demonstration phase.
- NAPL-contaminated material removed during the soil excavation step will be treated ex situ in lined and bermed treatment cells. Measured quantities of soil will be transferred from an onsite soil stockpile to the treatment cell and mixed with reagent. When the soil is adequately mixed, it will then be transferred to an onsite curing cell and then stockpiled. This material will be used for grading and to create landscape features.

At completion of ISS, the contractor will decontaminate equipment, dismantle the ISS rig and batch plant, complete installation of the soil cover described in Section 5.1.10, and then demobilize from the site.

5.6 Alternative 5 – Thermal Enhanced Extraction and In Situ Chemical Oxidation

Alternative 6 consists of the following components in addition to the common elements shown in Table 5-1:

- Core Area and East Shallow (LNAPL) target zone. In situ thermal enhanced extraction.
- North Shallow (LNAPL) target zones. ISCO using hydrogen peroxide.
- North Deep (DNAPL) target zone. ISCO using permanganate.
- Other Periphery target zone. Thermal enhanced extraction in the Core Area reaches out to a portion of this zone and ISCO using hydrogen peroxide is applied to the remainder.
- Polishing. EAB. An array of biosparge wells would be installed and operated following completion of treatment of the Core Area, North Area (LNAPL), East Area (LNAPL), and North Deep (DNAPL) target zones.

Biosparging has synergy with thermal and hydrogen peroxide-based ISCO treatment. Air injection promotes mixing of the residual dissolved phase contaminants with oxygen. The residual heat (thermal) and residual oxidant (hydrogen peroxide) promote accelerated NAPL dissolution and increased biological degradation rates. The catalyst for the hydrogen peroxide can also be selected to promote the generation of dissolved oxygen (e.g., ozone). The individual components for Alternative 5 and the target zone where they would be implemented are shown on Figure 5-3. Appendix G provides additional details for this alternative.

The estimated time frame to complete the remedial action is 7 to 12 years. This assumes that funding is available and can be allocated as the demand requires.

In the Core Area and a portion of the Other Periphery target zone, the treatment zone will be divided in half (approximately 50,000 CY each) as a result of infrastructure limitations, and treatment will be performed sequentially in each half. A low permeability surface cover will be installed, following completion of the Soil Excavation common element, at a depth of 4 feet bgs. Temporary sheet pile walls will also be installed to reduce dewatering rates and volumes requiring treatment in the GWTP. Thermal treatment will utilize steam injection through installed process wells. The steam would be produced in a propane-fired steam generator. Liquids and vapors will be co-extracted from process wells, during and after steam injection, and contaminants removed via treatment. NAPL will be separated and contaminated water treated in the existing GWTP. Vapors will be routed through a thermal oxidizer.

5.6.1 Thermal Enhanced Treatment

Thermal treatment employs several process options to treat contaminated soil and groundwater present in the Core Area and East Shallow (LNAPL) target zones. These process options include steam injection, vapor recovery, and vapor/liquid treatment. Upon recovery, the vapor/condensate stream is passed through a vapor-liquid separator, and the vapors treated in an ex situ thermal oxidation unit, similar to that described in Section 5.4.2. The liquid is treated ex situ to separate the NAPL followed by granular-activated carbon filtration of the water phase.

Steam injection would treat creosote-NAPL contaminated media by heating the subsurface. The heat reduces the creosote's viscosity, resulting in increased mobility. Steam injection under pressure can push NAPL toward extraction wells, and the higher temperatures increase the volatilization and solubilization rates of the NAPL components for recovery at extraction wells. Steam injection is most suitable for use in thin, higher permeability strata with confining layers.

As observed in the 2003 steam injection pilot study (U.S. Army Corps of Engineers, 2005), steam injected at depths below the water table, without an overlying confining layer, has a strong tendency to rise upward limiting its horizontal distribution at depth. Hence, spacing between injection and extraction wells must be close to overcome this condition. Greater well spacing may be possible by lowering the water table through dewatering to a depth below the base of the target zone. The applicability and well spacing for steam injection in the vadose zone would be restricted by injection pressure limitations posed by the small overburden pressure (i.e., the pressure sufficient to create preferential paths for steam to break through at the surface). Therefore, for shallow vadose zone treatment, a low permeability surface barrier will be installed to prevent release of contaminants and steam to the atmosphere.

Once contaminant recovery rates reach a low, asymptotic level, steam injection will cease while liquid and vapor extraction continue. Biosparging will then be implemented, while soil temperatures remain elevated, to enhance volatilization and to introduce oxygen for biological degradation. Upon further diminished contaminant recovery rates, vapor and liquid extraction will cease while biosparging continues. The remaining half of the Core Area will then be treated by repurposing as much of the equipment as practical and repeating the thermal treatment process.

5.6.2 ISCO Treatment

In the North Shallow (LNAPL) and a portion of the Other Periphery target zones, NAPL-contaminated material will be treated by ISCO using catalyzed hydrogen peroxide, also known as modified Fenton's reagent, as the oxidant. Bench-scale treatability tests and field-scale pilot testing will be performed during remedial design, and ISCO deployment preceded by the enhanced NAPL recovery common element described in Section 5.1.4. As described for Alternative 3, it is assumed that up to three ISCO injections, performed in a phased manner, would be required. Oxidant and catalyst injection will occur through direct push technology that moves across the target zone footprints. In select areas, based on the CSM, the injections will extend as deep as 15 feet below the water table into Compartment 2. Anticipated oxidant injection rates will require daily deliveries of concentrated hydrogen peroxide. Following completion of the Phase 3 injections, EAB would be implemented as needed to attain remedial goals.

In the North Deep (DNAPL) target zone, NAPL-contaminated material will be treated by ISCO using permanganate as the oxidant. The ISCO would be deployed as described in Alternative 3 (Section 5.4.3).

5.7 Alternative 6 – Excavation, Thermal Desorption, and Thermal Enhanced Extraction

Alternative 6 includes the following components in addition to the common elements shown in Table 5-1:

- Upper Core Area. Excavation to a depth of 35 feet bgs and ex situ treatment of contaminated soil by thermal desorption as described for Alternative 3 (Section 5.4.2).
- Lower Core Area, North Shallow (LNAPL), East Shallow (LNAPL), North Deep (DNAPL) and Other Periphery target zones. In situ thermal enhanced extraction as described for Alternative 5 (Section 5.6.1).
- Polishing. EAB. An array of biosparge wells would be installed and operated following treatment of the Core Area, North Area (LNAPL), East Area (LNAPL), and North Deep (DNAPL) target zones.

The estimated time to complete the remedial action is 7 to 10 years. This assumes that funding is available and can be allocated as the demand requires. The individual components for this alternative and the target zone where they would be implemented are shown on Figure 5-4. Appendix H provides additional details for this alternative.

In the upper portion of the Core Area, the target interval for excavation and ex situ thermal desorption extends to a depth of 35 feet bgs. Implementation of this component would be performed as described under Alternative 3 (Section 5.4.1) but to a lesser depth. In addition, at the bottom of the excavation, a low permeability clay barrier will be installed where the Aquitard is not encountered. The clay barrier will be installed to act as a confining layer to enhance in situ thermal treatment in the lower portion.

In situ thermal treatment for the North Shallow (LNAPL), East Shallow (LNAPL) and Other Periphery target zones would occur concurrently with excavation and thermal desorption of the Upper Core Area. Implementation of this component would be performed similarly as described for the Core Area in Alternative 5 including polishing with EAB. As described for Alternative 5, the North Shallow (LNAPL), East Shallow (LNAPL), and Other Periphery target zones would be divided into two roughly equal treatment volumes (approximately 50,000 CY) to maintain compatibility with site infrastructure limitations. Thermal treatment equipment will be reused for treatment of the Lower Core Area and North Deep (DNAPL) target zones.

In the North Deep (DNAPL) target zone and Lower Core Area, in situ thermal treatment will also be performed. However, steam injection will be supplemented with hot water to mobilize DNAPL for recovery and to enhance dissolution of soluble DNAPL components. Target hot water temperatures will be lower than steam temperatures to facilitate horizontal heat distribution and to maximize dissolution rates.

In situ thermal treatment rates are limited based on steam volumes. Under Alternative 6, steam will be generated using treated water from the GWTP, which is limited to about 80 gpm. The treated water from the GWTP will be used to generate a mix of steam and hot water for injection at relatively low pressure to minimize adverse DNAPL migration, and to develop a target soil treatment temperature of 160 °F to optimize dissolution of soluble components from residual DNAPL. The injection system will require installation of new process wells, piping, and downhole pumps for the injection of the steam and hot water and the extraction of the mobilized DNAPL and dissolved phase contaminants. As NAPL recovery and PAH concentrations in groundwater begin to subside, but while soil temperatures remain elevated, injection will cease and low-level air injection will be initiated to introduce oxygen for EAB. Biosparging points and new wells will be installed as needed to provide injection points for air to enhance aerobic biodegradation.

Implementing Alternative 6 will require close coordination between the excavation and thermal desorption, in situ thermal treatment, and EAB components. However, significant synergies exist between these technologies.

5.8 Summary of Alternatives on Fence and Cluster Diagrams

Cross-section drawings showing application of remedial action alternative technologies in the target zones and/or specific areas of the Wyckoff Site are provided in Appendix I. Technology implementation under Alternatives 3 to 6 is also shown on the fence and cluster diagrams provided in Appendix B.

5.9 Preliminary Screening of Alternatives

A preliminary screening of the alternatives will be performed in the Soil and Groundwater OU FFS Report to determine if all or just a subset of the alternatives described in this TM will be carried forward to the detailed analysis of alternatives step. In accordance with EPA guidance (*Feasibility Study Development and Screening Of Remedial Action Alternatives*, Directive 9355.3-01FS3, November 1989) it is expected that no more than five source control remedial action alternatives will be carried forward for detailed analysis. Based on the January 14, 2014, meeting discussions with EPA, Ecology, and CH2M HILL, it is expected that all of the alternatives described in this TM will be carried forward into the FFS for detailed evaluation.

6.0 References

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Tables

TABLE ES-1
Proposed Remedial Action Alternatives
Former Process Area, Soil and Groundwater OUs
Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Washington

		Common Elements													
Alternative No.	**Alternative Title/Key Technologies**	**Access Improve-ments**	**Demo, Decon, Reuse/ Disposal**	**Groundwater Extraction, Treatment**	**Enhanced NAPL Recovery**	**Dewatering, Treatment, Discharge**	**Soil Excavation**	**Propane System**	**ISCO**	**EAB**	**Surface Cover/ Sheet Pile Wall**	**Passive Groundwater Treatment**	**MNA**	**Access Controls**	**5-Year Reviews**
1	No Action	Not applicable													
2	Containment (current remedy)			X							X		X	X	X
3	Excavation, Thermal Desorption, and ISCO	X	X	X	X	X	X	X	X	X	X[a]	X	X	X	X
4	In Situ Stabilization/ Solidification	X	X	X	X	X	X				X[a]		X	X	X
5	Thermal Enhanced Extraction and ISCO		X	X	X	X	X	X	X	X	X[a]	X	X	X	X
6	Excavation, Thermal Desorption, and Thermal Enhanced Extraction	X	X	X	X	X	X	X		X	X[a]	X	X	X	X

Notes:

[a] The need for sheet pile wall maintenance to be determined during remedial design

Demo = demolition
Decon = decontamination
EAB = enhanced aerobic bioremediation
ISCO = in situ chemical oxidation
MNA = monitored natural attenuation
ROD = Record of Decision

TABLE 2-1
Wyckoff Soil and Groundwater OU Remedial Action Objectives
Former Process Area, Soil and Groundwater OUs
Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Washington

Narrative Objective	Numeric Standards
1. Ensure that surface soils meet cleanup levels protective of direct contact with humans and animals having unrestricted public access to the site as a public park.	To be Determined by EPA
2. If intertidal areas are present following implementation of the remedial action for OUs 2 and 4, ensure that surface soils within intertidal areas meet sediment standards protective of aquatic life and human health (see Note 1).	To be Determined by EPA
3. Prevent discharge of upper aquifer groundwater to surface water at concentrations that would result in exceedances of: a) surface water criteria applicable to Eagle Harbor and Puget Sound; and b) sediment standards protective of aquatic life and human health (see Notes 1 and 2).	To be Determined by EPA
4. Prevent further degradation in lower aquifer groundwater and restore that portion of the aquifer beyond the influence of saltwater intrusion to maximum contaminant levels (MCLs) within a reasonable timeframe.	To be Determined by EPA
5. That portion of the lower aquifer that is influenced by saltwater intrusion shall be protective of discharge to surface waters in Eagle Harbor and Puget Sound.	To be Determined by EPA

Notes:

[1] Sediment standards protective of aquatic life and human health will address the following pathways:

- Protection of benthic toxicity – based on promulgated numeric criteria or bioassay evaluation.
- Protection of human health via seafood consumption, direct contact, or incidental ingestion.

[2] Per the Model Toxics Control Act, where groundwater highest beneficial use is discharge to surface water, the point of compliance is at the point of discharge. Proposed monitoring locations and numeric criteria applicable at the monitoring locations are typically presented in the feasibility study, frequently based on modeling to take into account predicted attenuation between the monitoring point and the point of compliance.

[3] It is assumed that institutional controls will remain in place permanently to permanently prohibit withdrawal of upper aquifer groundwater for drinking water, irrigation or other beneficial uses.

[4] It is assumed that institutional controls will remain in place during the restoration timeframe to prohibit withdrawal of lower aquifer groundwater for drinking water, irrigation, or other beneficial uses.

EPA = U.S. environmental Protection Agency

TABLE 3-1
Volume Estimates of NAPL-Contaminated Soil and NAPL Present in the Upper Aquifer
Former Process Area, Soil and Groundwater OUs
Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Washington

Areas and Compartments	Total Sampled Soil Volume (CY)	NAPL-Contaminated Soil Volume (CY)	Volume Estimate of NAPL Present (gallons)
Upper Aquifer	755,018	109,069	678,872
-Compartment 1	382,951	56,633	301,946
-Compartment 2	198,772	24,779	127,751
-Compartment 3	173,296	27,657	249,174
Core Area	105,724	38,739	302,116
North Shallow (LNAPL)	49,183	4,719	29,722
East Shallow (LNAPL)	276,901	43,203	207,577
North Deep (DNAPL)	108,780	14,324	86,982
North Shallow and Deep (Overlap of LNAPL and DNAPL Areas)[a]	45,771	3,421	18,423
Other Periphery	44,025	4,273	33,064
No Treatment	124,633	390	988

[a] North Shallow and Deep is an overlap area encompassing zones from the LNAPL and DNAPL Areas, and is not called out as a separate target zone except in this table.
CY = cubic yards
DNAPL = dense non-aqueous phase liquid
LNAPL = light non-aqueous phase liquid
NAPL = non-aqueous phase liquid

TABLE 3-2

Capture Analysis of Base Case Treatment Areas for NAPL-Contaminated Soil and NAPL Volume Present in the Upper Aquifer

Former Process Area, Soil and Groundwater OUs

Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Washington

Areas and Compartments	Total NAPL-Contaminated Soil Volume (CY)	Total Soil Volume in Target Zone (CY)	NAPL-Contaminated Soil Volume Captured by Target Zone (CY)	Percentage of NAPL-Contaminated Soil Volume Captured by Target Zone (%)	Percentage of NAPL Volume Captured by Target Zone (%)	Percentage of Total NAPL Volume Not Captured (%)
Upper Aquifer	109,069	258,643	100,195	92	96	3.9
-Compartment 1	56,633	149,913	53,065	94	97	1.3
-Compartment 2	24,779	59,541	21,857	88	92	1.5
-Compartment 3	27,657	49,189	25,273	91	97	1.0
Core Area	38,739	103,843	38,668	100	100	0.0
North Shallow (LNAPL)	4,719	14,055	4,151	88	94	0.3
East Shallow (LNAPL)	43,203	88,267	39,158	91	93	2.0
North Deep (DNAPL)	14,324	32,485	11,832	83	92	1.0
North Shallow and Deep (Overlap of LNAPL and DNAPL Areas) [a]	3,421	11,030	2,874	84	92	0.2
Other Periphery	4,273	8,963	3,513	82	96	0.2

[a] North Shallow and Deep is an overlap area encompassing zones from the LNAPL and DNAPL Areas, and is not called out as a separate target zone except in this table.

CY = cubic yards

DNAPL = dense non-aqueous phase liquid

LNAPL = light non-aqueous phase liquid

NAPL = non-aqueous phase liquid

TABLE 4-1
Summary of Retained Remedial Technologies
Former Process Area, Soil and Groundwater OUs
Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Washington

General Response Action	Technology Type	Key Process Options	Target Zone, COCs
No Action	No Action	No Action	Not applicable
Access Restrictions	Fencing	Signs/cyclone fence	All Zones and COCs
	ICs	Land use zoning, deed restrictions, restrictive covenants	
Containment	Surface Barrier	Multi-layer impermeable barrier and ET barrier	All Zones and COCs
	Subsurface Barrier	Sheet pile wall	All Zones, NAPL, PAHs, PCP
	Hydraulic Containment	Groundwater extraction, treatment, and discharge	All Zones, NAPL, PAHs, PCP
Removal	Shallow Excavation (< 15 ft)	Standard equipment, shoring, dewatering, stockpiles/run-on and run-off controls	All Zones and COCs
	Deep Excavation (> 15 ft)	Standard equipment, shoring, dewatering, stockpiles/run-on and run-off controls	All Zones and COCs
	Extraction	Groundwater extraction, treatment, and discharge	All Zones, NAPL, PAHs, PCP
Disposal	Offsite RCRA Landfill/TSD Offsite Subtitle D landfill	Standard transportation methods (truck, rail), waste acceptance	All Zones and COCs
Ex situ Treatment	Thermal Treatment	Offsite incineration	Dioxin-contaminated soil
		Onsite thermal desorption	All Zones and COCs
	Ex Situ Stabilization	Backhoe mixing	All Zones (shallow soil) and COCs
In Situ Treatment	MNA	Naturally occurring non-degradation and degradation processes	All Zones, NAPL, PAHs, PCP
	In Situ Stabilization	Auger mixing, jet grouting	All Zones and COCs
	Thermal	Steam	
	Chemical	ISCO	
	Physical	Funnel/Tidal gate with reactive media	
	Biological	Biosparging (enhanced aerobic biodegradation)	

COC = contaminant of concern
ET = evapotranspiration
ft = feet; foot
ISCO = in situ chemical oxidation
MNA = monitored natural attenuation
NAPL = non-aqueous phase liquid
PAH = polycyclic aromatic hydrocarbons
PCP = pentachlorophenol
RCRA = Resource Conservation and Recovery Act
TSD = treatment, storage, or disposal

TABLE 5-1
Remedial Action Alternative–Common Elements
Former Process Area, Soil and Groundwater OUs
Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Washington

	Alternatives					
Common Element	**1**	**2**	**3**	**4**	**5**	**6**
Access Improvements			X	X		X
Demolition, Decontamination/Reuse, and Disposal			X	X	X	X
Groundwater Extraction and Treatment		X	X	X	X	X
Enhanced NAPL Recovery			X	X	X	X
Dewatering, Treatment, and Discharge			X	X	X	X
Soil Excavation			X	X	X	X
Propane System			X		X	X
In Situ Chemical Oxidation			X		X	
Enhanced Aerobic Biodegradation			X		X	X
Surface Cover/Sheet Pile Wall		X	X	X	X	X
Passive Groundwater Treatment			X		X	X
Monitored Natural Attenuation		X	X	X	X	X
Access Controls		X	X	X	X	X
5-year reviews [a]		X	X	X	X	X

[a] Five-year reviews provided here for completeness. For the purposes of this FFS, it is assumed that the cost of five-year reviews is included within the scope of the remedial action alternative.

TABLE 5-2

Stoichiometric Requirement for Complete Mineralization of Target Contaminants

Former Process Area, Soil and Groundwater OUs

Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Washington

Target Compound	Hydrogen Peroxide (gram H_2O_2 per gram of target)	Persulfate (gram $Na_2S_2O_8$ per gram of target)	Permanganate (gram $NaMnO_4$ per gram of target)
Naphthalene	6.4	44.6	18.7

Notes:

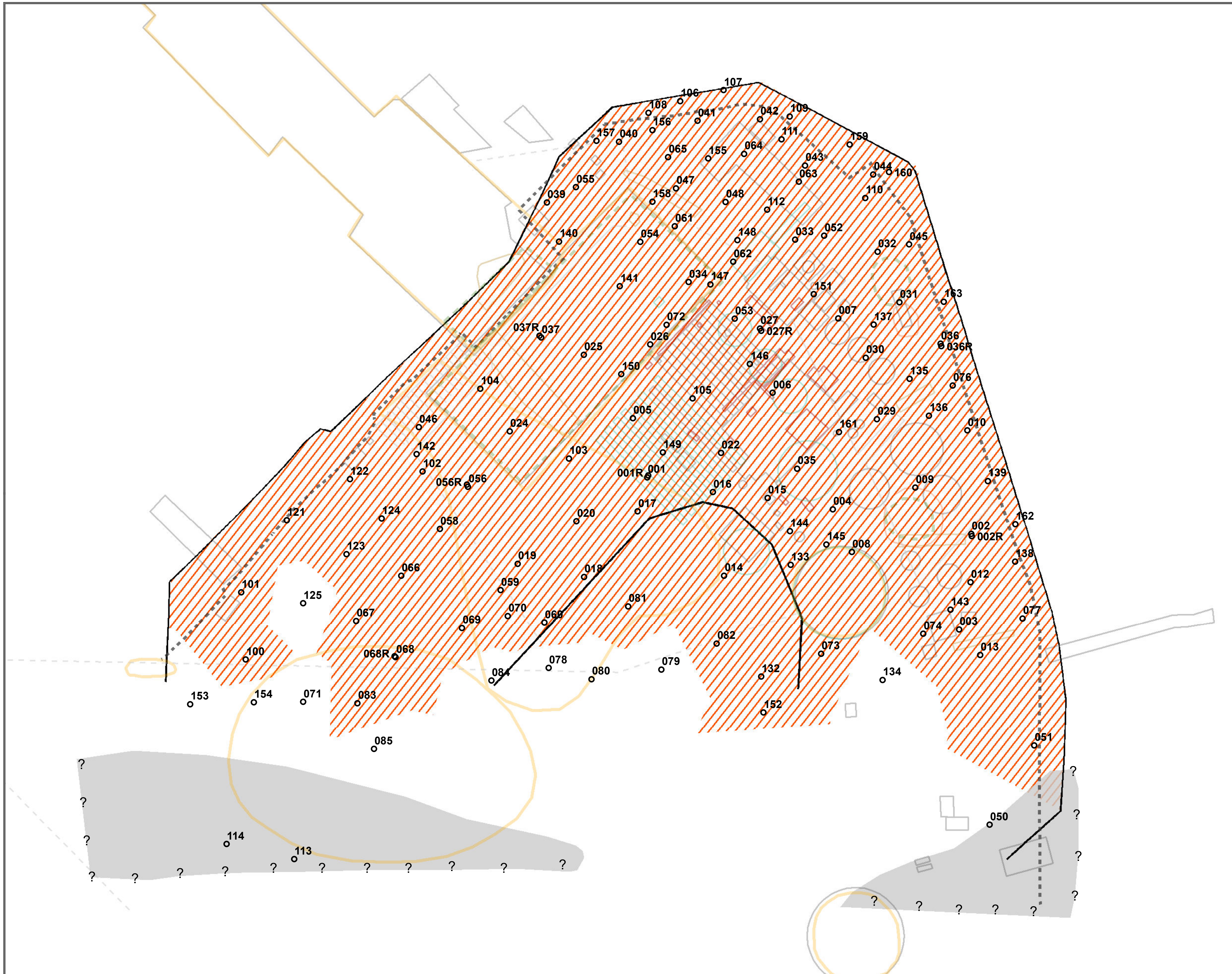
Chemical formulas shown are for the identified oxidant. The table entries show the theoretical mass of oxidant required per unit mass of naphthalene. For example, 6.4 grams of hydrogen peroxide are required for each gram of naphthalene destroyed.

TABLE 5-3
Excavated Soil Volumes
Former Process Area, Soil and Groundwater OUs
Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Washington

Alternative	Target Zone	Size (Acres)	Excavated Volume (CY)	Soil Handling[a]
Alternative 2 – Containment	No soil excavation performed			
Alternative 3 – Excavation, Thermal Desorption, and ISCO Alternative 6 – Excavation, Thermal Desorption, and Thermal Enhanced Extraction	Core	1.8	87,100 (based on average 30-ft depth)	Stockpile, sample, and test; assume 50% is designated clean and used as fill onsite; assume 50% is treated by MTTD process and then used as fill onsite.
	North and East Shallow (LNAPL)	2.4	116,000 (based on average 30-ft depth)	Stockpile, sample and test; assume 50% is designated clean and used as fill onsite; assume 50% is treated by MTTD process and then used as fill onsite.
	Demolition Only	5.8	37,400	Assume designated as “contained out” by existing data. Excavate and stockpile next to trench; backfill after demolition material is removed.
Alternative 4 – In Situ Solidification/Stabilization	Core	1.8	20,300	Stockpile, sample and test; assume 50% is designated clean and used as fill onsite; assume 50% is treated in ex situ cell and reused onsite
	North and East Shallow (LNAPL)	2.4	27,100	If designated as “contained out” by existing data, stockpile and use as fill onsite. If “contained out” determination not obtained, treat in ex situ cell and reuse onsite.
	Demolition Only	5.8	37,400	Assume designated as “contained out” by existing data. Excavate and stockpile next to trench; backfill after demolition material is removed.
Alternatives 5 – Thermal Enhanced Extraction and ISCO	Core	1.8	11,600	Stockpile, sample and test; assume 50% is designated clean and used as fill onsite; assume 50% is disposed in hazardous waste landfill.
	Periphery Non-Core	7.2	46,500	Assume designated as “contained out” by existing data. Excavate and stockpile next to trench; backfill after demolition material is removed.

[a] For the purposes of this FFS, it is assumed that hazardous material generated during implementation of Alternatives 3, 4, and 6 can be treated and a “contained out” determination obtained, thus allowing onsite reuse. Alternative 5 technologies cannot handle ex situ soil and debris treatment; therefore, hazardous material will be transported to offsite Subtitle C facility.
CY = cubic yards
ft = feet
ISCO = in situ chemical oxidation
LNAPL = light non-aqueous phase liquid

Figures



LEGEND

- RA Target Area for Upper Aquifer (TarGOST >= 10 %RE)
- TarGOST Location

Historic Features and Potential Source Areas

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

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

N

0 50 100 200 Feet

Figure 3-1
Former Process Area Remedial Action Target Zones

Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives
Wyckoff/Eagle Harbor Superfund Site

CH2MHILL

C:\USERS\GGEE\DOCUMENTS\GIS\WYCKOFF\MAPFILES\2013\FS EVAL\REPORT FIGURES\FIGURE3-1_RATARGETAREA.MXD GGEE 11/25/2013 10:07:09 AM

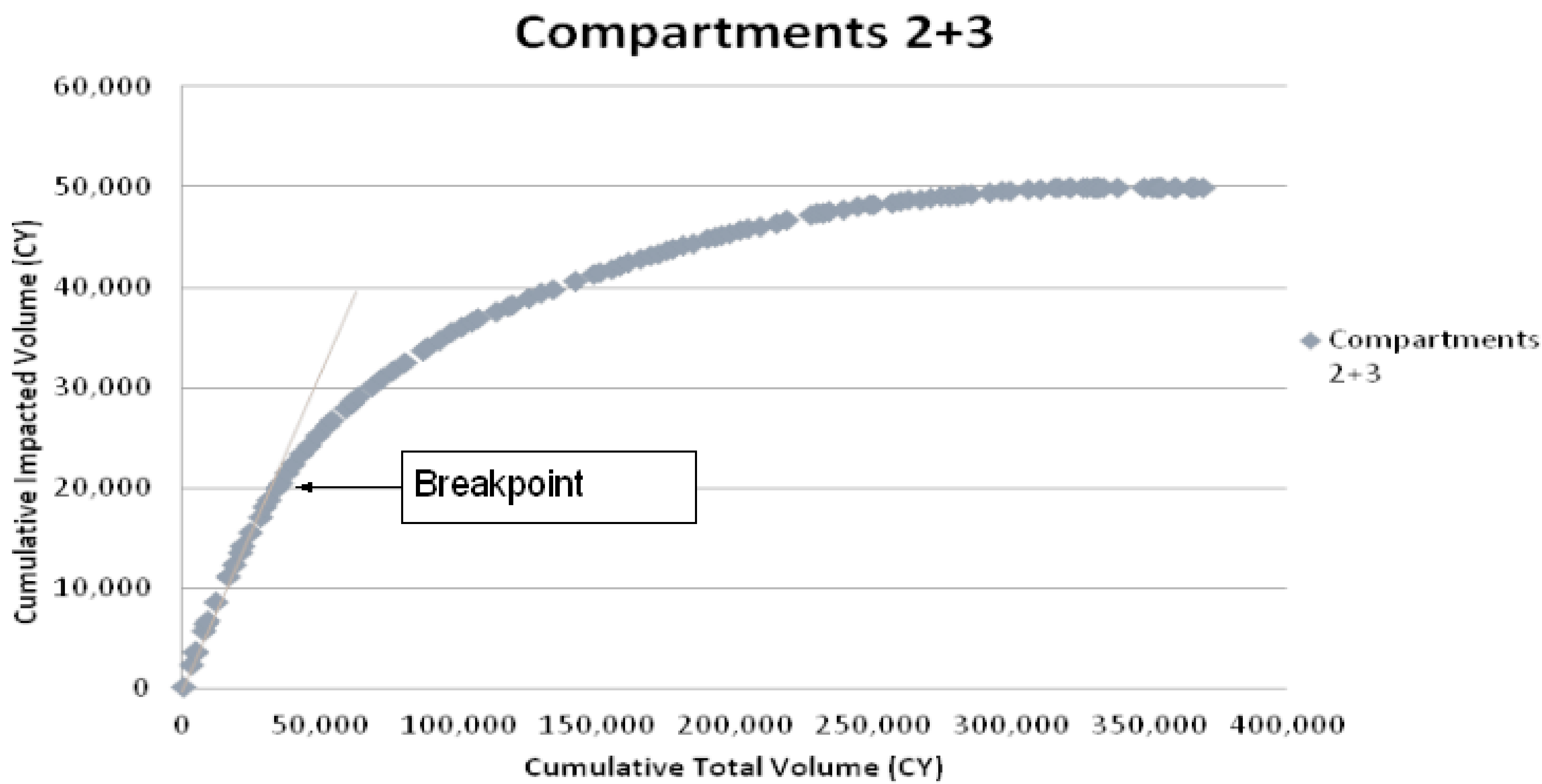
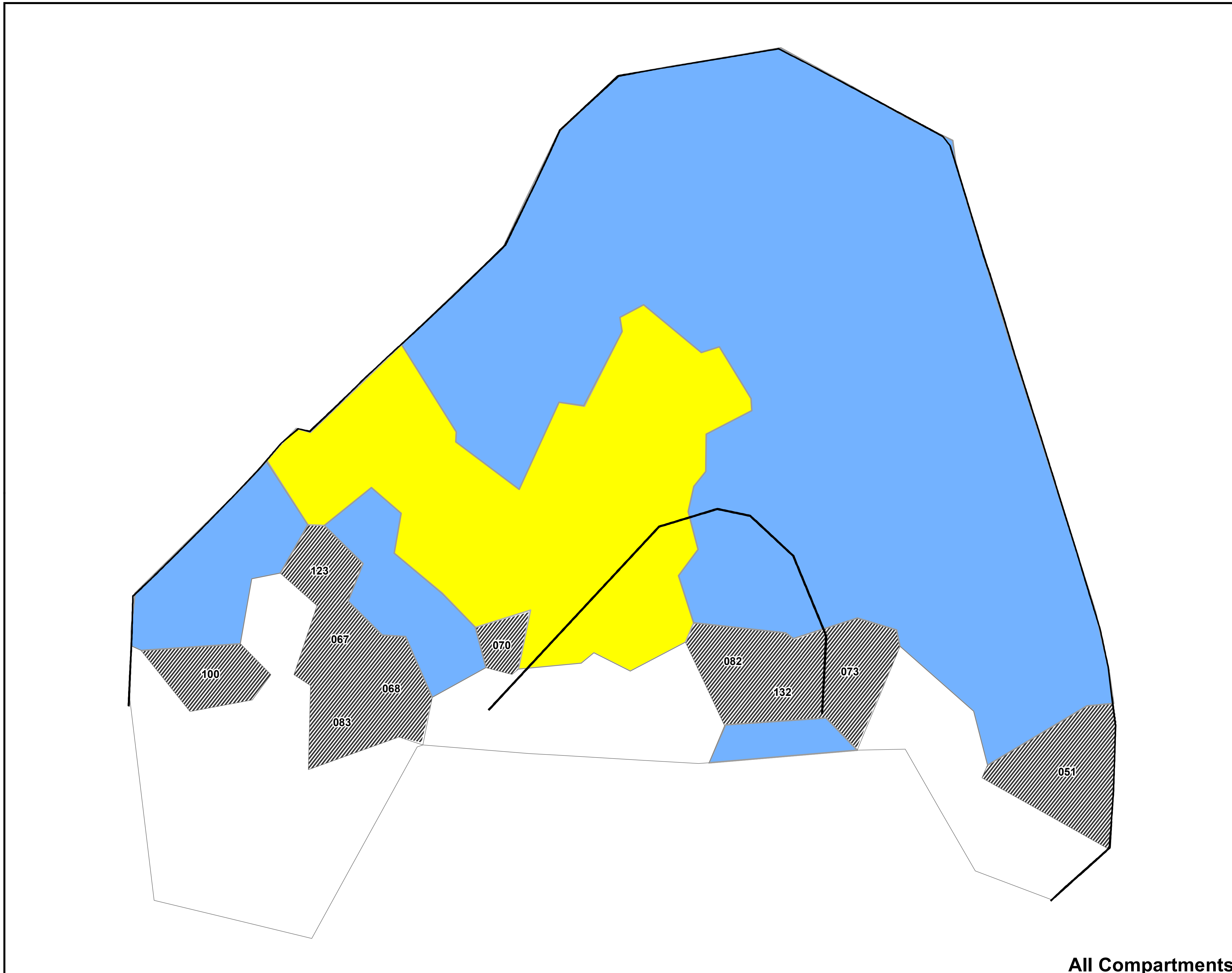


Figure 3-2
NAPL-Contaminated Soil Volume Versus Total Soil Volume for Compartments 2 + 3
Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives

Wyckoff/Eagle Harbor Superfund Site

CH2MHILL.



LEGEND

Initial Core and Periphery Indentification

- NAPL Core Area
- NAPL Periphery Area
- NAPL-Impacted Thickness < 2 ft (Not Assigned to Target Zone)
- No Response Above 10%RE
- Current Outer and Inner Sheet Pile Wall

Labels:

036 TarGOST Boring

N

0 50 100 200 Feet

Figure 3-3

Core and Periphery Treatment Areas
All Compartments
Upland Dataset

Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives
Wyckoff/Eagle Harbor Superfund Site

CH2MHILL.

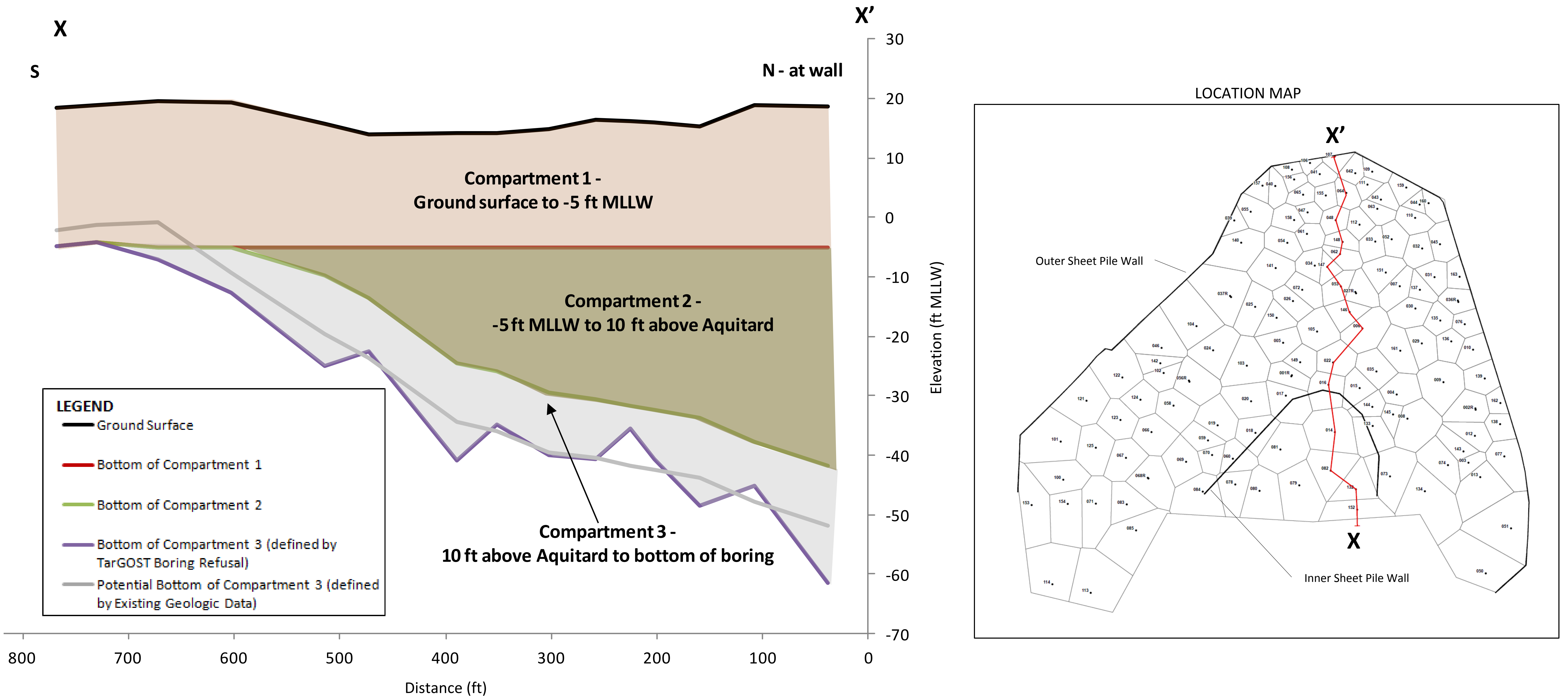


Figure 3-4
Remedial Action Target Zone Compartments
Upland Dataset
Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives
Wyckoff/Eagle Harbor Superfund Site

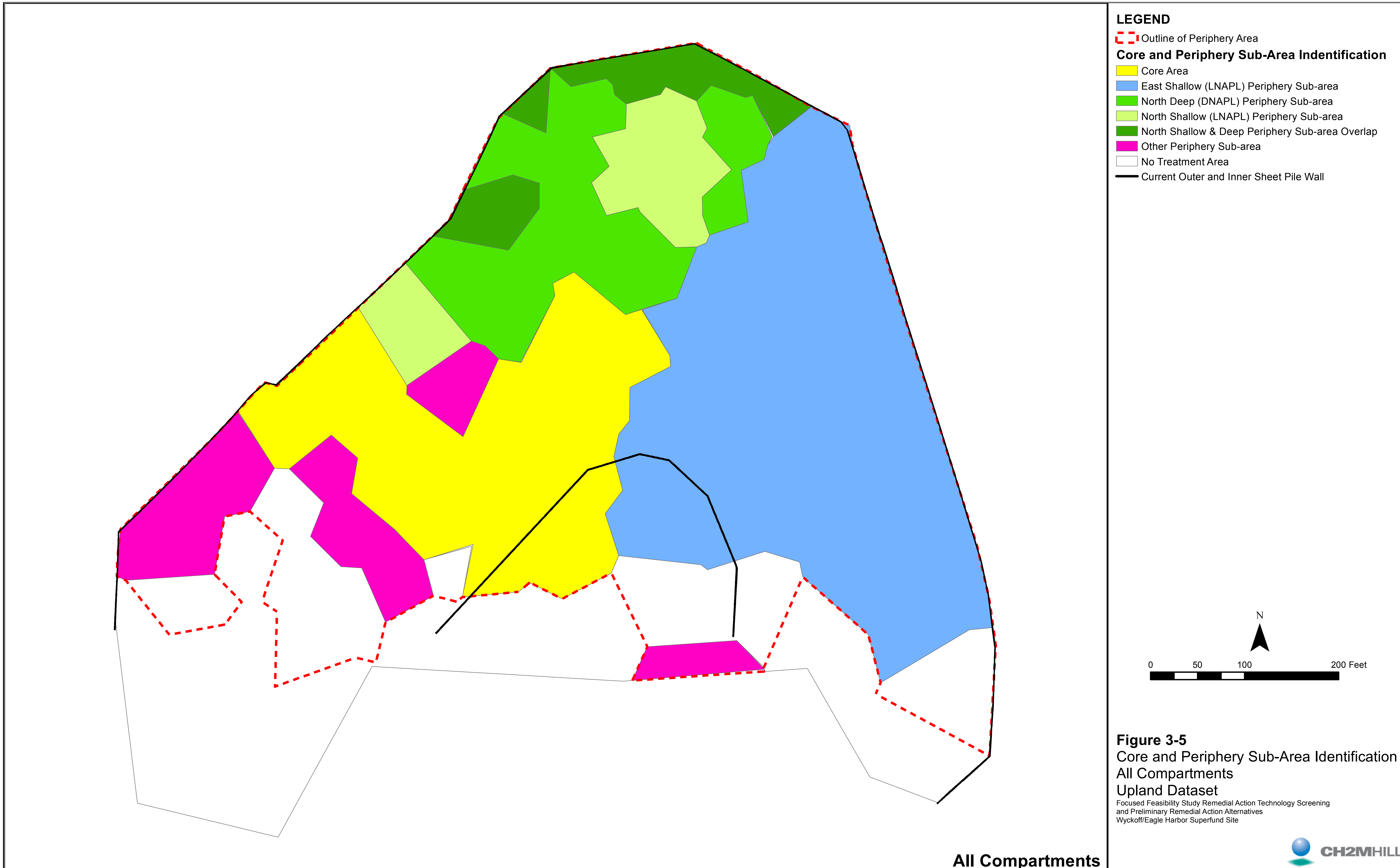
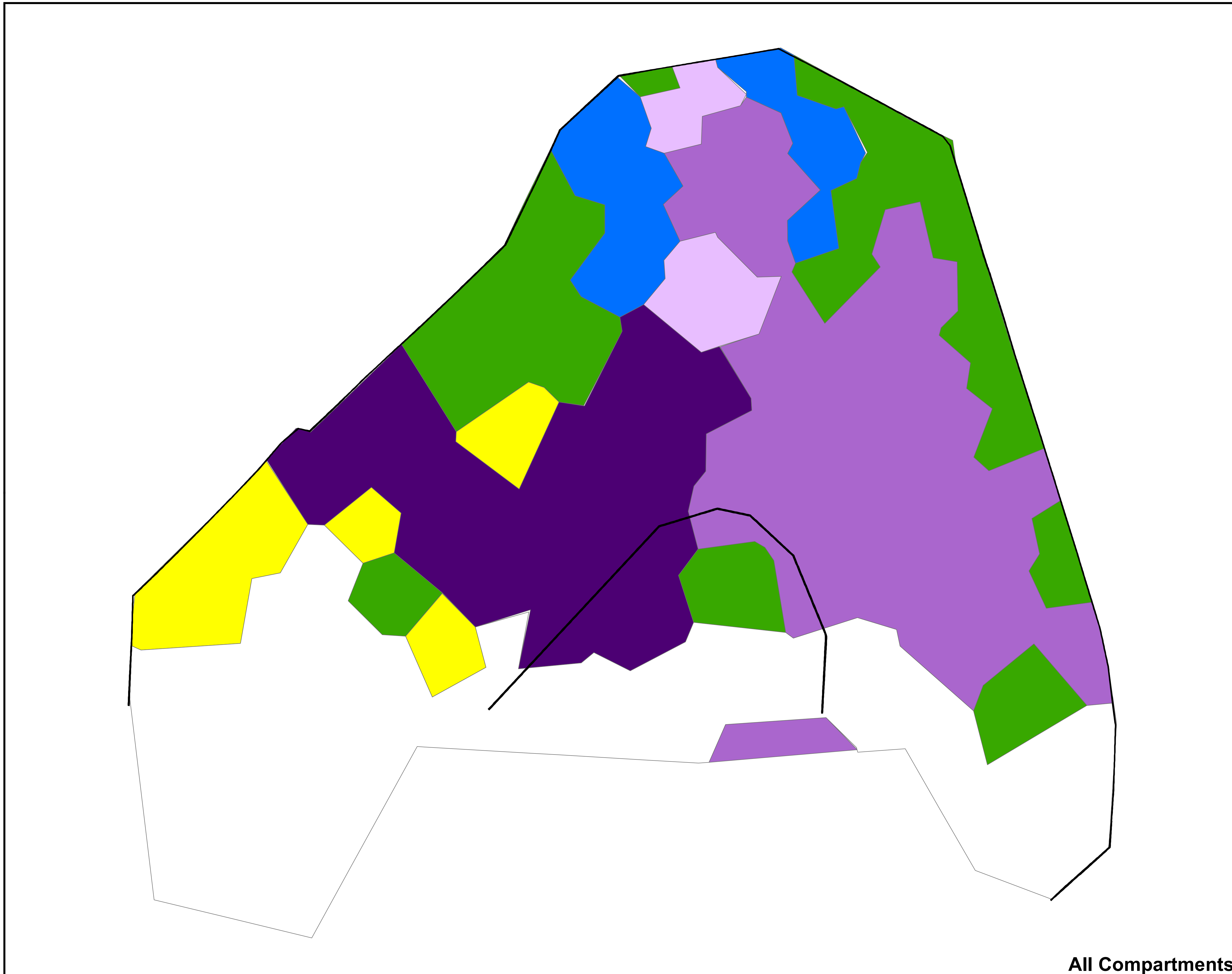


Figure 3-5
Core and Periphery Sub-Area Identification
All Compartments
Upland Dataset

Focused Feasibility Study Remedial Action Technology Screening
and Preliminary Remedial Action Alternatives
Wyckoff/Eagle Harbor Superfund Site



LEGEND

Alternative 3

- Thermal Desorption - Core
- Thermal Desorption - LNAPL
- Thermal Desorption (Compartment 1) / ISCO - DNAPL Overlap
- ISCO - LNAPL
- ISCO - DNAPL
- Enhanced Aerobic Biodegradation
- No Treatment
- Current Outer and Inner Sheet Pile Wall

N

0 50 100 200 Feet

Figure 5-1
Alternative 3 – Excavation, Thermal Desorption, and ISCO
All Compartments
Upland Dataset

Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives
Wyckoff/Eagle Harbor Superfund Site

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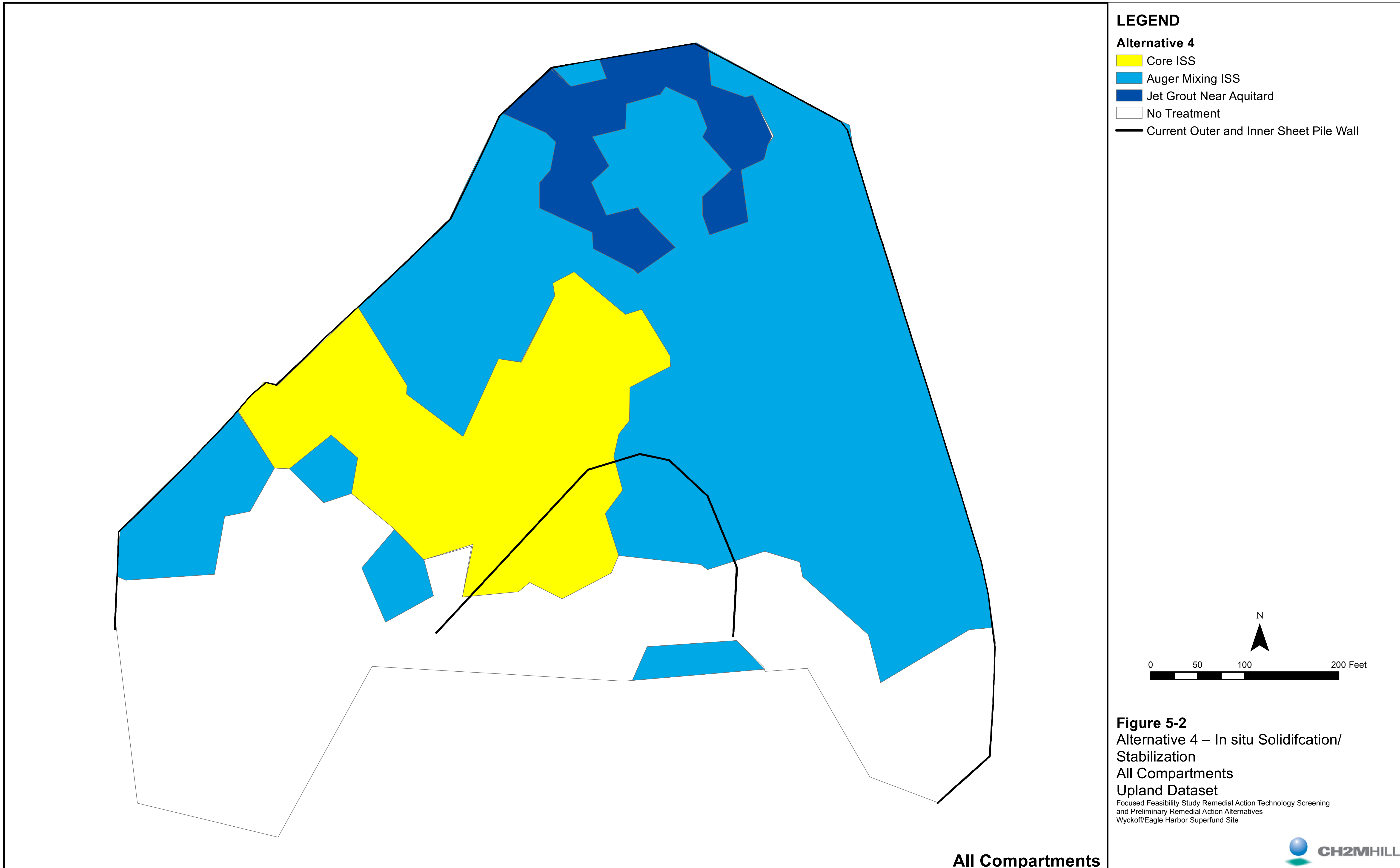

Figure 5-2
Alternative 4 – In situ Solidifcation/ Stabilization
All Compartments
Upland Dataset

Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives
Wyckoff/Eagle Harbor Superfund Site

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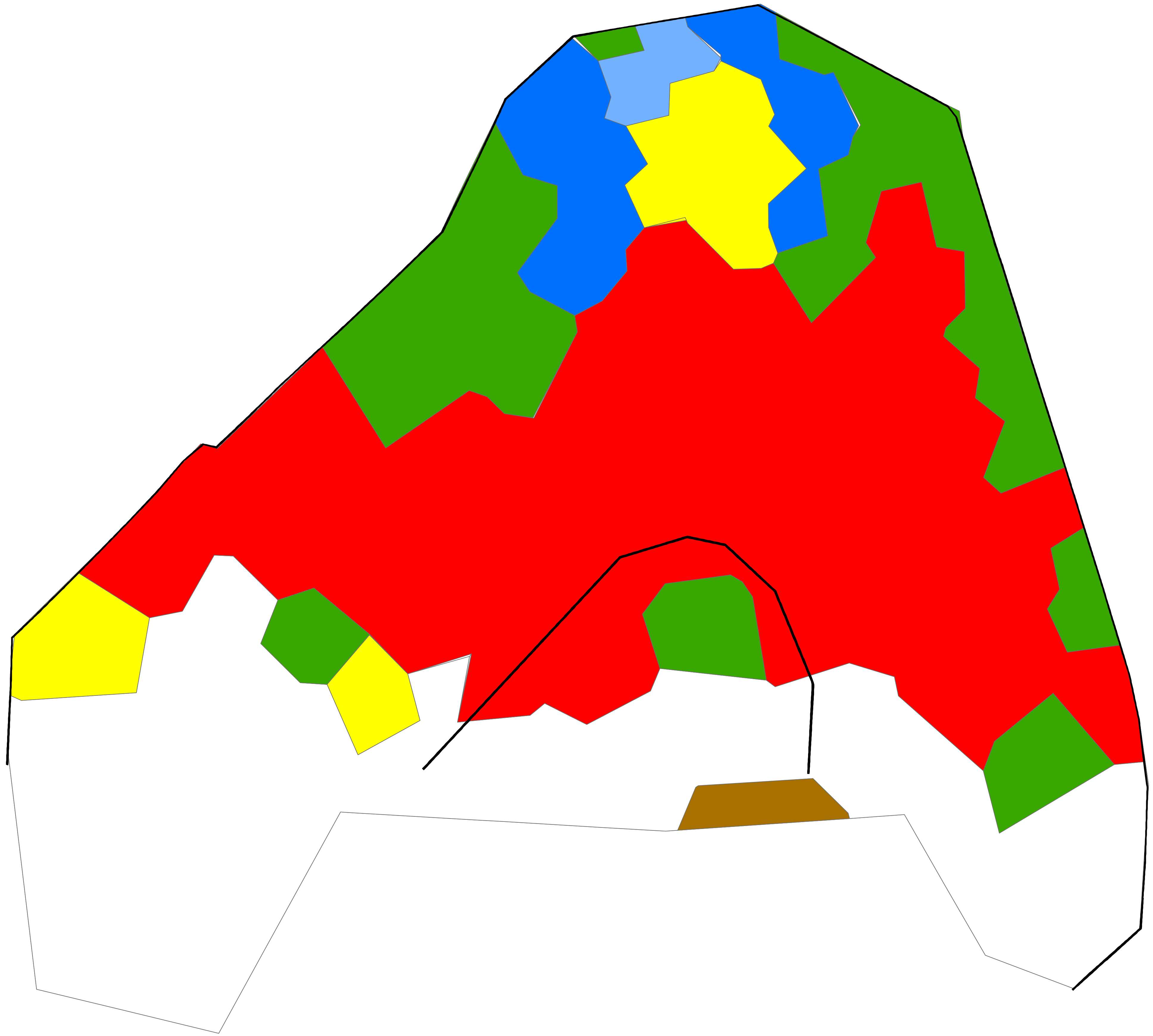

LEGEND

Alternative 5

- Thermal
- ISCO - LNAPL
- ISCO - DNAPL
- Overlap - ISCO - LNAPL and DNAPL
- Dig and dispose
- Enhanced Aerobic Biodegradation
- No Treatment
- Current Outer and Inner Sheet Pile Wall

N

0 50 100 200 Feet

Figure 5-3
Alternative 5 – Thermal Enhanced Extraction and ISCO
All Compartments
Upland Dataset

Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives
Wyckoff/Eagle Harbor Superfund Site

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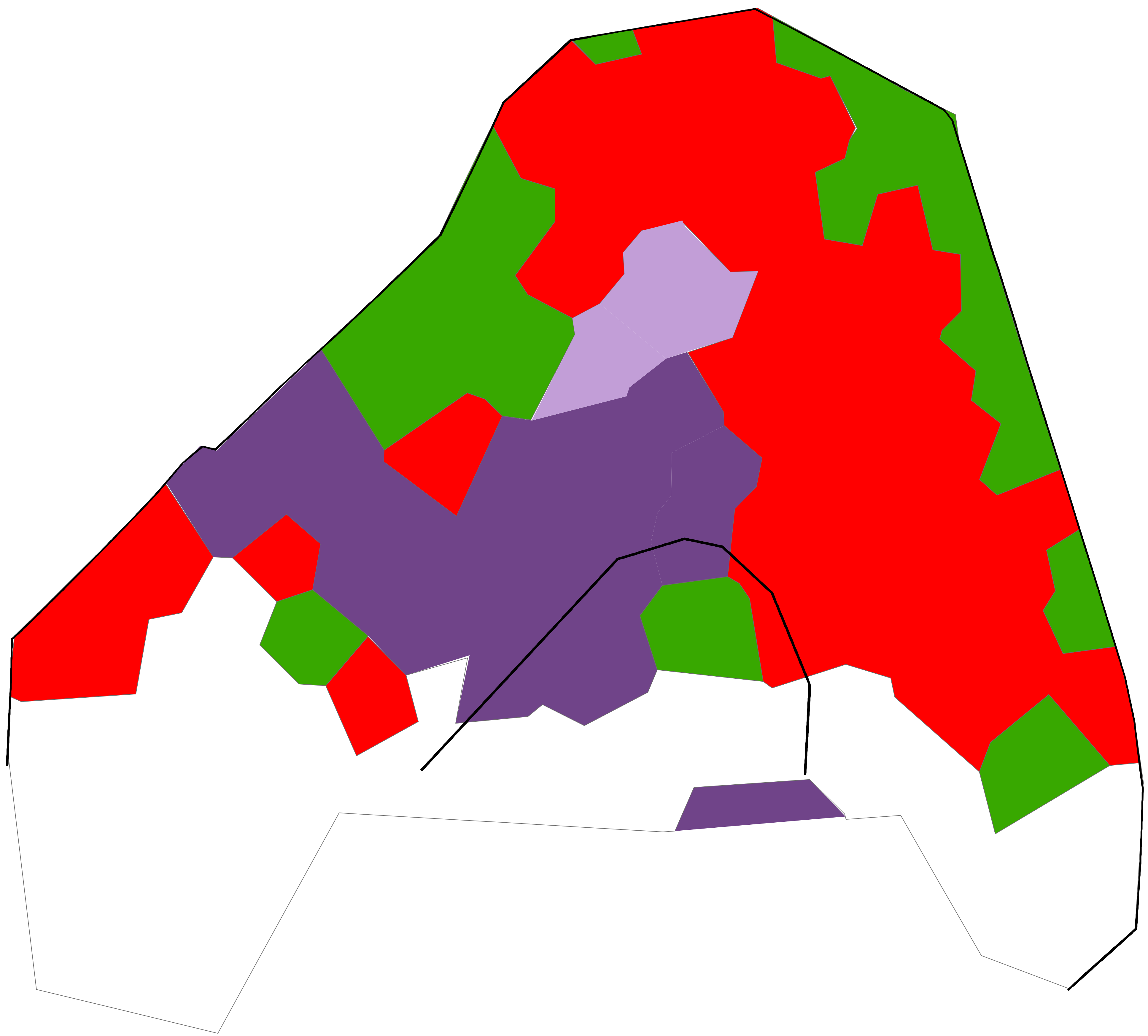

Figure 5-4
Alternative 6 - Excavation, Thermal Desorption, and Thermal Enhanced Extraction
All Compartments
Upland Dataset

Focused Feasibility Study Remedial Action Technology Screening and Preliminary Remedial Action Alternatives
Wyckoff/Eagle Harbor Superfund Site

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C:\USERS\GGEE\DOCUMENTS\GIS\WYCKOFF\MAPFILES\2013\FS EVAL\REPORT FIGURES\FIGURE5-4_ALT6.MXD GGEE 2/4/2014 7:57:55 AM