Feasibility Study Report

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007843 | C2D2 | 403 | Report No 139 | ~~December 9 2016~~January 25 2017

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List of Acronyms

ADP	Anthropogenic Density Plume
ANC	acid-neutralizing capacity
Anchor	Anchor QEA
AOC	Administrative Order on Consent
ARARs	Applicable or Relevant and Appropriate Requirements
ARF	Army Reserve Facility
AWQC	Ambient Water Quality Criteria
bgs	below ground surface
Bluffs	Puget Sound Bluffs
BML	below mud line
CB/NT site	Commencement Bay Nearshore/Tideflats Superfund site
CD	Consent Decree
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cis-1,2-DCE	cis-1,2-dichloroethene
cm/s	centimeters per second
COC	contaminant of concern or contaminants of concern
CRA	Conestoga-Rovers & Associates (now GHD)
CSM	Conceptual Site Model
CVOC	chlorinated volatile organic compound or chlorinated volatile organic compounds
DCA	Disproportionate Cost Analysis
DNAPL	dense non-aqueous phase liquid
DOC	dissolved oxygen content
Ecology	Washington State Department of Ecology
EHEPA	ecological health exposure pathway assessment
ENVs	environmental heads
ERH	electrical resistance heating
ERT	Evaluation of Remedial Technologies
FEHs	freshwater equivalent heads
FFAs	Federal Facility Agreements
FS	Feasibility Study
ft	feet
ft/d	feet per day
gpm	gallons per minute
GSH	Glenn Springs Holdings, Inc.
GRAs	General Response Actions
GWETS	groundwater extraction and treatment system
HASP	health and safety plan
HCB	hexachlorobenzene
HCBD	hexachlorobutadiene
HHEPA	human health exposure pathway assessment
Hylebos	Hylebos Waterway

List of Acronyms

ICs	Institutional Controls
ISB	in situ bioremediation
ISCO	in situ chemical oxidation
JARPA	Joint Aquatic Resources Permit Application
lbs	pounds
lbs/ft^3	pounds per cubic foot
Meq	megaequivalents
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MSP	Mass Reduction by Strategic Groundwater Pumping
MTCA	Model Toxics Control Act
MVS/EVS	Mining Visualization System/Environmental Visualization System software package
NaCl	sodium chloride (salt)
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NGVD	National Geodetic Vertical Datum
NPDES	National Pollutant Discharge Elimination System
O&M	operation and maintenance
OCC	Occidental Chemical Corporation
OSHA	United States Occupational Safety and Health Administration
PCBs	polychlorinated biphenyls
PCE	tetrachloroethene or perchloroethylene
PDCE barrier	physical direct contact exposure barrier
POT	Port of Tacoma
PTW	potential principal threat waste
RAGs	Remedial Action Goals (or Remedial Action Objectives)
ROD	Record of Decision
SCR	Site Characterization Report (or Remedial Investigation Report [RI Report])
SEPA	Washington State Environmental Policy Act
SMCL	secondary maximum contaminant level
SMS	MTCA Sediment Management Standards
SOW	Statement of Work for the Administrative Order on Consent
SQAPP	Sampling and Quality Assurance Project Plan
SQOs	Sediment Quality Objectives
SSLs	soil screening levels
s.u.	standard units of pH
SVE	soil vapor extraction
SVOC	semi-volatile organic compound or semi-volatile organic compounds
TCE	trichloroethene or trichloroethylene
TCVOC	total chlorinated volatile organic compound or total chlorinated volatile organic compounds
TDS	total dissolved solids
µg/L	micrograms per liter
Upland Areas	Portions of the Site inland from the Embankment Area as defined in the SOW
US Navy	United States Navy
USEPA	United States Environmental Protection Agency

List of Acronyms

VC	vinyl chloride
VI	vapor intrusion
VOC	volatile organic compound or volatile organic compounds
WAC	Washington Administrative Code
Waterway	Hylebos Waterway
Waterways	Blair Waterway and Hylebos Waterway
WISHA	Washington Industrial Safety and Health Act
WMUs	waste management units
yd^2	square yards
yd^3	cubic yards
yrs	years

1. Introduction

Occidental Chemical Corporation (OCC) has been working with the Washington State Department of Ecology (Ecology) and the United States Environmental Protection Agency (USEPA) (together referred to as the "Agencies") to address remaining environmental issues at the "Occidental" Site associated in part with the former OCC facility located in Tacoma, Washington (Site) under an Administrative Order on Consent (AOC) (USEPA, 2005a). The work activities required under the AOC are outlined in the "Statement of Work for the Administrative Order on Consent" (SOW) (Conestoga-Rovers & Associates [CRA], 2005). Additional work not anticipated in the SOW has been conducted and scheduled consistent with the AOC.

This Feasibility Study (FS) Report presents the evaluation of remedial alternatives to address impacts at the Upland Areas of the Site. The evaluation was conducted in accordance with the Model Toxics Control Act (MTCA) Cleanup Regulation, as amended October 12, 2007 (MTCA Regulations) Chapter 173-340-350, and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and builds on the identification and screening of remedial technologies and process options presented in the Draft Evaluation of Remedial Technologies (ERT) Report (CRA, 2014b), the previous Draft Feasibility Study report (CRA, 2015) (2015 Draft FS report), and Agencies' comments on the 2015 Draft FS report (Ecology, 2016a and amendments).

This FS Report is organized as follows:

i)	Section 2	Conceptual Site Model (CSM): provides a summary of the Site characterization including the physical setting, nature and extent of impacts, contaminant fate and transport and exposure pathways assessment.
ii)	Section 3	Identify Remedial Action Goals (RAGs) and Potential Applicable local, State, and Federal Laws: presents medium-specific goals for protecting human health and the environment based on the contaminants of concern (COC), and potential receptors and exposure pathways. It also presents General Response Actions (GRAs) that, alone or in combination, satisfy the RAGs for each medium of concern, and potential applicable local, State, and Federal laws.
iii)	Section 4	Identify Alternatives: identifies and describes a reasonable number and type of remedial alternatives; detailing technologies selected for media and subdivisions of the Upland Areas of the Site.
iv)	Section 5	Containment Alternatives - Initial Screening and Detailed Evaluation: evaluates the identified alternatives to potentially reduce the number for detailed evaluation by eliminating alternatives that do not meet the minimum Washington Administrative Code (WAC) requirements, for which costs are clearly disproportionate, or that are technically not implementable. Evaluates the remaining alternatives with respect to compliance with the minimum requirements in WAC 173-340-360(2), benefits and drawbacks, disproportionate-cost analysis and consistency with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (USEPA, 1994).

v)	Section 6	VOC (volatile organic compounds) Mass Removal/Reduction Alternatives - Initial Screening and Detailed Evaluation: evaluates the alternatives with respect to estimated mass removed over time in addition to the same criteria in Section 5.
vi)	Section 7	pH Reduction/Enhanced Containment Alternatives - Initial Screening and Detailed Evaluation: evaluates the alternatives with respect to same criteria in Section 6.
vii)	Section 8	Select Preferred Remedy: presents a recommended remedy based on the detailed evaluation of alternatives, Agency's expectations (WAC 173-340-370), and known public concerns, discussion of proposed performance objectives for the recommended remedy, and documents reasons for the recommendation.
viii)	Section 9	References: lists the documents referenced in this FS Report.

2. Conceptual Site Model

This section presents a summary of the physical and chemical characterization of the Site as it relates to the development and analysis of remedial alternatives. OCC has conducted extensive investigations into the Site's physical characteristics, potential contaminant sources, nature and extent of impacts, and contaminant fate and transport. The primary sources of information presented in this summary are the approved Final Conceptual Site Model Report (CRA, 2014a) (CSM Report), the Site Characterization Report (CRA, 2014c) (SCR; also referred to as Remedial Investigation Report [RI Report] as approved on October 11, 2016 [Ecology, 2016b]) and Data Summary Report (Anchor QEA, 2016) for surface sediment and near-surface porewater in the Hylebos Waterway (Waterway or Hylebos) adjacent to the Site (Anchor Report).

2.1 Site Description

The Site is located on the eastern-most peninsula of the area of ownership and operations of the Port of Tacoma (POT) that extends into Commencement Bay at the mouth of the Puyallup River Valley and is defined in the AOC. A general location map showing the Site, including the formerly OCC-owned properties and that portion of Segment 5 of the Hylebos Waterway contained within the Site, is presented on Figure 2.1.

A plan showing local property ownership is presented on Figure 2.2. The properties formerly owned and/or operated on by OCC or its predecessors include:

- 605 Alexander Avenue property (former OCC Facility currently owned by Mariana Properties, Inc. [Mariana])
- 709 Alexander Avenue property (currently owned by Mariana)

The properties are referred to as the '605 Alexander Ave.' and '709 Alexander Ave.' properties on Figure 2.2. The properties are bounded on the west, north, and south by former Todd Shipyards and/or United States Navy (US Navy) properties (now owned by the POT), and on the east by the Waterway.

The approximate extent of groundwater impacts at the Site is shown on Figure 2.1. The Site is within the roughly 12-square-mile area Commencement Bay Nearshore/Tideflats Superfund site (CB/NT site) which includes several waterway problem areas and adjoining uplands as described by the CB/NT site Record of Decision (ROD) (USEPA, 1989). The Site includes part of Segment 5 of the Mouth of Hylebos Problem Area where impacted sediments were dredged and disposed in 2003-05 (CRA, 2014c), or excavated and capped 2007-08 (Hart Crowser, 2013). This work was performed under the Mouth of Hylebos Consent Decree (USEPA, 2005b).

2.2 Historical Operations

Historical operations at the Site in the past 100 years have included: (a) chemical manufacturing; (b) ship building, maintenance, and dismantling; and (c) petroleum and fuel storage and distribution. Those operations primarily occupied the real properties designated as 401 Alexander Avenue (now the Port of Tacoma's Early Business Center, formerly described as the Port Industrial Yard, the United States Naval Station Tacoma, and Todd Shipyards), 605 Alexander Avenue (the Former OCC Facility), 709 Alexander Avenue (now owned by Mariana Properties and formerly described as the PRI Northwest and Fletcher Oil facilities), and 901 Alexander Avenue (now Port of Tacoma property, a portion formerly designated as 721 Alexander Avenue and formerly described as the Maxwell Petroleum, General Petroleum, and United States Air Force facilities). Those historical operations have been described in previous Site reports, and are generally summarized below. See, e.g., approved CSM Report (CRA, 2014a); Draft ERT Report (CRA, 2014b), and Appendix B of SCR (CRA, 2014c) approved on October 11, 2016 (Ecology, 2016b).

Chemical Manufacturing

OCC's predecessor's chemical manufacturing operations began at the Site in 1929 at 605 Alexander Avenue and were continued by OCC and others until 2002. The operations primarily involved the production of chlorine and caustic soda, but during various time frames also involved the production of sodium hypochlorite, trichloroethene/tetrachloroethene (TCE/PCE), ammonia, muriatic acid, calcium chloride, saturated (hydrogenated) oil, aluminum chloride, and sodium aluminate. Chlorine and caustic soda production occurred throughout the Former OCC Facility history, using electrolysis. TCE/PCE production occurred from 1947 to 1973, primarily on the North 10 Acres of 605 Alexander Avenue. Other production processes occurred for various time periods. Wastes generated during the various manufacturing processes were managed at 605 Alexander Avenue, and included wastewater treatment (settling) ponds, settling barges, landfills, disposal pits, and waste piles. Seventeen waste management units were historically located on the property. Chemical manufacturing ceased in 2002, and nearly all buildings and structures at 605 Alexander Avenue were demolished between 2006 and 2008. The property continues to be the operations center for the groundwater treatment and containment facility installed by OCC and operated since 1996.

Building, Maintenance, and Dismantling of Ships

Shipbuilding began at the Site at least as early as World War One, with the establishment of the Todd Shipyards facility at 401 Alexander Avenue and on a portion of 605 Alexander Avenue (the portion described as the North 10 Acres). Shipbuilding by Todd Shipyards and by the United States occurred in those locations during both World War One and World War Two. The North 10 Acres of 605 Alexander Avenue was used during World War Two for the gathering and incineration of shipyard wastes, among other activities, and in 1945 became the location of the "Navy Todd Dump" on the shoreline of the Hylebos Waterway. The Todd Shipyards facility subsequently became the United States Naval Station Tacoma where ships were stored, maintained, and dismantled until the 401 Alexander Avenue property was acquired by the Port of Tacoma from the United States. Since 1960, numerous tenants' operations have included additional shipbuilding and dismantling. In connection with the historical ship-related activities, waste landfilling, incineration, and disposal (among other activities) occurred along the shoreline and in the uplands.

Petroleum and Fuel Storage Distribution

The petroleum and fuel tank farm facilities located at 709 Alexander Avenue and 901 Alexander Avenue operated from approximately the 1930s to the 1980s. Those historical operations resulted in an area of contaminated soil and groundwater at those and adjacent properties currently being addressed under Ecology oversight and Agreed Order DE 9835 by the Port of Tacoma and Mariana Properties, Inc. The 709 Alexander Avenue property also includes an embankment fill area along the Hylebos Waterway shoreline that was associated with the former chemical manufacturing operations at 605 Alexander Avenue. The 709 Alexander Avenue embankment, as well as the 605 Alexander Avenue embankment, are being addressed as part of the Site.

2.3 Physical Site Setting

Regionally, the Site, Puyallup River Valley, and surrounding area are part of the Puget Sound Lowlands, which are surrounded by the Puget Sound Bluffs (Bluffs). The Bluffs extend along the sides of the Puyallup River Valley, and correspond to the highland areas at the east and west sides of the POT. The Bluffs extend upwards from the eastern shoreline of the Waterway to approximately 350 feet (ft) above the Site peninsula.

The peninsula on which the Site is located is man-made and was created in the early 1900s. The Hylebos and Blair Waterways located on the east and west sides of the Site peninsula, respectively, were dredged and the materials were used to build up the land mass. The Waterways were dredged through the existing tidal mud flats at the mouth of the Puyallup River Valley.

2.3.1 Regional and Site Geology

Regional Geologic Conditions

The geologic framework of the Puyallup River Valley consists of nearly 2,000 ft of unconsolidated sediments overlying bedrock. The area has experienced several glacial advances and retreats. The most recent glacial advance, the Vashon Stade of the Fraser Glaciation, scoured a channel into the pre-Vashon sediments along the Puyallup River Valley. Figure 2.3 shows a conceptual model of the regional geology where the channel scoured into the pre-Vashon sediments is in-filled by post-Vashon sediments, referred to here as deltaic deposits. The deposition of the deltaic material occurred at varying rates and under varying stream flow and sea level conditions, resulting in a series of sand units with interbedded and interfingered silt and clay units with occasional gravelly sand units.

Site Geologic Conditions

Figure 2.4 shows the conceptual geologic conditions for the Puyallup River Valley and Bluffs in the Site vicinity, and is based on the regional geologic conditions described in Appendix A of the approved CSM Report (CRA, 2014a).

Within the Puyallup River Valley, the generalized geologic conditions are based on Site borings and described as follows (from ground surface):

- Fill - variable mixture of sand, silt, and gravel material placed through dredging of the Hylebos and Blair Waterways to develop the Site peninsula. The thickness of the fill across the Site ranges from approximately 10 to 15 ft with hydraulic conductivity values that range from approximately 1.0×10^{-4} to 1.0×10^{-2} centimeters per second (cm/s) (0.3 to 30 feet per day [ft/d]).
- Deltaic deposits - heterogeneous mixture of interbedded sands, silts, and clays. The thickness of the deltaic deposits across the Site ranges from approximately 30 to 200 ft in the eastern and northeastern portion of the Site to greater than approximately 300 ft in the southwestern portion of the Site. Hydraulic conductivity values for the deltaic deposits range from approximately 1.0×10^{-5} to 1.0×10^{-2} cm/s (0.03 to 30 ft/d).
- Glacial deposits - heterogeneous mixture of interbedded gravel, sands, silts, and clays. The thickness of the glacial deposits beneath the Site has not been determined, but based on regional information, is more than 1,000 ft. Hydraulic conductivity values for the glacial deposits range from approximately 5.0×10^{-5} to 5.0×10^{-3} cm/s (0.15 to 15 ft/d). The top surface of the glacially derived deposits slopes downward to the north, west, and south from a mound observed under the central portion of the Site, as shown on Figure 2.4. The glacial deposits are not encountered at borings in the west, southwest, and south portion of the Site peninsula and are inferred to dip downward in this area below the depth of the Site borings.

The extensive Site stratigraphic data indicate that there is an increased frequency of lower permeability lenses, comprised mainly of silt and clay, in the lower deltaic deposits. This is shown schematically on Figure 2.4.

Within the Bluffs, Figure 2.4 shows an alternating sequence of sand/gravel and silt/clay layers based on the regional geologic conditions described in Appendix A of the approved CSM Report (CRA, 2014a).

2.3.2 Regional Hydrogeology/Groundwater Non-Potable Classification

Regional Hydrogeologic Conditions

Regional surface water and groundwater flow through the Puyallup River Valley discharges to Commencement Bay from south to north. Shallow groundwater discharges to rivers, creeks, and waterways as they extend through the Valley. Groundwater within the Puyallup River Valley is replenished by regional upland groundwater inflow into the Valley and by precipitation infiltration. Regional groundwater flow within the Bluffs discharges through seepage faces along the Bluffs and to the waterways/Commencement Bay.

Ecology's letter dated March 30, 2015 (Ecology, 2015) included as Appendix A of this FS Report, determined that the peninsula groundwater meets the MTCA Section 720 non-potable classification. The underlying and surrounding groundwater has salinity levels that exceed USEPA drinking water standards (e.g., total dissolved solids [TDS] >500 milligrams per liter [mg/L], secondary maximum contaminant level [SMCL]).

2.3.3 Site Hydrogeology

Groundwater beneath the Site discharges to the surrounding surface water bodies. Fresh groundwater inflow toward the Site peninsula occurs from the south due to upland regional groundwater flow along the Puyallup River Valley, and from the east due to regional groundwater flow in the Bluffs aquifers discharging to the Valley. Infiltration of precipitation over the Site peninsula contributes a further source of fresh groundwater, and establishes a shallow radial groundwater flow pattern towards the surface water bodies.

The groundwater table at the Site peninsula is located in the fill that was placed on top of the native mud flats. The mud flats historically existed throughout the POT, but the mud flats have not been identified consistently in all Site borings. This might be due to a lack of precision in the stratigraphic logs, or might be due to stream channels that could have incised the fine-grained sediments of the mud flats. For the CSM, a mud flats stratigraphic unit is conceptualized as depicted on Figure 2.4.

In general, the mud flats are assumed to have hydraulic conductivity similar to silts and clays identified within the deltaic deposits. While lower permeability sediments within the mud flats may not be entirely continuous, they clearly create a hydraulic separation between the fill and the underlying deltaic deposits in the southern portion of the Site. Here, groundwater elevations in the fill are approximately 2 ft higher than groundwater elevations in the deltaic deposits immediately beneath the mud flats.

The majority of the Site-related impacts exist within the deltaic deposits. The extensive groundwater quality data indicate that the vertical limit of impacts appears to coincide with the increased frequency of lower permeability lenses in the lower deltaic deposits or the top of the glacial deposits. A discrete continuous layer of low-permeability material is not observed in Site borings in the lower deltaic deposits. However, the groundwater quality, density, and hydraulic evidence supports the concept that the increased frequency of lower permeability lenses inhibits vertical flow creating a zone of apparent confining effect in the lower deltaic deposits. The presence of this zone of apparent confining effect is inferred from:

- Upward vertical hydraulic gradients observed from the upper glacial deposits to the lower deltaic deposits in the east, northeast, and north portion of the Site peninsula where the glacial deposits were encountered.
- Fresh to relatively fresh groundwater observed within the glacial deposits.
- Downward migration of the COC appears to be limited to within the lower deltaic deposits or top of the underlying glacial deposits.

The glacial deposits beneath the deltaic deposits appear to be an aquifer system composed of several glacially-derived aquifers and aquitards separated from the deltaic deposits.

A zone of apparent confining effect in the lower deltaic deposits is consistent with some features of the salt water and fresh groundwater distributions observed at the Site. Relatively fresh groundwater is observed in deeper parts of the deltaic deposits and in the glacial deposits. This fresh water appears to be caused by environmental heads (ENVs) in the deeper deposits that are greater than in the deltaic deposits. The higher pressures in the deeper deposits create upward vertical hydraulic gradients into the deltaic deposits. These upward gradients are supported by fresh groundwater entering the deeper deposits from up-gradient regional groundwater inflow. A zone of apparent confining effect, corresponding to the increased frequency of lower permeability lenses in the lower deltaic deposits, explains these observed conditions.

The observed salt water and fresh groundwater distributions are translated to the approved CSM of hydrogeological conditions in the Site vicinity on Figure 2.5. The salt water distributions and groundwater flow conditions illustrated on Figure 2.5 are generalized representations of pre-contamination conditions. The groundwater flow conditions illustrated on Figure 2.5 are summarized as follows:

- Recharge from precipitation infiltration contributes shallow fresh groundwater in the fill. This recharge migrates laterally through the fill and downward into the underlying deltaic deposits. Lateral flow in the fill and deltaic deposits discharges to the Blair and Hylebos Waterways.
- Fresh groundwater is also introduced to both the deltaic and glacial deposits from the uplands along the Puyallup River Valley and from the east from beneath the Bluffs aquifers that lie below sea level.
- Elevated freshwater equivalent heads (FEHs) in the Bluffs limit the inland extent of the salt water along the east side of the Hylebos.
- Available salinity data from borings completed beneath the Hylebos Waterway show a zone of fresher groundwater from the eastern bluffs extending adjacent to and beneath the Hylebos.
- Available bromide data used as a tracer for identifying naturally-occurring salt water suggest a relatively complex pattern of salt water at intermediate depths underlain by fresher groundwater at depth at some locations.

Releases of high-density liquids from historical Site operations/processes (lime sludge/solvent residue, caustic soda, and salt brine) have a critical influence on groundwater flow and contaminant transport, as described in Subsection 5.6.2.5.1 of the SCR (CRA, 2014c) approved on October 11, 2016 (Ecology, 2016b).

2.4 Nature and Extent of Impacts

Extensive investigations have been conducted at the Site to define the nature and extent of impacts. The chemical characterization of soil, groundwater, porewater, and sediment is based upon the extensive analytical data obtained during the various investigations summarized in the approved SCR (CRA, 2014c) and Anchor Report (Anchor QEA, 2016). This subsection summarizes the potential contaminant sources, media of concern, and contaminant fate and transport. Table 2.1 presents Sitewide COC and media, which are further discussed below.

2.4.1 Potential Contaminant Sources

Past operations at the property generated wastes that were managed on Site. Waste management practices included wastewater treatment (settling) ponds, settling barges, landfills, disposal pits, and waste piles. In total, 17 waste management units (WMUs) were historically located at the Site, in addition to the Navy Todd Dump. Detailed discussions of the WMUs and the chemicals associated with them were presented in the SCR (CRA, 2014c) approved on October 11, 2016 (Ecology, 2016b).

Environmental investigations at the Site began in the 1980s and have shown that the following parameters are the principal COC:

- Chlorinated volatile organic compounds (CVOC)
- Fuel-related volatile organic compounds (fuel-related VOC)
- Caustic (sodium hydroxide)
- Salt (sodium chloride or NaCl)
- Metals (arsenic, chromium, copper, lead, mercury, nickel, thallium, zinc)
- Semi-volatile organic compounds (SVOC) (hexachlorobenzene [HCB] and hexachlorobutadiene [HCBD], which are by-products of solvent production)
- polychlorinated biphenyls (PCBs)
- Dioxins/furans

The principal COC were either used, produced, generated, and/or stored in various locations at the Site. In addition, some wastes generated in the production processes were managed on Site. Key "potential source areas" where the vast majority of releases occurred are listed below and described more fully in the SCR (CRA, 2014c) approved on October 11, 2016 (Ecology, 2016b).

The metals listed above as principal COC were not used in Former OCC Facility operations at the Site, but some of those metals were used in former ship building, maintenance, and dismantling operations at the Site. Geochemical conditions created by the release of caustic and brine (dissolved NaCl), and reducing conditions in groundwater, have resulted in the mobilization of some of these metals in the subsurface. The PCBs listed above as principal COC were used in the shipbuilding, maintenance, and dismantling operations at the Site. PCBs were not used in Former OCC Facility operations at the Site, other than in electrical equipment (such as transformers and capacitors). The dioxins/furans listed above as principal COC were used in and generated by the ship building, maintenance, and dismantling operations at the Site. Dioxins/furans were not used in Former OCC Facility operations other than potentially in spent graphite anodes used at the former chemical production facility, and in overheated electrical equipment (such as transformers and capacitors) containing PCBs.

VOC Potential Sources

Chlorinated solvents (TCE and PCE) were produced at the Site from 1947 to 1973. The former solvent production plant and associated WMUs are shown on Figure 2.6. A single area around the former solvent production plant and WMUs is shown on Figure 2.6 as the "potential CVOC source area". The TCE and PCE impacts in soil and groundwater appear to be primarily associated with the former solvent production plant (S1), former settling ponds (WMU A [S3], WMU G [S4], and WMU H [S5]), former settling barge (WMU F [S2]), and Area 5106. Lime sludge and solvent residue from the chlorinated solvents process were sent to settling ponds and a settling barge over time and in the first year of production were discharged to the Waterway through a direct discharge line.

CVOC and fuel-related VOC groundwater impacts are present on the 709 and 721 Alexander Avenue properties. These properties are being addressed under Agreed Order No. DE 9835, effective October 3, 2013.

Caustic Potential Sources

The elevated pH present in groundwater at the Site is primarily due to the release of sodium hydroxide (caustic soda) produced at the Site. Historical locations of the production and handling of caustic soda are shown on Figure 2.7. The principal potential source area appears to be the Caustic House (S8). A single area around the locations of Caustic House and caustic soda storage/handling is shown on Figure 2.7 as the "potential caustic source area".

Salt Potential Source

Salt was used as a feedstock in the production of chlorine, chlorinated solvents, and caustic soda. Salt was delivered to the Site by ship and stored in open piles on the Salt Pad. Figure 2.8 shows the location of the Salt Pad. Uncovered salt piles were maintained on this pad from the early 1960s until operations ceased. Water was sprayed on the salt piles to make brine. The asphalt pad was diked and sloped to a sump. However, cracks, if they existed, in the asphalt pad or leaks in the sump could have led to salt impacts beneath the Salt Pad.

Metals Potential Sources

Figure 2.9 shows the N Landfill and the Navy Todd Dump located adjacent to the embankment of the Waterway. The N Landfill was used between 1929 and 1971 and investigations have shown that the landfill received wastes containing metals, corrosives, chlorinated organics, and non-burnable debris. The Navy Todd Dump was created in approximately 1945, as a result of World War Two ship construction and waste disposal/incineration activities. Navy Todd Dump investigations have shown that the waste material contains metals (primarily cadmium, chromium, copper, mercury, nickel, and zinc). The N Landfill and Navy Todd Dump are considered potential metals sources.

The approximate boundary of metals impacted embankment fill areas is also shown on Figure 2.9. In addition to the N Landfill and Navy Todd Dump, metals impacted waste material derived from shipbuilding and dismantling activities during and after World War Two as well as chemical production were disposed along the embankment of the Waterway.

The vast majority of metals in the groundwater are present as a result of geochemical conditions (high pH and ionic strength) created by the release of other COC. The geochemical conditions mobilize (dissolve) metals at concentrations above those that would exist naturally in groundwater. This process is described in Subsection 5.4.5.2 of the SCR (CRA, 2014c) approved on October 11, 2016 (Ecology, 2016b).

SVOC Potential Sources

Potential sources of SVOC are shown on Figure 2.10. The two SVOC detected most often at concentrations above their respective criteria are HCB and HCBD. These compounds are by-products of the production of chlorinated solvents, and are found (to some degree) in areas where chlorinated solvents were produced or stored, or where the waste products were handled and disposed.

PCBs and Dioxins/Furans Potential Sources

Potential sources of PCBs and dioxin/furans are shown on Figure 2.11. Significant potential sources of PCBs at the Site would be from the US Navy shipbuilding operations performed at the Site including PCB-containing materials disposed at the Navy Todd Dump, and from ship dismantling and maintenance operations performed at the Site involving PCB-containing materials disposed and handled at the Site. Other potential sources of PCBs in the soil and sediment at the Site would be spills from equipment such as transformers and capacitors containing PCBs.

Dioxins (the common name for polychlorinated dibenzo-para-dioxins) and furans (polychlorinated dibenzofurans) are two closely related groups of chemical byproducts that are found at background levels in most industrial areas. A potential source of dioxins/furans was the incinerator installed and used at the Site for waste disposal by the US Navy and Todd Shipyards during World War Two. The burning of wastes such as PCB-containing materials in the incinerator and along the embankment at the Navy Todd Dump would have been a potential source for dioxins/furans detected at the Site. Various other forms of combustion and smelting processes (e.g., welding), occurred at the World War Two shipyard, which also potentially produced dioxins/furans. Another potential source of dioxins/furans is spent graphite anodes used at the former chemical production facility, and disposed on Site. Other potential sources of dioxins/furans at the Site would have included overheated electrical equipment (such as transformers and capacitors) containing PCBs.

Anthropogenic Density Plume (ADP) Potential Sources

A plume of elevated groundwater density, termed the "Anthropogenic Density Plume" (ADP), exists beneath the Site due to releases of high density materials from historical operations. The potential sources for the ADP consist of:

- Lime was placed in WMU A, WMU F, WMU G, and WMU H, while lime sludge/calcium chloride was placed in WMU C. Lime sludge (calcium chloride) is miscible in water, and a calcium chloride solution with water can have a specific gravity of approximately 1.3 (at 15 degrees Celsius).
- Caustic soda, with a specific gravity of approximately 1.3 to 1.5, is another component of the Site ADP. The "Potential Caustic Source Area" shown on Figure 2.7 represents a potential source location for the ADP.
- Brine (sodium chloride) was created at the Salt Pad and had a specific gravity of approximately 1.2 and is a further component of the ADP. The Salt Pad, shown on Figure 2.8, represents a potential source location for the ADP.

The noted potential contaminant sources have resulted in contamination of environmental media at the Site. A summary of the nature and extent of Site COC in each medium is provided in the following sub-sections.

2.4.2 Soil

The nature and extent of impacts in unsaturated soil is summarized as follows:

- CVOC, primarily as PCE, are present in unsaturated soil at concentrations exceeding the unsaturated soil screening levels (SSLs), primarily in the vicinity of WMU A, the Salt Pad/WMU G, WMU H, and the N Landfill.
- Site SVOC, primarily HCB and HCBD, are present in unsaturated soil at concentrations exceeding the SSLs within the same general areas as CVOC, as well as at several embankment locations.
- PCBs are present in unsaturated soil at concentrations exceeding the SSL primarily near the Navy Todd Dump and the N Landfill.

- Metals, primarily copper, but to a lesser degree arsenic, zinc, and nickel, are present at concentrations exceeding the SSLs in the vicinity of the Salt Pad/WMU G, the former Caustic House, the N Landfill, and Navy Todd Dump.

The nature and extent of impacts in saturated soil is summarized as follows:

- CVOC, primarily as PCE, TCE, and associated degradation products, are present in saturated soil at concentrations exceeding the saturated SSLs. This presence is greatest below the Facility near WMU A, the Salt Pad/WMU G, and WMU R, as well as below the Hylebos. CVOC are present to a lesser degree along the embankment and in the vicinity of the N Landfill.
- Site SVOC, primarily as HCB, are present in saturated soil at concentrations exceeding the SSLs within the same general areas as CVOC.
- Pesticides and PCBs are present in saturated soil at concentrations exceeding the SSLs along the embankment primarily near the Navy Todd Dump and the N Landfill.
- Metals, primarily copper, total chromium, nickel, arsenic, and zinc, are present at concentrations exceeding the SSLs in nearly all samples analyzed across the Site. The highest concentrations occur along the embankment in the vicinity of the N Landfill and Navy Todd Dump.

2.4.3 Dense Non-Aqueous Phase Liquid (DNAPL)

Specific investigations were conducted at the Site to identify the presence of dense non-aqueous phase liquid (DNAPL) following the procedures presented in Kueper and Davies (Kueper, B.H. and K. Davies, 2009). Confirmed DNAPL was identified in the vicinity of the Salt Pad/WMU G and WMU R within the 15-ft and 25-ft zones. Confirmed DNAPL was also detected in the 100-ft, 130-ft, and 160-ft zones. Confirmed DNAPL was not identified in the 50- and 75-ft zones.

2.4.4 Groundwater

The nature and extent of impacts in groundwater is summarized as follows:

- CVOC are present in groundwater at concentrations above the groundwater screening criteria as follows:
  - 25-ft zone – The areas of highest concentrations are located near the Salt Pad and WMU A
  - 50-ft zone – The extent of PCE and TCE is similar to the 25-ft zone, but the extent of vinyl chloride (VC) increases significantly within the 50-ft zone area beyond the limits of PCE and TCE toward the eastern side of the Hylebos
  - 75-ft zone – The highest CVOC concentrations extend eastward under the Hylebos, with lower concentrations extending further north
  - 100-ft zone – The area of highest concentration is somewhat reduced, but has migrated further north
  - 130-ft zone – The area of highest concentration is somewhat reduced, but has migrated north and east when compared to the 100-ft zone
  - 160-ft zone – CVOC concentrations in the 160-ft zone are reduced compared to the 130-ft zone, but the plume continues further northward

- Site SVOC, primarily HCB and HCBD, are present along the embankment and beneath the Hylebos at depths down to 111 ft below ground surface (bgs) upland and 164 ft below mud line (BML) below the Waterway.
- PCBs are present in groundwater primarily along the embankment in the vicinity of the Navy Todd Dump and N Landfill and below the Hylebos.
- Metals, primarily arsenic, copper, and nickel, are present at concentrations exceeding the groundwater screening criteria. The highest concentrations occur in the vicinity of the Salt Pad and Navy Todd Dump, along the embankment, and beneath the Hylebos.
- Elevated pH groundwater is present above the groundwater screening criteria as follows:
    - 25-ft zone – elevated pH was measured across the Site, with the highest values (>13 s.u. [standard units of pH]) detected along the eastern portion of the Site beneath the former plant production areas
    - 50-ft zone – the extent of the highest pH values increases in size relative to the 25-ft zone and is located more to the north toward the Salt Pad
    - 75-ft zone – the extent of the pH plume within the 75-ft zone is reduced relative to the 50-ft zone, but has migrated east with the highest groundwater pH (>12 s.u.) located in the vicinity of the former caustic tanks and the south end of Dock 1
    - 100-ft zone – the pH plume has migrated north and east, with the highest pH near the north end of Dock 1, but is limited to beneath the facility and Hylebos
    - 130-ft zone – the pH plume continues further northeast
    - 160-ft zone – the area of high pH values is much smaller in the 160-ft zone, with the highest readings diminishing
- The seep study performed in the Hylebos confirmed that seepage of impacted groundwater was occurring to some extent into the Hylebos.

2.4.5 Sediment

The August 2016 Anchor QEA investigation of potential CVOC in sediments in the Hylebos included collection of surface sediment samples from the 0- to 10-cm interval at 33 locations in the Hylebos adjacent to the Site and comparison of reported concentrations to the CB/NT site Sediment Quality Objectives (SQOs~~).~~), which were developed in consideration of the MTCA Sediment Management Standards (SMS). The investigation determined that most CVOC were below detection and no reported concentrations exceeded the CB/NT site SQOs.

~~Therefore, developing remedial alternatives for sediments in the Hylebos is not necessary and is not part of this FS Report.~~

Therefore, based on the results presented in the 2016 Anchor QEA Data Summary Report for sediment and porewater, there is no need to develop an FS or remedial alternatives for sediments at this time. It should be noted that it has been over 10 years since dredging was completed and re-contamination of the sediments has not occurred based on the 2016 data. Additionally, there is evidence from data collected in the Hylebos that natural recovery is occurring as predicted for the CB/NT site. Some future monitoring of COC concentrations in sediments may be appropriate to ensure that existing conditions of sediment quality do not change over time, however unlikely this may be.

2.4.6 Porewater

The July/August 2016 Anchor QEA investigation of potential CVOC in porewater beneath the Hylebos included attempted collection of near-bottom surface water samples from 2 to 4 cm above the mudline at 6 locations, and porewater samples from depths of 2 to 4 cm (near-surface), 10 cm, 30 cm, and 90 cm below the mudline at 33 locations in the Hylebos adjacent to the Site. The reported concentrations for near-bottom surface water and near-surface porewater samples collected at 2 to 4 cm above and below the mudline, respectively, were compared to Ambient Water Quality Criteria (AWQC). Only one parameter VC, reported in one sample (adjacent to the northern end of the 605 Alexander Avenue property), had the potential to marginally exceed the associated screening criterion at the applicable point of compliance. Therefore, this migration pathway is not considered significant at this time. Based on the fact that the remedy for the Site will include ~~groundwater~~ containment, it is unlikely that future impacts will occur ~~and this migration pathway is not considered significant~~. Some future monitoring of COC concentrations in porewater may be appropriate to ensure that existing conditions of porewater quality do not change over time, however unlikely this may be.

2.4.7 Indoor Air

The vapor intrusion (VI) investigation included nine buildings in the Site area, including the Army Reserve Facility (ARF), Buildings 326, 407, 532, 592, 595, and 596, and the Guard Shack located on properties owned and/or controlled by the POT, and the OCC Office Building.

The most frequently occurring exceedances of screening levels in indoor air and their potential sources were as follows:

- Indoor sources: 1,2,4-trimethylbenzene, 1,4-dichlorobenzene, naphthalene, m&p-xylenes, styrene, PCE, and TCE
- Outdoor sources: none
- Sub-slab sources: PCE and TCE

The majority of exceedances were concluded to be likely attributable to indoor sources (e.g., vehicle operations, paint operations, miscellaneous power and hand tools, parts washing tubs, chemical storage tanks, flammable material storage lockers, paint cans, cleaning products, miscellaneous building materials, aerosol cans containing chemical cleaners, lubricants, cutting oils, and diesel fuel). Only a few of the exceedances were concluded to be potentially attributable to sub-slab sources, and two of which were sources likely unrelated to the OCC Site. The recommendations for future actions at the nine buildings are as follows:

- Manage occupancy: OCC Office
- Continued monitoring: 595
- No Further Action: ARF, 326, 407, 532, 592, 596, and Guard Shack

2.5 Potential Principal Threat Waste (PTW)

An evaluation of the presence of potential principal threat waste (PTW) at the Site was undertaken and the details and results of this evaluation are presented in Appendix B. The regulatory framework regarding the identification and remediation of hazardous substances and PTW includes

WAC 173-340-350, WAC-173-340-370, CERCLA §121, and the NCP [40 CFR 300.430 (a) (1) (iii)]. A summary of the PTW delineation is presented below.

In general, MTCA, CERCLA, and the NCP consider hazardous substances/PTW to be those source materials that are:

- Highly toxic or
- Highly mobile that generally cannot be reliably contained or
- Would present a significant risk to human health or the environment should exposure occur

MTCA, CERCLA, and the NCP establish an expectation that treatment will be used to address hazardous substances/PTW at a site wherever practicable. This is clearly stated in WAC 173-340-370(1) as follows:

"The department expects that treatment technologies will be emphasized at sites containing liquid wastes, areas contaminated with high concentrations of hazardous substances, highly mobile materials, and/or discrete areas of hazardous substances that lend themselves to treatment."

However, MTCA, CERCLA, and the NCP also acknowledge that hazardous substances/PTW may be contained rather than treated due to difficulties in treating the source material. Ecology's position is stated in Focus No. 94-130 as follows: "***Protecting Human Health and the Environment.*** *The cleanup action selected must either remove or destroy the contamination, restoring the site to cleanup levels, or contain the contamination in such a way that will minimize future exposure of humans and ecological receptors (plants and animals).*" (Ecology, 2013)

As stated in the preamble to the NCP (55 FR at 8703, March 8, 1990), there might be situations where PTW may be contained rather than treated due to difficulties in treating the wastes. Specific situations that might limit the use of treatment are summarized in USEPA (1991) as follows:

- Treatment technologies are not technically feasible or are not available within a reasonable timeframe.
- The extraordinary volume of materials or complexity of the site makes implementation of treatment technologies impracticable.
- Implementation of a treatment-based remedy would result in a greater overall risk to human health and the environment due to risks posed to workers or the surrounding community during implementation.
- Severe effects across environmental media resulting from implementation would occur.

The decision to treat or contain hazardous substances/PTW is made on a site-specific basis through the remedy selection process (USEPA, 1991 and WAC 173-340-360).

The DNAPL and caustic source material that could potentially be considered hazardous substances/PTW were identified following the guidance presented in MTCA, CERCLA, the NCP, and USEPA, 1991. All confirmed DNAPL source zones were considered to be PTW because of their toxic composition and the significant risk that could result should exposure occur. The distribution of potential DNAPL PTW is shown on Figures 3a and 3b in Appendix B. All unsaturated and saturated soil where the soil or groundwater pH was equal to or greater than 12.5 s.u. was considered PTW because they are considered to be characteristically hazardous for corrosivity in accordance with the Code of Federal Regulations (40 CFR 261.22). The areas of caustic-impacted soil that could be considered PTW are shown on Figure 8 in Appendix B.

As presented above, MTCA, CERCLA, and the NCP have an expectation for treatment of hazardous substance/PTW, wherever practicable. At this Site, the complete treatment of hazardous substance/PTW may be considered impracticable for the following reasons:

- Feasible treatment technologies are not available
- Very large volumes of hazardous substances/PTW
- Complex geologic and geochemical conditions
- Potential for increased risks during implementation of treatment

2.6 Contaminant Fate and Transport

Site investigations have confirmed that there are four primary groundwater plumes: the ADP, pH plume, CVOC, and metals. Other COC have not developed large, distinct groundwater plumes. This is likely due to a combination of factors, such as low mobility in groundwater, limited contaminant mass, and attenuation processes.

The primary groundwater plumes have migrated from the potential sources noted in Subsection 2.4.1 via several transport mechanisms that are summarized below.

Table 2.2 Primary Groundwater Plumes and Related Transport Mechanisms

COC Type	Transport Mechanism
ADP	• Density-dependent flow • Migration with groundwater
pH plume	• Density-dependent flow • Migration with groundwater
CVOC	• DNAPL migration • Migration with the ADP • Displacement by the ADP • Migration with groundwater • Volatilization to ambient air and/or indoor air
Metals	• Migration with the ADP • Migration with groundwater
SVOC	• Migration with groundwater
PCBs	• Migration with groundwater

Metals and PCBs have also migrated from potential sources at ground surface via surface water runoff.

2.6.1 Anthropogenic Density Plume (ADP)

Historical Site operations resulted in surface releases of high density fluids from the potential sources described previously (primarily the settling ponds/barge, Potential Caustic Source Area, and Salt Pad). Mixing of lime sludge/solvent residue, caustic soda (sodium hydroxide), and brine (sodium chloride) in groundwater has resulted in a comingled plume of high density that under current conditions consists of specific gravity values ranging to approximately 1.2 (density of 74.9 pounds per cubic foot [lbs/ft^3]). The ADP tends to sink due to its higher density relative to the density of fresh groundwater and salt water. A conceptual figure showing the ADP during the early period of Site operations is shown on Figure 2.12. The early time ADP is envisioned as being within the fill and upper portion of the deltaic deposits below the settling ponds/barge (WMU C, F, G, and H), Salt Pad, and Potential Caustic Source Area. The solvent residue, comprised of PCE and TCE, is the highest density material that was released, and thus the early time ADP is shown to extend somewhat deeper under the settling ponds/barge on Figure 2.12.

Over time, the ADP migrated away from the potential source areas via density-dependent (i.e., gravity-driven) flow. While migrating downwards, the higher density plume displaced the fresh groundwater and salt water initially present beneath the release locations. The fresh groundwater and salt water displacement caused by the downward density plume migration caused lateral groundwater flow that has contributed to the lateral spreading of the density plume, as well as the spreading of impacted groundwater surrounding or comingled with the density plume. This lateral spreading has resulted in a portion of the CVOC plume migrating eastward, beneath the Waterway, opposite the average groundwater flow directions currently observed. The lateral spreading of the CVOC plume caused by the early time ADP is illustrated on Figure 2.13. The primary CVOC found beneath the Waterway currently is VC, which is a biodegradation product of the initially-released PCE and TCE.

The ADP will spread laterally and migrated vertically until encountering lower permeability soil layers or counterbalancing hydraulic pressures, as follows:

- Lateral migration would continue until reaching equilibrium, or counterbalancing hydraulic pressures (i.e., opposing horizontal hydraulic gradients counterbalancing the lateral density-driven gradients), or until encountering a vertical low-permeability barrier, such as the buried valley wall along the Bluffs east of the Waterway. These factors prevented eastward migration of the ADP into the sediments beneath the Bluffs.
- Vertical migration would continue until reaching a combination of the upward vertical hydraulic gradients from the upper glacial deposits to lower deltaic deposits and the increased frequency of lower permeability lenses in the lower deltaic deposits (i.e., the zone of apparent confining effect). Upward vertical hydraulic gradients in the upper glacial deposits counterbalance the tendency of the dense water to sink, and the increased frequency of lower permeability lenses in the lower deltaic deposits limits the vertical rate of migration.

The distribution of the current ADP is shown on Figure 2.14. The ADP is centered beneath the settling ponds/barge and Salt Pad, with the southern portion of the ADP underlying the Potential Caustic Source Area. The ADP has remained relatively consistent since 2006 based on comparison with upland groundwater density data from 2012.

The highest densities of the ADP are well below the groundwater table, reflecting the fact that the major density sources ceased or were removed prior to Site investigations. The ADP has also spread laterally beneath the Waterway and to the north toward Commencement Bay. The vertical migration of the ADP is limited by the zone of apparent confining effect in the lower deltaic deposits and upward vertical hydraulic gradients within the upper glacial deposits. The ADP has migrated northward due to northward-directed hydraulic gradients. The northward ADP migration also appears to be influenced by a northwestward dipping trough in the glacial deposits observed beneath the northeastern portion of the Site peninsula. The zone of apparent confining effect in the lower deltaic deposits appears to follow the trough, and correspondingly the ADP above this. Once the density-driven gradients of the ADP dissipate, diffusion and groundwater advection were the predominant mechanisms for any further migration of the ADP, and COC comingled with the ADP.

2.6.2 pH Plume

Historical Site operations resulted in surface releases of high density/high pH caustic fluids from the Potential Caustic Source Area described in Subsection 2.4.1. The caustic fluids co-mingled with the brine released from the Salt Pad to form the ADP. Thus, the pH plume is largely coincident with the ADP plume. The distribution of the current pH plume is shown on Figure 2.15.

Interaction of historical caustic releases with the aquifer materials has resulted in the formation of hydroxide and silicate ions, primarily within the shallow fill material. These ions react with fresh precipitation infiltration to produce high pH groundwater. Thus, shallow soil that was impacted with caustic is a continuing source of elevated pH to groundwater.

The position and extents of the pH plume has remained relatively consistent since 2006.

2.6.3 Chlorinated Volatile Organic Compounds (CVOC)

The migration of CVOC occurs by several mechanisms:

- DNAPL migration
- Migration of dissolved-phase with the ADP
- Displacement migration at the perimeter of the ADP
- Migration of dissolved-phase with fresh groundwater
- Migration to ambient and indoor (potentially) air

DNAPL Migration

The distribution of DNAPL in the subsurface is shown on Figure 2.16. This figure shows the general distribution of the confirmed and potential DNAPL beneath the Site. DNAPL is observed beneath the former solvent production plant, WMU A, and WMU G. Historical DNAPL release rates and mass likely would have been highly variable, resulting in the separation between confirmed DNAPL at the upper and lower depths within the deltaic deposits shown on Figure 2.16. During vertical migration of the DNAPL, significant lateral migration has occurred, likely due to the DNAPL encountering low-permeability lenses within the deltaic deposits that increase in frequency in the lower portion of the deltaic deposits. DNAPL has also moved northwestward at depth consistent with the zone of apparent confining effect in the lower deltaic deposits following the trough in the glacial deposits. Given the significant timeframe since the initial releases occurred, the tortuous migration of the DNAPL through the heterogeneous deltaic deposits, and increased frequency of lower permeability lenses in the lower deltaic deposits, the current DNAPL distribution is likely stable.

Residual DNAPL will result in a continuing source of dissolved CVOC. Additionally, diffusion into lower permeability (i.e., silt and clay) lenses adjacent to DNAPL will accumulate CVOC mass. The silt and clay then act as secondary sources of aqueous contamination through back-diffusion once groundwater concentrations in higher permeability zones decline. The process of back-diffusion from lower permeability lenses into higher permeability zones, where the bulk of the active groundwater flow occurs, will significantly prolong groundwater remediation timeframes and might result in rebounding of concentrations after certain types of treatment.

Migration with the ADP and Displacement Migration at the Perimeter of the ADP

Figure 2.17 shows the current distribution of CVOC in groundwater at the Site. The CVOC potential sources were in close proximity to the Salt Pad, and as a result, dissolved CVOC have comingled and migrated with the ADP. As the ADP displaced fresh groundwater or salt water in the subsurface, comingled CVOC within the ADP were carried by the ADP as it migrated laterally and downward. In addition, CVOC already dissolved in groundwater at the periphery of the ADP would have been displaced laterally and vertically in advance of the ADP migration. The lateral ADP migration is a primary reason for the presence of CVOC beneath the Hylebos east of the Potential CVOC Source Area even though the average groundwater flow direction observed under current conditions is more north to northwest.

Migration in Groundwater

Dissolved-phase CVOC in groundwater outside the ADP will migrate with groundwater. This will lead to northward migration as the regional groundwater flow direction in the deltaic deposits is generally toward Commencement Bay, with groundwater discharge to the surrounding surface water bodies. This northward flow has resulted in a shallow component of CVOC plume at the northern end of the Site peninsula. This component of the CVOC plume occurs above the salt water/freshwater transition zone, as illustrated on Figure 2.17.

Migration of dissolved-phase CVOC in groundwater is attenuated by the following processes: adsorption; diffusion into low-permeability (i.e., silt and clay) lenses; and degradation.

Adsorption of CVOC onto soil particles depends on the amount of organic matter naturally present in soil and the relative affinity of individual hydrophobic compounds to adhere to organic matter. Adsorption results in the dissolved-phase CVOC plume migrating more slowly than the average groundwater flow velocity.

Diffusion of dissolved-phase CVOC into lower permeability (i.e., silt and clay) lenses also slows the rate of CVOC migration relative to the average groundwater flow velocity in higher permeability zones. The silt and clay then act as secondary sources of dissolved-phase contamination through back-diffusion once groundwater concentrations in higher permeability zones decline.

Degradation of the CVOC is occurring both biologically and abiotically. Biological degradation of PCE and TCE (parent compounds) has produced cis-1,2-dichloroethene (cis-1,2-DCE) and VC (daughter products) at the Site. The distribution of the parent and daughter products in groundwater is shown on figures in the approved CSM Report (CRA, 2014a). In general, the concentrations of PCE and TCE are highest near the surface sources and DNAPL source zones. The concentrations of daughter products are highest in the source zones and beyond the PCE and TCE plume. The presence of cis-1,2-DCE and VC, which are daughter products of the biological degradation of PCE and TCE, confirms that PCE and TCE biodegradation is occurring. Ethene has also been detected in groundwater samples, indicating that complete degradation of VC is occurring at least in some areas of the Site.

The abiotic degradation of PCE and TCE might also be occurring as suggested by the presence of dissolved acetylene in groundwater.

It does not appear that the high ionic strength of the salt water, ADP, and pH plume have a direct effect on CVOC migration because CVOC are non-polar molecules.

The concentrations of CVOC at the base of the Waterway are significantly lower than groundwater concentrations at depth. The shallow concentrations are attenuated because of flushing (dilution) with surface water, which is enhanced via tidal fluctuation. Also, within the salt water zone adjacent to the Waterway mudline, salt water recharges to the aquifer resulting in dilution of the salt water zone. These processes contribute to the presence of low to non-detectable CVOC concentrations near the mudline observed at some Waterway sample locations. In particular, this is expected to occur in areas that are not affected by the ADP where high density groundwater discharge can occur against the salt water equilibrium or in areas that are not affected by high water levels from the eastern Bluffs. Although along the center and eastern shores of the Hylebos, impacted groundwater was detected nearer the mudline. This was confirmed by the findings of the 2016 Anchor QEA porewater investigation, which found no exceedances of AWQC near the mudline in these areas (see Subsection 2.4.6).

Migration to Ambient and Indoor (Potentially) Air

VOC can volatilize from impacted shallow groundwater or from the impacted vadose zone soil. VOC in the vapor phase will then migrate by diffusive and advective mechanisms through the unsaturated soil and be emitted to ambient air and potentially indoor air of enclosed buildings.

Concentrations of PCE and TCE above sub-slab screening levels potentially related to the OCC Site were identified in vapor samples collected from immediately beneath the concrete slabs of the POT Building 595 and OCC Office (TCE only). However, exceedances of indoor air screening levels for PCE and TCE were not identified in POT Building 595 where the sub-slab vapor concentrations are adequately attenuated. Exceedances of an indoor air screening level for TCE were identified in the OCC Office; however, the occupancy of this building is being managed by OCC to mitigate potential exposure.

2.6.4 Metals

The migration of metals occurs by several mechanisms:

- Migration of dissolved metals with the ADP
- Migration of dissolved-phase with fresh groundwater
- Metals transport in surface water runoff

Migration with the ADP

As the ADP displaced fresh groundwater or salt water in the subsurface, comingled dissolved metals within the ADP were carried by the ADP as it migrated laterally and downward. In addition, metals already dissolved in groundwater at the periphery of the ADP would have been forced to migrate laterally and vertically in advance of the ADP migration.

Migration in Groundwater

Infiltrating groundwater that comes into contact with soil containing metals will dissolve some of the metals, carrying them to the water table and into groundwater. Once in groundwater, the metals are transported along with groundwater flow.

The metals concentrations and migration in groundwater are influenced by numerous mechanisms, the most important at the Site are:

- Sorption onto naturally-occurring ferric oxide coatings on aquifer soil particles. This sorption slows the transport of metals in groundwater.
- Suppression of sorption onto the ferric oxide coatings by the high pH of the water in the pH plume mobilizing metals (that would otherwise be adsorbed) and keeping the metals in solution longer.
- Enhancement of the solubility of some metals in soil (both naturally-occurring and anthropogenic) by the high pH of the water in the pH plume.
- Limitation of the sorption of metals due to ion-ion interactions associated with the high ionic strength of the ADP (i.e., competition for sorption sites) keeping the metals in solution.

Migration of metals in groundwater is highly dependent on the pH plume and the ADP. As groundwater pH decreases and the ADP dissipates, natural sorption processes would precipitate metals and reduce the concentrations of metals dissolved in groundwater.

Surface Water Runoff

Precipitation at the Site comes into contact with surficial soil and carries soil particles with the surface water runoff, especially during heavy rainfall events. The surface water at the Site is conveyed by overland flow and the storm sewer system to adjacent surface water bodies.

There has been a storm sewer monitoring program in place at the Site designed to determine if storm water discharge is within regulatory limits. The monitoring program has shown the Site to be in compliance with the Site Storm Water Pollution Plan and has not identified any significant impacts. Based on this fact, it is unlikely that future impacts will occur and this migration pathway is not considered significant. Storm water monitoring data were summarized and presented in the SCR (CRA, 2014c) approved on October 11, 2016 (Ecology, 2016b).

2.6.5 Semi-Volatile Organic Compounds (SVOC)

The migration of SVOC could potentially occur via several mechanisms:

- DNAPL migration
- Migration of dissolved phase with the ADP
- Migration of dissolved phase with fresh groundwater

DNAPL Migration

Because the SVOC were formed as by-products of the solvent manufacturing process, they are inferred to have been present in the DNAPL released to the subsurface at the Site. The SVOC would have then migrated downward along with the DNAPL as described in Subsection 5.6.2.5.1 of the SCR (CRA, 2014c) approved on October 11, 2016 (Ecology, 2016b). The presence of HCB and HCBD in deep soil samples is consistent with this hypothesis.

Migration with the ADP and in Groundwater

The most predominant Site SVOC (HCB and HCBD) tend to sorb strongly to the soil and have limited mobility in groundwater compared to the CVOC. Some dissolution will occur though, as will the sorption to suspended particles (i.e., colloids) in groundwater. However, the migration of the SVOC in the groundwater is, as expected, much more limited than CVOC. Detected concentrations above the Site screening levels tend to be near to the identified potential SVOC source areas described in Subsection 2.4.1.

2.6.6 Polychlorinated Biphenyls (PCBs) and Dioxins/Furans

PCBs and dioxins/furans sorb very strongly to soil particles and therefore migration in the groundwater is limited, although some sorption to colloids might occur, which could result in a limited enhancement of PCBs and dioxins/furans migration. Surface water runoff could also potentially carry suspended soil particles with PCBs or dioxins/furans, if present, into surface water bodies. However, there are very few locations where concentrations are above screening levels on the Site and the mobility of PCBs and dioxins/furans is considered to be very limited. This observation is consistent with the distribution of PCBs and dioxins/furans in groundwater, which indicated the detected concentrations tend to be near the identified potential source areas described in Subsection 2.4.1.

2.7 Exposure Pathway Assessment

An Exposure Pathway Assessment was conducted for the Site in accordance with Ecology and USEPA guidance. The assessment included a human health exposure pathway assessment (HHEPA) and an ecological health exposure pathway assessment (EHEPA). The purpose of the assessment was to identify media and locations that might need corrective action, risk-management measures, or further evaluation. The Exposure Pathway Assessment was presented in the approved SCR Report (CRA, 2014c) and is summarized below.

The transport of COC may lead to the exposure and uptake of COC by human and ecological receptors. Potentially complete human and ecological exposure pathways and receptors are shown schematically on Figure 2.18. These exposure pathways and receptors are summarized below and assume that the future land use of the Site remains industrial/commercial.

Human Receptors and Exposure Pathways

The primary human receptors and exposure pathways at the Site are summarized below.

Table 2.3 Primary Human Receptors and Exposure Pathways

Receptor	Exposure Pathway
Industrial/Commercial Worker	• Inhalation of indoor air impacted by VOC volatilizing from soil and shallow groundwater • Incidental ingestion and dermal contact with impacted surface soil • Incidental ingestion and dermal contact of sediments in the intertidal zone
Construction/Utility Worker	• Incidental ingestion and dermal contact with surface and subsurface soil • Incidental ingestion and dermal contact with impacted groundwater while conducting subsurface excavations that

Table 2.3 Primary Human Receptors and Exposure Pathways

Receptor	Exposure Pathway
	extend to the groundwater table • Inhalation of soil particulates and/or ambient air
Trespasser	• Incidental ingestion and dermal contact with impacted surface soil • Inhalation of soil particulates and/or ambient air • Incidental ingestion and dermal contact of sediments in the intertidal zone
Recreational User	• Incidental ingestion and dermal contact with surface water in the Waterway
Fisher	• Ingestion of fish tissue

The HHEPA identified the following media and exposure pathways that might require corrective action, risk-management measures, or further evaluation.

Table 2.4 Media and Exposure Pathways

Medium	Exposure Pathway
Soil	• Inhalation of indoor air impacted by VOC volatilizing from soil • Inhalation of ambient air impacted by VOC volatilizing from soil • direct contact with impacted surface soil
Groundwater	• Inhalation of indoor air impacted by VOC volatilizing from shallow groundwater • Inhalation of ambient air impacted by VOC volatilizing from shallow groundwater • Direct contact with shallow groundwater
Sediment	• Direct contact with impacted sediment

As noted above in Subsection 2.4.5, the 2016 Anchor QEA investigation surface sediment results determined that most CVOC were below detection and no reported concentrations exceeded the CB/NT site SQOs~~. Therefore, there are no unacceptable risks associated with sediment~~, which were developed in consideration of the MTCA SMS.

Ecological Receptors

Under the industrial/commercial use of the Site, only limited exposure of terrestrial ecological receptors is expected, primarily along the embankment of the Waterway. The primary ecological exposure pathway at the Site is associated with the potential for discharge of impacted groundwater to the biologically active zone of the Waterway and Commencement Bay. The terrestrial and aquatic ecological receptors and exposure pathways at the Site are summarized below.

Table 2.5 Primary Ecological Receptors and Exposure Pathways

Receptor	Exposure Pathway
Soil invertebrates and burrowing animals	• Direct contact and ingestion of soil • Impacted soil gas vapors
Benthic organisms in Sediment of Waterway and Commencement Bay	• Impacted sediment within the biologically active zone • Impacted groundwater discharge into the biologically active zone

Table 2.5 Primary Ecological Receptors and Exposure Pathways

Receptor	Exposure Pathway
Avian carnivore, piscivore, insectivore	- Dietary uptake of prey/food
Aquatic vegetation and invertebrates	- Exposure to impacted groundwater through root uptake and direct contact - Direct contact and ingestion of sediment
Forage and predator fish	- Dietary uptake of plants and small aquatic species

As noted above in Subsection 2.4.5, the 2016 Anchor QEA investigation surface sediment results determined that most CVOC were below detection and no reported concentrations exceeded the CB/NT site SQOs. ~~Therefore, there are no unacceptable risks associated with sediment.~~ As noted above in Subsection 2.4.6, the 2016 Anchor QEA investigation near-bottom surface water and near-surface porewater results showed that only one parameter VC, reported in one sample (adjacent to the northern end of the 605 Alexander Avenue property), had the potential to marginally exceed the associated screening criterion at the applicable point of compliance. ~~Therefore, there are no unacceptable risks associated with the porewater, which represents ecological exposure pathways at the Site related to the potential for discharge of impacted groundwater to the Waterway~~Based on the fact that the remedy for the Site will include containment, it is unlikely that future impacts will occur. Some future monitoring of COC concentrations in sediment and porewater may be appropriate to ensure that existing conditions of sediment and porewater quality do not change over time, however unlikely this may be.

3. Identify Remedial Action Goals (RAGs) and Potential Applicable Local, State, and Federal Laws

This section presents the RAGs and potential applicable local, state, and federal laws and relevant and appropriate requirements identified for the Site.

3.1 Remedial Action Goals (RAGs)

In accordance with MTCA, CERCLA, and the NCP, the development of RAGs is required before the screening of remedial technologies and process options can be completed. The RAGs provide the basis for developing cleanup options that will be protective of human health and the environment. RAGs consist of medium-specific or operable-unit-specific goals expected to be achieved by the cleanup. They are protective of human health and the environment and are based on the COC, and potential receptors and exposure pathways.

Media of concern are defined as those media in which chemicals exceed their respective cleanup or screening levels. The extensive Site characterization data have shown that the media of concern at the Site include soil (unsaturated and saturated), groundwater, sediment, and indoor air. A listing of all chemicals that exceeded screening levels in the media of concern is presented in Table 2.1. Examination of this table shows that types of chemicals that exceed cleanup or screening levels include VOC, SVOC, pesticides, PCBs, dioxins/furans, metals, and pH.

RAGs were previously developed and agreed to among OCC and the Agencies for groundwater, surface water, and sediment. These RAGs were originally presented in the SOW (CRA, 2005). The 2005 RAGs were re-visited based on the current Site characterization and determination that future use of groundwater is non-potable. The media-specific RAGs for the Site developed cooperatively with the Agencies based upon evaluations of site-specific risk accomplished by OCC and by the Agencies working with a contractor (Ridolfi Environmental), and are presented in the table below:

Table 3.1 Remedial Action Goals (RAGs)

Environmental Medium	Remedial Action Goals (RAGs)
Groundwater	1. Prevent discharge of contaminated groundwater to Hylebos Waterway and Commencement Bay resulting in surface water contaminant concentrations exceeding Ambient Water Quality Criteria (AWQC) and applicable health based standards for aquatic life and human consumption of resident fish and shellfish. 2. Prevent discharge of contaminated groundwater to sediments in the Hylebos Waterway and Commencement Bay at concentrations that will re-contaminate the sediments above sediment quality standards for Site contaminants and applicable health based standards for aquatic life and human consumption of resident fish. 3. Prevent use of aquifer groundwater for drinking water, irrigation, or industrial purposes which would result in unacceptable risks to human health. 4. Prevent further migration of the contaminant plume and high pH plume to prevent the spread of contaminated groundwater to the Hylebos Waterway, Commencement Bay, and non-impacted portions of the aquifer.
Surface Water	1. Prevent marine ecological receptors from contacting surface waters that have contaminant concentrations that exceed surface water cleanup levels. 2. Prevent migration of hazardous substances, pollutants, or contaminants to the surface waters at concentrations that exceed surface water cleanup levels. 3. Control bioaccumulation exposures to human receptors associated with releases to surface water from the Site.
Sediment	1. Reduce to protective levels risks to benthic invertebrates and other biota from exposure to contaminated sediments and debris. 2. Reduce risks from direct contact (skin contact and incidental ingestion) to contaminated sediments and debris to protect human health.
Soil	1. Prevent human health risks associated with direct contact, ingestion, or inhalation of shallow soil contaminated above levels for industrial use. 2. Prevent terrestrial ecological receptors from contacting soils

Table 3.1 Remedial Action Goals (RAGs)

Environmental Medium	Remedial Action Goals (RAGs)
	that have contaminant concentrations that exceed industrial soil cleanup levels. 3. Prevent migration of hazardous substances, pollutants, or contaminants from soil to the surface waters at concentrations that exceed surface water cleanup levels.
Indoor air	1. Prevent human exposure to hazardous substances, pollutants, or contaminants from subsurface soil vapor at concentrations in excess of applicable standards and risk-based cleanup levels.

3.2 General Response Actions (GRAs)

GRAs are those actions that, singly or in combination, satisfy the RAGs for each medium of concern. GRAs may include treatment, containment, excavation, extraction, disposal, institutional actions, or a combination of these.

GRAs are applied to the media of concern. As a result, the estimates of the areas or volumes of media to which treatment might be applied were calculated. The areas and volumes are summarized below (not including indoor air, for which an area/volume could not be calculated and sediment, for which the area and volume is zero (0) since reducing risk is not required based on the 2016 Anchor QEA investigation).

Unsaturated Soil

The Exposure Pathway Assessment, presented in the SCR (CRA, 2014c), approved on October 11, 2016 (Ecology, 2016b), and summarized herein and in the approved CSM Report (CRA, 2014a), has shown that potential human exposure to COC in soil may result in unacceptable exposures. The potentially complete pathways that might result in unacceptable exposures were inhalation of indoor air and/or ambient air, and direct contact. The combined total area of the unsaturated impacted soil is approximately 149,000 square yards (yd^2) (CRA, 2014b). Assuming an average depth to water table of 7.5 ft, the estimated volume of impacted unsaturated soil is approximately 372,500 cubic yards (yd^3).

DNAPL

The mass of confirmed DNAPL was estimated using the mass of total chlorinated volatile organic compounds (TCVOC) in soil/porous media. The mass was calculated using the Mining Visualization System/Environmental Visualization System (MVS/EVS) software package, developed by C Tech Development Corporation (C Tech) (C Tech, 2007) model for the Site (as described in the CRA Technical Memorandum – Revised DNAPL Mass Estimates dated November 11, 2014 presented in Appendix C). A threshold soil TCVOC concentration of 100 milligrams per kilogram (mg/kg) was used to define the maximum extent of DNAPL. The ~~mass of~~total TCVOC mass at the Site was determined to be approximately 780,000 ~~pounds~~lbs as presented in Appendix C.

Groundwater

The groundwater plumes with the greatest distribution are the CVOC plume, ADP, and pH plume. The volume of these three plumes (porous media + water volume) was estimated using the MVS/EVS models for these plumes. In the case of the CVOC plume, the volume at a concentration greater than or equal to 2.4 micrograms per liter (μg/L) was estimated. This was based on the SSL for VC. The pH plume volume was determined at pH value greater than or equal to 8.5 s.u., based on the SSL. The ADP volume was estimated at a density greater than or equal to 64 lbs/ft^3 (specific gravity of 1.026). This value was selected because at this density the groundwater is clearly affected by anthropogenic activities.

The total plume volume was then used to estimate the volume of impacted groundwater within each plume by assuming a porosity of 0.43. The estimated plume and impacted water volumes are summarized in the following table.

Table 3.2 Estimated Plume and Impacted Water Volumes

Plume	Total Plume Volume (yd^3)	Impacted Water Volume (yd^3)
CVOC	7,852,223	3,376,456
ADP	2,962,518	1,273,883
pH	13,169,259	5,662,781

Site-specific GRAs were developed for each medium of concern to satisfy the RAGs. The GRAs and corresponding RAGs (from Subsection 3.1) are presented in Table 3.3.

3.3 Identification of Potential Applicable Local, State, and Federal Laws

WAC 173-340-710 discusses requirements for identifying applicable local, state, and federal laws. The requirements in WAC 173-340-710 "*…are similar to the ARAR (applicable, relevant, and appropriate requirements) approach of the federal superfund law. Sites that are cleaned up under an order or decree may be exempt from obtaining a permit under certain laws but they must still meet the substantive requirements of these laws. (See WAC 173-340-710(9).)*"
[(WAC 173-340-700(6)(a)].

In accordance with WAC 173-340-710(2), this section identifies potential applicable local, state, and federal laws that may be considered legally applicable or relevant and appropriate requirements for the Site. "*The department shall make the final interpretation on whether these requirements have been correctly identified and are legally applicable or relevant and appropriate.*"
[WAC 173-340-710(2)].

"*Legally applicable requirements include those cleanup standards, standards of control, and other environmental protection requirements, criteria, or limitations adopted under state or federal law that specifically address a hazardous substance, cleanup action, location or other circumstances at the site.*" [WAC 173-340-710(3)].

"*Relevant and appropriate requirements include those cleanup standards, standards of control, and other environmental requirements, criteria, or limitations established under state or federal law that, while not legally applicable to the hazardous substance, cleanup action, location, or other* *circumstance at a site, address problems or situations sufficiently similar to those encountered at the site that their use is well suited to the particular site.*" [WAC 173-340-710(4)].

Table 3.4 presents the potential applicable local, state, and federal laws and relevant and appropriate requirements identified for the Site.

4. Identify Alternatives

4.1 Alternatives Development

The Draft ERT Report (CRA, 2014b) presented the identification and screening of remedial technologies and process options to address impacts at the Site. The purpose of that evaluation was to identify appropriate remedial technologies and representative process options that could be used to assemble remedial alternatives for further evaluation in an FS report. The Agencies selected the remedial technologies and representative process options to be retained based on the evaluation presented in the Draft ERT Report (CRA, 2014b) and other sources.

The initial remedial technologies and representative process options that were retained for the development of remedial alternatives were presented in the 2015 Draft FS report. Following Agency review of the 2015 Draft FS report, Ecology provided the Agencies' comments on January 5, 2016. Based on these comments and subsequent discussions among the Agencies and OCC's team, a revised list of remedial technologies and representative process options was developed that included three groups of alternatives. The groups include containment alternatives, VOC mass removal/reduction alternatives, and pH (>12.5 s.u.) reduction/enhanced containment alternatives. Along with the three groups of alternatives, there are Common Elements that will be included in the final selected cleanup action, namely, Institutional Controls (ICs) and monitoring.

The following Subsection 4.2 describes the Common Elements of ICs and monitoring included in all remedial alternatives. Subsection 4.3 describes the Containment Alternatives. Subsection 4.4 describes the VOC Mass Removal/Reduction Alternatives. Subsection 4.5 presents the pH Reduction/Enhanced Containment Alternatives. Consistent with the 2015 Draft FS report, the subsurface was divided into two zones namely: the shallow zone that is defined from ground surface to -60 ft National Geodetic Vertical Datum (NGVD); and the deep zone that is defined as below -60 ft NGVD. The shallow zone corresponds to the approximate base of the Waterway and the deep zone is below the Waterway.

4.2 Common Elements to the Remedial Alternatives

The following elements are common to all remedial alternatives in accordance with WAC 183-340-350(8)(c)(i)(C), except No Action ~~containment alternatives~~alternative:

- Institutional Controls (ICs)
- Groundwater Quality Monitoring
- Soil Vapor Monitoring

4.2.1 Institutional Controls

All remedial alternatives, except No Action ~~containment alternatives~~alternative, will incorporate ICs. ICs are measures undertaken to limit or prohibit activities that interfere with the integrity of a remedy or that might result in exposure to hazardous substances at a site. In most cases, ICs are recorded as part of the property deed to warn future property owners of the condition and to restrict activities or use of the property that could result in exposure to hazardous substances. Tenants must also be notified of the restrictions in any lease agreement.

The circumstances where institutional controls are required as part of a cleanup action include the following (WAC 173-340-440):

- Sites where contamination remains at concentrations that exceed the established cleanup levels.
- Sites where cleanup levels are established representing concentrations that are protective of human health and the environment for specified site uses and conditions.
- Sites where cleanup levels are established based on industrial land use (soil) or a site-specific risk assessment (groundwater).
- Sites where a conditional point of compliance is used.
- Any time an institutional control is required under WAC 173-340-7490 through 173-340-7494 (ecological concerns).
- Where the department determines such controls are required to assure the continued protection of human health and the environment or the integrity of the interim or cleanup action.

Types of ICs include:

- Proprietary controls: easements that restrict use (negative easements) and restrictive covenants.
- Governmental controls: zoning; building codes; state, tribal, or local groundwater use regulations; and commercial fishing bans and sports/recreational fishing limits posed by federal, state, and/or local resources and/or public health agencies.
- Enforcement and permit tools with IC components: administrative orders, permits, Federal Facility Agreements (FFAs), and Consent Decrees (CDs), that limit certain site activities or require the performance of specific activities (e.g., monitor and report on IC effectiveness).
- Informational devices: state registries of contaminated sites, notices in deeds, tracking systems, and fish/shellfish consumption advisories.

ICs for the Site may include:

- Physical barrier to control access to the site (e.g., constructed and routinely maintained fence).
- Use restrictions such as limitations on the use of property or resources.
- Maintenance requirements for engineered controls such as the inspection and repair of perimeter physical barrier, monitoring wells, treatment systems, caps (direct contact barriers), or groundwater barrier systems.
- Educational programs such as signs, postings, public notices, health advisories, mailings, and similar measures that educate the public and/or employees about site contamination and ways to limit exposure.
- Financial assurances.

- Administrative Order used as legal tool that limit certain site activities or require the performance of specific activities (e.g., monitor and report on effectiveness of ICs).
- A Washington Industrial Safety and Health Act and United States Occupational Safety and Health Administration (WISHA/OSHA) compliant worker health, safety and training program to address current and future health and safety issues related to indoor air in the existing OCC Property buildings.
- No future buildings with and without basements or crawlspaces unless engineered to prevent vapor intrusion (e.g., vapor intrusion barriers or other active engineering controls [pressurized buildings or depressurized sub-slab systems] and monitoring).
- Groundwater use restrictions recorded under the deed except when used as part of remedy.
- No excavation or below grade construction without appropriate worker health and safety plans and training as detailed in a Soil and Groundwater Management Plan.
- No excavation or below grade construction without the proper handling, characterization, and disposal of the excavated soil/materials as detailed in a Soil and Groundwater Management Plan.
- Relocation and reuse of soil consistent with the corrective measures and a Soil and Groundwater Management Plan.

Where ICs are required, Agencies will conduct a review of the site every five years to ensure the continued protection of human health and the environment.

4.2.2 Groundwater Quality Monitoring

The purpose of a groundwater quality monitoring program is to verify that plumes are not migrating to non-impacted areas and to verify reduction in overall contaminant concentrations in groundwater over time. WAC 173-340-410(1)(a) states that Protection Monitoring is to "*confirm that human health and the environment are adequately protected during construction and the operation and maintenance period of an interim action or cleanup action as described in the safety and health plan.*" Groundwater quality monitoring will be part of the protection monitoring to ensure the remedy is performing as intended.

A groundwater quality sampling and analysis plan will be developed and submitted to the Agencies with the operation and maintenance plan (WAC 173-340-400) for review and approval during the implementation of the cleanup action. The plan will specify the groundwater samples to be collected, the handling of the samples, and the analysis procedures to be performed per WAC 173-340-820.

4.2.3 Soil Vapor Monitoring

The purpose of a soil vapor monitoring program is to monitor VOC in subsurface soil to determine if concentrations are increasing, decreasing, or remaining constant over time. ~~Increasing concentrations over time might indicate vapor migration from soil and/or groundwater that could affect indoor air concentrations negatively (i.e., higher indoor air concentrations), which might require reassessment of potential mitigation for a building. Decreasing or constant concentrations over time would indicate that reassessment is unnecessary.~~ Soil vapor monitoring will be part of the protection monitoring to ensure the remedy is performing as intended.

A soil vapor sampling and analysis plan will be developed and submitted to the Agencies with the operation and maintenance plan (WAC 173-340-400) for review and approval during the implementation of the cleanup action. The plan will specify the soil vapor samples to be collected, the handling of the samples, and the analysis procedures to be performed per WAC 173-340-820.

4.3 Containment Alternatives

Containment alternatives were determined based on the 2015 Draft FS report and Agencies' review of and comments on that report. More specifically, they are based on the Upland Remedial Alternative#2 (URA#2) presented in the 2015 Draft FS with variations in the proposed groundwater extraction rates. The four containment alternatives include:

1. No Action.
2. C100: Physical direct contact exposure (PDCE) barrier for 605 & 709 Alexander Avenue Properties, sheet pile vertical barrier wall adjacent to Hylebos, hydraulic containment based on URA#2 estimated groundwater pumping rates, and the Common Elements in Subsection 4.2.
3. C150: PDCE barrier for 605 & 709 Alexander Avenue Properties, sheet pile vertical barrier wall adjacent to Hylebos, hydraulic containment based on up to 50 percent greater estimated pumping rates compared to C100, and the Common Elements in Subsection 4.2.
4. C200: PDCE barrier for 605 & 709 Alexander Avenue Properties, sheet pile vertical barrier wall adjacent to Hylebos, hydraulic containment based on up to 100 percent greater estimated pumping rates compared to C100, and the Common Elements in Subsection 4.2.

The following subsections describe the four containment alternatives; designated as No Action, C100, C150, and C200, selected for inclusion in this FS Report, which are listed in Table 4.1 along with other grouped alternatives.

4.3.1 No Action ~~Containment~~ Alternative

Under the No Action alternative, the Site would remain in its present condition with no remedial action performed. This alternative is required by CERCLA and the NCP and is the baseline alternative against which the effectiveness of the other alternatives is compared. This alternative does not include the implementation of any ICs, such as deed restrictions, or future groundwater and soil vapor monitoring. It was also assumed that the current groundwater extraction and treatment system (GWETS) would not be operated.

4.3.2 Containment Alternative C100

Containment Alternative C100 was designed to eliminate, reduce, or otherwise control risks posed through potentially complete exposure pathways and migration routes, and includes the following elements:

- Common Elements (ICs and monitoring) described in Subsection 4.2
- PDCE Barrier for 605 & 709 Alexander Avenue Properties, Navy Todd Dump, N Landfill, and 709 Embankment Fill Area (See Figure 2.9)
- Sheet pile vertical barrier wall adjacent to the Hylebos
- Hydraulic containment through a newly constructed GWETS

The C100 alternative layout is presented on Figure 4.1. Figure 4.1 includes contours for TCVOC concentrations of 0.1 mg/L and 10 mg/L, and pH of 10 s.u. and 12.5 s.u. Figure 4.2a presents north/south and east/west cross-sections showing the TCVOC plume developed from the MVS/EVS that includes the above concentrations and others. Figure 4.2b presents north/south and east/west cross-sections showing the pH plume developed from the MVS/EVS that includes the above pH values and others. The cross-section locations are shown on Figure 4.1. As shown on Figure 4.1, the TCVOC concentrations greater than 10 mg/L are generally at the north end of the 605 Alexander Avenue property and further north and east, and pH greater than 12.5 s.u. are mostly within the east side of the 605 Alexander Avenue property. The cross-sections indicate that there are negligible areas where the TCVOC concentrations greater than 10 mg/L and pH greater than 12.5 s.u. are mixed. This was confirmed with the MVS/EVS used to develop plumes for the Site.

The Upland high pH, elevated VOC and DNAPL (refer to Appendices B, C, and D), and SVOC and metals (see Subsection 2.4) in shallow soil (down to -21 ft NGVD) are covered with a physical direct contact exposure (PDCE) barrier. The elevation -21 ft NGVD represents the depth in the shallow zone corresponding to highest TCVOC concentrations in soil (See Appendix D). The PDCE barrier would be placed over the area shown on Figure 4.1 to cover the contaminants. The primary purpose of the PDCE barrier is to isolate the contaminated soil from potential direct contact with human and ecological receptors and prevent the transport of contaminated soil to other portions of the Site. PDCE barriers can consist of a membrane liner, reinforced concrete, asphalt, clay soil, or a combination of these materials and are often used in combination with physical or hydraulic containment of groundwater. For estimating cost, it was assumed that the PDCE barrier would consist of asphalt and would cover approximately 34.5 acres.

The C100 alternative also includes a sheet pile vertical barrier wall placed along the eastern boundary of the Site as shown on Figure 4.1. Sheet pile technology was selected for the vertical barrier wall due to the greater implementability within a waterway, which will allow the vertical barrier to separate the upland portions of the Site from the Hylebos. Sheet pile technology has a long life expectancy in the order of 50 to 75 years, and could be repaired if necessary. The primary purpose of the vertical barrier wall is to eliminate the horizontal discharge from seeps and shallow groundwater with high pH to the Waterway. In addition, the vertical barrier wall would limit transient tidal effects on shallow groundwater levels, thereby resulting in less contaminant "flushing" in the vicinity of the embankment and more consistent performance of the groundwater extraction system in this area. The vertical barrier wall would also contain the contaminated embankment area, Navy Todd Dump, the N Landfill and the 709 Embankment Fill areas (See Figure 2.9). Additionally, approximately 25-30 percent of Area 5106 (see Figure 2.6) would be contained within (i.e., west of) the vertical barrier wall. The former intertidal zone on the upland side of the vertical barrier wall would be backfilled and covered by the PDCE barrier. The loss of intertidal zone would likely be offset by mitigation to comply with the Clean Water Act.

The proposed sheet pile vertical barrier wall alignment is shown on Figure 4.1. The vertical barrier wall would be approximately 2,200 ft long and approximately 70-75 ft deep. The vertical barrier wall would be installed with a top elevation of approximately 12 ft NGVD and a base elevation of approximately -61.25 ft NGVD, a few feet below the base of the Hylebos. The bottom elevation was selected to prevent potential direct horizontal discharge of shallow impacted groundwater to the Hylebos. A schematic cross-section along the embankment within the Area 5106 removal area is shown on Figure 4.3.

Impacts from ~~DNAPL,~~ shallow and deep DNAPL, TCVOC, and high pH ~~impacts,~~ would be contained through a GWETS in conjunction with the sheet pile vertical barrier wall. Extraction wells would be located to minimize mass discharge outside the containment area by controlling groundwater flow and contaminant migration, and to avoid pumping directly from areas of high pH (i.e., pH ≥10 s.u.). All extraction wells were modeled in upland areas where the groundwater pH was less than 10 s.u. Direct pumping from areas of high pH would be avoided in order to minimize/prevent: potential fouling of the GWETS; the need for treatment of high pH water; and disposal of additional solids associated with this high pH groundwater. Difficulties with GWETS fouling due to pumping high pH water at the Site have been well document during 22 years of operating the existing GWETS. Additionally, the numerous treatability studies that have been conducted for the Site have not determined a practical solution for overcoming the difficulties of direct pumping of groundwater from areas of high pH.

The extracted groundwater would be conveyed to an ex situ treatment system. The treatment plant would need to address groundwater with elevated VOC, as well as other chemistry. This alternative includes a network of ten new extraction wells and one existing inactive extraction well (EXT-9). The locations and depths of the proposed extraction wells were developed through a groundwater flow modeling optimization evaluation presented in Appendix E. The proposed extraction well layout and groundwater pumping rates are shown on Figure 4.1. Although some wells appear in plan view on the figure to be within higher pH, they are not because their depths (screen intervals) do not coincide with the groundwater with the high pH.

The ex situ treatment system would potentially include components such as building, controls, equalization tank, clarifier, filter press, filters, air stripper, thermal oxidizer, scrubber, pumps, and meters. A contingency for pH treatment has been included as per Agencies' request in the event that some high pH water is drawn into the system at some time in the future. The contingency is based on diluting up to 50 percent of the extracted groundwater with City of Tacoma potable water at a ratio of 1:1 prior to pH adjustment within the treatment system. The 50 percent value was selected because approximately half of the groundwater extraction would be from wells closer to the high pH areas. It is reasonable to assume that if the pH increased in a well, it would do so at a gradual rate since the pH would need to be drawn from areas of high pH through areas of lower pH towards the wells. Therefore, the quantity of dilution water required would increase gradually as well. The 1:1 ratio of groundwater to dilution water was selected as a reasonable estimate of the amount of dilution water that might be needed to minimize solids/silica gel formation based on the above and the pH pilot studies completed for the Site. Based on the pH pilot studies (CRA, 2011), dilution of the groundwater using potable water would limit the amount of solids/silica gel that might form if the pH is lowered rapidly by chemical treatment within the treatment plant. The groundwater with high pH is analogous to a super saturated solution of silica and the potable water adds some additional solute volume to keep the silica dissolved during treatment to reduce the pH. Salt water or groundwater with lower pH generally has higher dissolved solids and therefore would not likely provide the same solute volume as potable water.

GHD has confirmed with the City of Tacoma (email received on May 24, 2016 from Tacoma Water) that sufficient quantities of water are available at the Site (potentially up to approximately 150 gallons per minute [gpm]) for use as dilution water; however, the need for and best source of dilution water will be subject to examination and optimization during the design phase.

4.3.3 Containment Alternative C150

Containment Alternative C150 was designed to eliminate, reduce, or otherwise control risks posed through potentially complete exposure pathways and migration routes, and includes the same elements as Containment Alternative C100, but with a higher overall groundwater pumping rate. The purpose of a higher pumping rate is to evaluate the potential benefits of increasing overall drawdown on the degree and demonstrability of groundwater capture. The evaluation of the potential benefits is discussed in Section 5. The proposed extraction well layout is the same as the C100 alternative and is shown on Figure 4.4, along with the extraction well pumping rates for Alternative C150.

The target groundwater pumping rates for the Containment Alternative C150 extraction wells were 50 percent higher than the pumping rates for Containment Alternative C100. If the groundwater flow model predicted that a 50 percent increased pumping rate could not be sustained in an individual extraction well, then the pumping rate in the affected extraction well was reduced until a sustainable rate was achieved in the groundwater flow model. The groundwater flow modeling presented in Appendix E showed that a combined groundwater pumping rate of approximately 226.25 gpm is achievable with the well network. This represents an overall pumping rate increase of approximately 44 percent compared to Containment Alternative C100. The ex situ treatment system would be similar to that described in Subsection 4.3.2, but sized for the combined modeled flow rate and dilution water for contingency pH treatment.

4.3.4 Containment Alternative C200

Containment Alternative C200 was designed to eliminate, reduce, or otherwise control risks posed through potentially complete exposure pathways and migration routes, and includes the same elements as Containment Alternatives C100 and C150, but with an even higher overall groundwater pumping rate. The purpose of a higher pumping rate is to evaluate the potential benefits of increasing overall drawdown on the degree and demonstrability of groundwater capture. The evaluation of the potential benefits is discussed in Section 5. The proposed extraction well layout is the same as the C100 alternative and is shown on Figure 4.5, along with the extraction well pumping rates for Alternative C200.

The target groundwater pumping rates for the Containment Alternative C200 extraction wells were 100 percent higher than the pumping rates presented for Containment Alternative C100. If the groundwater flow model predicted that a 100 percent increased pumping rate could not be sustained in an individual extraction well, then the pumping rate in the affected extraction well was reduced until a sustainable rate was achieved in the groundwater flow model. The groundwater flow modeling presented in Appendix E showed that a combined groundwater pumping rate of approximately 281.5 gpm is achievable with the well network. This represents an overall pumping rate increase of approximately 79 percent compared to Containment Alternative C100. The ex situ treatment system would be similar to that described in Subsection 4.3.2, but sized for the combined modeled flow rate and dilution water for contingency pH treatment.

4.4 VOC Mass Removal/Reduction Alternatives

VOC Mass Removal/Reduction Alternatives were determined based on the 2015 Draft FS report and Agencies' review of and comments on that report and subsequent discussions among the Agencies and OCC’s team. The alternatives are focused on evaluating selected potential technologies and process options for more immediately removing or reducing VOC concentrations in soil and/or groundwater. The ten VOC mass removal/reduction alternatives include:

~~1. No Action.~~

1. No Additional Action (i.e., only a containment alternative from Subsection 4.3 is implemented).
2. VOC source area mass reduction by groundwater extraction, which includes three variations of groundwater pumping rates referred to as M100, M150, and M200, and ex situ treatment.
3. VOC source area mass reduction by strategic groundwater pumping, which is referred to as mass reduction by strategic groundwater pumping (MSP), and ex situ treatment.
4. M3: VOC source area mass removal by shallow soil excavation and on-Site ex situ treatment and backfilling.
5. M4: VOC source area mass removal by shallow soil excavation and off-Site transport, ex situ treatment, and disposal.
6. M5: VOC source area mass reduction by shallow soil in situ treatment.
7. M6: VOC source area mass removal by shallow soil excavation and on-Site ex situ treatment and backfilling, and VOC source area mass reduction by shallow soil in situ treatment.
8. M7: VOC source area mass removal by shallow soil excavation and off-Site transport, ex situ treatment, and disposal, and VOC source area mass reduction by shallow soil in situ treatment.
9. M8: VOC mass reduction by shallow groundwater in-situ treatment and VOC source area mass reduction by shallow soil in situ treatment.
10. M9: VOC mass reduction by shallow and deep groundwater in-situ treatment and VOC source area mass reduction by shallow and deep soil in situ treatment.

The VOC targeted by the above alternatives include TCVOC mass in shallow (ground surface to -60 ft NGVD) and/or deep (-60 ft NGVD to the bottom of the impacted aquifer) zones within portions of the upland areas. The estimated total soil volumes and quantity of TCVOC mass in the shallow and deep target zones based on the estimated total DNAPL mass of 780,000 ~~pounds (~~lbs~~)~~ presented in Appendix C are shown on Figure 4.6 and summarized in the table below.

Table 4.2 Summary of Estimated Soil Volumes and Quantity of TCVOC Mass within Target Zones

Targeted Zone	Estimated Impacted Soil Volume (yd^3)	Estimated Quantity of TCVOC Mass (lbs)
Shallow	98,229	107,260
Deep	472,590	669,430
Not Targeted	16,230	3,310

Table 4.2 and Figure 4.6 also include the small portion that is not targeted.

The following subsections describe the ten VOC mass removal/reduction alternatives, including: No Additional Action; three sub-alternatives for groundwater extraction, designated as M100, M150, and M200; MSP; and M3 through M9 selected for inclusion in this FS Report, which are listed in Table 4.1 along with other grouped alternatives.

4.4.1 No Additional Action VOC Mass Removal/Reduction Alternative

Under the No Additional Action alternative, only a containment alternative (see Subsection 4.3) would be implemented with no additional remedial action performed. This VOC mass removal/reduction alternative~~ is required by CERCLA and the NCP and~~ is the baseline alternative against which the effectiveness of the other VOC mass removal/reduction alternatives is compared.

4.4.2 VOC Mass Reduction Alternatives M100, M150, and M200

4.4.2.1 VOC Mass Reduction Alternative M100

Mass Reduction Alternative M100 was designed to extract shallow and deep groundwater with high concentrations of VOC outside the areas of high pH (i.e., less than 10 s.u. as noted in Subsection 4.3.2). Direct pumping from areas of high pH would be avoided in order to minimize/prevent: potential fouling of the extraction and treatment system; the need for treatment of high pH water; and disposal of additional solids associated with this groundwater. The locations and depths of two proposed extraction wells, one shallow and one deep, were developed through a groundwater flow modeling optimization evaluation presented in Appendix E. The proposed extraction well layout and pumping rates for the M100 alternative are presented on Figure 4.7. The locations are the same that were proposed for the Upland Remedial Alternative#3 (URA#3) presented in the 2015 Draft FS report. The extracted groundwater would be conveyed to an ex situ treatment system. This would be the same system constructed for one of the containment alternatives described in Subsection 4.3.

Figure 4.7 depicts the layout of the Site and includes contours for TCVOC concentrations of 0.1 mg/L and 10 mg/L. Figure 4.7 also shows the target areas for all of the VOC ~~Mass~~mass removal/reduction alternatives that are further discussed in the following Subsections. Figure 4.8 presents north/south and east/west cross-sections showing the TCVOC plume developed from the MVS/EVS that includes the these concentrations and others, and identifies the approximate locations of the shallow and deep groundwater with high TCVOC dissolved concentrations targeted for extraction by the two proposed wells. The cross-section locations are shown on Figure 4.7. As shown on Figure 4.7 the TCVOC greater than 10 mg/L are generally at the north end of the 605 Alexander Avenue property and further north and east.

The groundwater flow modeling presented in Appendix E showed that the combined groundwater pumping rate of 35 gpm could be maintained by the two extraction wells. The rationale for this pumping rate is discussed in Appendix E. The evaluation of groundwater pumping for mass reduction is discussed in Section 6. The total mass ~~captured~~outside pH >10 s.u. removed over ~~100~~20 years was estimated by the model to be ~~99,037 lbs (dissolved) or 663,127~~275,132 lbs (dissolved, sorbed, and DNAPL phases), which represent ~~12.7 or 85~~35.3 percent~~, respectively,~~ of the estimated total DNAPL mass of 780,000 lbs presented in Appendix C**. Note that estimated mass removal rates were determined using the three-dimensional (3D) groundwater flow model that was specifically constructed and calibrated for the Site. The Site groundwater flow model provides a useful tool to evaluate the potential effectiveness of the groundwater mass reduction remedial alternatives that incorporate groundwater extraction.** It is noted that the model assumes idealized mass transport controlled by advection and equilibrium sorption and all mass is assumed to be either dissolved in the groundwater or sorbed onto the aquifer matrix.

Potential effects of non-aqueous phase liquids are not included. The potential effects of diffusion into low-permeability units or areas are not included. Additionally, the estimates do not include potential effects of high pH potentially reaching extraction wells, all contributing to the uncertainty of the mass estimates. However, the evaluation approach was applied consistently for all alternatives.

4.4.2.2 VOC Mass Reduction Alternative M150

Mass Reduction Alternative M150 includes the same elements as Mass Reduction Alternative M100, but with a higher overall groundwater pumping rate. The purpose this alternative is to evaluate the potential benefits of increasing the rate of VOC mass reduction and potentially total VOC mass reduction, noting that generally a higher overall pumping rate would result in higher overall costs. The evaluation of the potential benefits is discussed in Section 6. The proposed extraction well layout (same as M100) and extraction well pumping rates (higher than M100) are shown on Figure 4.9.

The target groundwater pumping rates for the Mass Reduction Alternative M150 extraction wells were 50 percent higher than the pumping rates presented for Mass Reduction Alternative M100. The groundwater flow modeling presented in Appendix E predicted that a 50 percent increased pumping rate could be sustained for both wells. The combined groundwater pumping rate for this alternative is approximately 52.5 gpm. The total mass ~~captured~~outside pH >10 s.u. removed over ~~100~~20 years was estimated by the model to be ~~116,755 lbs (dissolved) or 698,995~~285,394 lbs (dissolved, sorbed, and DNAPL phases), which represents ~~15 or 90~~36.6 percent~~, respectively,~~ of the estimated total DNAPL mass of 780,000 lbs presented in Appendix C.

4.4.2.3 VOC Mass Reduction Alternative M200

Mass Reduction Alternative M200 includes the same elements as Mass Reduction Alternatives M100 and M150, but with an even higher overall groundwater pumping rate to aid in evaluating the potential benefits of increasing the rate of VOC mass reduction and potentially total VOC mass reduction. The evaluation of the potential benefits is discussed in Section 6. The proposed extraction well layout (same as M100 and M150) and extraction well pumping rates (higher than M100 and M150) are shown on Figure 4.10.

The target groundwater pumping rates for the Mass Reduction Alternative M200 extraction wells were 100 percent higher than the pumping rates presented for Mass Reduction Alternative M100. The groundwater flow modeling presented in Appendix E predicted that a 100 percent increased pumping rate could be sustained for both wells. The combined groundwater pumping rate for this alternative is approximately 70 gpm. The total mass ~~captured~~outside pH >10 s.u. removed over ~~100~~20 years was estimated by the model to be ~~127,786 lbs (dissolved) or 719,904~~291,648 lbs (dissolved, sorbed, and DNAPL phases), which represents ~~16~~37.4~~ or 92~~ percent~~, respectively,~~ of the estimated total DNAPL mass of 780,000 lbs presented in Appendix C.

4.4.3 VOC Mass Reduction Alternative MSP (Mass Reduction by Strategic Groundwater Pumping)

Mass Reduction Alternative MSP was designed to extract shallow and deep groundwater within areas of high concentrations of VOC outside the areas of high pH (i.e., less than 10 s.u. as noted in Subsection 4.3.2) to achieve a higher initial rate of mass reduction than the Mass Reduction Alternatives M100, M150, and M200. For this alternative, a greater number of wells were strategically placed in areas of high VOC concentrations in both saturated soil and groundwater (i.e., near DNAPL source zones). The location of extraction wells near CVOC source zones can accelerate mass dissolution from DNAPL and thus expedite source area depletion. Strategic pumping can increase mass removal efficiency and decrease mass loading to groundwater (i.e., reduces dissolved phase contamination).

Similar to Mass Reduction Alternatives M100, M150, and M200, direct pumping from areas of high pH would be avoided in order to minimize/prevent: potential fouling of the extraction and treatment system; the need for treatment of high pH water; and disposal of additional solids associated with this groundwater. The locations and depths of the proposed extraction wells were developed through a groundwater flow modeling optimization evaluation presented in Appendix E. The proposed extraction well layout and pumping rates for the MSP alternative are presented on Figure 4.11. The extracted groundwater would be conveyed to an ex situ treatment system. The treatment system would be similar to the system constructed for the M150 or M200 containment alternatives described in Subsection 4.3.

Figure 11 depicts the layout of the Site and includes contours for TCVOC groundwater concentrations of 0.1 mg/L and 10 mg/L. Figure 11 also shows the target areas for all of the VOC ~~Mass~~mass removal/reduction alternatives that are discussed in the following Subsections. Figure 12 presents north/south and east/west cross-sections showing the TCVOC groundwater plume developed from the MVS/EVS, and identifies the approximate locations of the shallow and deep high TCVOC concentration areas. The cross-section locations are shown on Figure 11. As shown on Figure 11 the TCVOC concentrations greater than 10 mg/L in groundwater are generally at the north end of the 605 Alexander Avenue property and further north and east.

The groundwater flow modeling presented in Appendix E showed that the combined groundwater pumping rate of 210 gpm could be maintained by the extraction wells. The rationale for this pumping rate is discussed in Appendix E. The evaluation of groundwater pumping for mass reduction is discussed in Section 6. The total mass ~~captured~~outside pH >10 s.u. removed over ~~the initial 10~~20 years was estimated by the model to be ~~656,140~~323,883 lbs, which represents ~~84~~41.5 percent of the estimated total DNAPL mass of 780,000 lbs presented in Appendix C~~. This is greater than 30 percent more than the M100, M150, and M200 alternatives for which the model estimates percentages of 42, 48, and 52, respectively. The total mass captured over 100 years was estimated by the model to be 766,835 lbs, which represents 98 percent of the estimated total DNAPL mass and is greater than the M100 (85%), M150 (90%), and M200 (92%) alternatives~~.

4.4.4 VOC Mass Removal Alternative M3

Mass Removal Alternative M3 was designed to remove near-surface soil potentially containing DNAPL (PTW) that could be a future source of contamination in soil and groundwater. The M3 alternative includes the following elements:

- Excavation of shallow soil above -4 ft NGVD containing TCVOC concentrations greater than 100 mg/kg
- Removal of VOC from the excavated soil by on-Site treatment
- Backfill on Site of treated excavated soil

The TCVOC concentration of 100 mg/kg is representative of areas with confirmed or potential DNAPL as presented in Appendix C and is considered PTW as presented in Appendix B.

The M3 alternative layout is presented on Figure 4.13. Figure 4.13 shows the areas above -4 ft NGVD that have TCVOC concentrations greater than 100 mg/kg. Figure 4.14 presents north/south and east/west cross-sections showing the TCVOC plume developed from the MVS/EVS through some of these areas. The cross-section locations are shown on Figure 4.13. The mass of TCVOC within the volume of soil defined by the parameters above is approximately 23,200 lbs, which represents 3.0 percent of the estimated total DNAPL mass of 780,000 lbs presented in Appendix C. The vertical extent of the target zone is shown on Figure 4.14.

Soil above -4 ft NGVD that has TCVOC concentrations greater than 100 mg/kg would be excavated and consolidated into piles set up for treatment to reduce VOC concentrations. Excavated soil that is saturated would require dewatering/drying before treatment. The excess water from the piles would drain back into the excavations. Soil that has TCVOC concentrations less than 100 mg/kg overlying the soil targeted for on-Site treatment would be temporarily stockpiled separately for reuse. The on-Site treatment would involve ex situ soil vapor extraction (SVE) to remove VOC from the soil followed by treatment of the extracted vapors by a portable thermal oxidizer system and/or activated carbon. SVE is typically an in situ remedial technology that may be applied to stockpiles of excavated soil. There are various types of vapor extraction methods including vertical and horizontal pipes, gravel beds, and trenches. Synthetic membranes are often placed over the soil surface to prevent short-circuiting and to increase the radius of influence of the extraction pipes. Thermal oxidation would involve transferring extracted soil vapors through a vessel that uses thermal processes (e.g., exposure to flame) to oxidize VOC into innocuous compounds before being released to the atmosphere. Activated carbon treatment would involve transferring extracted soil vapors through filtrate vessels, which promote adsorption of VOC via contact with filter material.

Following completion of the SVE, the treated soil and soil suitable for reuse would be backfilled on the 605 Alexander Avenue property within and around the excavations and ultimately would be under a PDCE barrier (see Subsection 4.3.2). Excavations beyond the 605 Alexander Avenue property would be backfilled with soil suitable for reuse and/or imported clean material. The surfaces would be returned to the same or better conditions that were present prior to the excavation.

4.4.5 VOC Mass Removal Alternative M4

Mass Removal Alternative M4 includes the same excavation element as Mass Removal Alternative M3, but with off-Site transportation, treatment, and disposal of the excavated material containing TCVOC concentrations greater than 100 mg/kg. Figure 4.13 presents the layout and Figure 4.14 presents cross-sections related to the M4 alternative. The mass of TCVOC targeted for this alternative is the same as the M3 alternative described above in Subsection 4.4.4.

Soil above -4 ft NGVD that has TCVOC concentrations greater than 100 mg/kg would be excavated. Unsaturated soil would be consolidated directly into licensed trucks that would transport the material to an appropriate facility licensed to accept, treat, and dispose of the material. Saturated soil would be consolidated into temporary piles adjacent to the excavations to allow for some drying. The excess water from the piles would be permitted to drain back into the excavations. Once appropriate moisture content levels were achieved to allow proper transport, this soil would be consolidated into licensed trucks that would transport the material to an appropriate facility licensed to accept, treat, and dispose of the material. Soil that has TCVOC concentrations less than 100 mg/kg overlying the soil targeted for off-Site disposal would be temporarily stockpiled separately for reuse. Excavations would be backfilled with the soil suitable for reuse and imported clean material to replace the soil that was removed and transported off Site for treatment and disposal. The surfaces would be returned to the same or better conditions that were present prior to the excavation.

4.4.6 VOC Mass Reduction Alternative M5

Mass Reduction Alternative M5 was designed to further reduce, compared to the M3 and M4 alternatives, TCVOC concentrations in shallow soil potentially containing DNAPL (PTW) that could be a future source of contamination in soil and groundwater. The M5 alternative includes in situ treatment with the following elements:

- Treatment using in situ electrical resistance heating (ERH) of shallow saturated soil below 2.5 ft NGVD and above -21 ft NGVD containing TCVOC concentrations greater than 500 mg/kg.
- Treatment using in situ SVE of shallow unsaturated (vadose zone) soil above 2.5 ft NGVD containing TCVOC concentrations greater than 500 mg/kg.

The TCVOC concentration of 500 mg/kg represents the lower limit to identify areas with potential DNAPL for potential remediation based on a significantly declining benefit (i.e., diminishing returns) analysis presented in Appendix D. As shown in Appendix D, shallow soil down to -21 ft NGVD contains this potential DNAPL mass in the shallow zone. It is also considered PTW as presented in Appendix B.

The M5 alternative layout is presented on Figure 4.15. Figure 4.15 shows the areas above 2.5 ft NGVD and between 2.5 ft NGVD and above -21 ft NGVD that have TCVOC concentrations greater than 500 mg/kg. Figure 4.16 presents north/south and east/west cross-sections showing the TCVOC plume developed from the MVS/EVS through some of these areas. The cross-section locations are shown on Figure 4.15. The mass of TCVOC within the volume of soil defined by the parameters above is approximately 62,200 lbs, which represents 8.0 percent of the estimated total mass of DNAPL of 780,000 lbs presented in Appendix C. The vertical extent of the target zones are shown on Figure 4.16.

ERH is a thermal treatment technology that increases the temperature of the saturated zone and allows contaminants to be more easily volatilized, mobilized, and extracted from the subsurface. ERH involves the installation of electrodes in the ground and passing an alternating current through the electrodes, thereby heating the soil. Steam is generated when the subsurface temperature is raised to the boiling point of the saturated media. The steam strips the contaminants from the subsurface and enables extraction through liquid or vapor recovery wells.

SVE is an in situ remedial technology where a vacuum is applied through extraction wells located near the source of elevated chemical concentrations in the unsaturated soil zone. Volatile constituents of the chemical mass volatilize and the vapors are drawn toward the extraction wells thus reducing the concentrations of VOC sorbed to the soil in the vadose zone. The extracted vapors are then typically treated as necessary using thermal oxidation or activated carbon before being released to the atmosphere. Synthetic membranes are often placed over the soil surface to prevent short-circuiting and to increase the radius of influence of the extraction wells.

As shown on Figure 4.15, the area designated for treatment by SVE is within the area designated for treatment by ERH. Since SVE is necessary over the ERH treatment area to collect VOC migrating to the surface during the ERH process, the in situ ERH treatment (with in situ SVE) will cover the smaller area shown on Figure 4.15 designated for SVE treatment alone.

4.4.7 VOC Mass Removal/Reduction Alternative M6

Mass Removal/Reduction Alternative M6 was designed to remove near-surface impacted soil and to further reduce TCVOC concentrations in shallow soil potentially containing DNAPL (PTW) that could be a future source of contamination in soil and groundwater. The M6 alternative is a combination of the excavation and in situ ERH treatment elements from the M3 and M5 alternatives, respectively, and includes the following elements:

- Excavation of shallow soil above -4 ft NGVD containing TCVOC concentrations greater than 100 mg/kg.
- Removal of VOC from the excavated soil by on-Site treatment.
- Backfill on Site of treated excavated soil.
- Treatment using in situ ERH (with SVE) of shallow soil below -4 ft NGVD and above -21 ft NGVD containing TCVOC concentrations greater than 500 mg/kg.

The M6 alternative layout is presented on Figure 4.17, which shows the areas above -4 ft NGVD that have TCVOC concentrations greater than 100 mg/kg and between -4 ft NGVD and above -21 ft NGVD that have TCVOC concentrations greater than 500 mg/kg. Figure 4.18 presents north/south and east/west cross-sections showing the TCVOC plume developed from the MVS/EVS through some of these areas. The cross-section locations are shown on Figure 4.17. The mass of TCVOC within the volume of soil defined by the parameters above is approximately 66,200 lbs, which represents 8.5 percent of the estimated total mass of DNAPL of 780,000 lbs presented in Appendix C. The vertical extent of the target zones are shown on Figure 4.17.

Descriptions of excavation, on-Site treatment, and backfilling are provided in Subsection 4.4.4. Descriptions of ERH and SVE technologies are provided in Subsection 4.4.6 above.

4.4.8 VOC Mass Removal/Reduction Alternative M7

Mass Removal/Reduction Alternative M7 includes the same elements as Mass Removal/Reduction Alternative M6, but with off-Site transportation, treatment, and disposal of the excavated material containing TCVOC concentrations greater than 100 mg/kg. It is a combination of the excavation and in situ ERH treatment elements from the M4 and M5 alternatives, respectively. Figure 4.17 presents the layout and Figure 4.18 presents cross-sections related to the M7 alternative. The mass of TCVOC targeted for this alternative is the same as the M6 alternative described above in Subsection 4.4.7.

4.4.9 VOC Mass Removal/Reduction Alternative M8

Mass Reduction Alternative M8 was designed to further reduce TCVOC concentrations in shallow groundwater and in shallow soil potentially containing DNAPL (PTW) that could be a future source of contamination in soil and groundwater. The M8 alternative includes elements from the M5 alternative (ERH and SVE) plus elements for in situ treatment of shallow groundwater as follows:

- Treatment using in situ chemical oxidation (ISCO) of shallow groundwater above -60 ft NGVD containing TCVOC concentrations greater than 10 mg/L within the zone where pH is between 10 s.u. and 12.5 s.u.

- Treatment using enhanced in situ bioremediation (ISB) of shallow groundwater above -60 ft NGVD containing TCVOC concentrations greater than 10 mg/L within the zone where pH is less than 10 s.u.

The TCVOC concentration of 10 mg/L was selected because in situ groundwater treatment is usually applied to concentrated source areas and not to widely-dispersed, low-concentration plumes.

The M8 alternative layout is presented on Figure 4.19. Figure 4.19 shows the areas above 2.5 ft NGVD and between 2.5 ft NGVD and above -21 ft NGVD that have TCVOC concentrations greater than 500 mg/kg. It also shows areas above -60 ft NGVD that have TCVOC concentrations greater than 10 mg/L within the zones where pH is between 10 s.u. and 12.5 s.u. and less than 10 s.u. Figure 4.20 presents north/south and east/west cross-sections showing the TCVOC plume developed from the MVS/EVS through some of these areas. The cross-section locations are shown on Figure 4.19.

The mass of TCVOC within the volume of soil defined by the parameters above is the same as the M5 alternative (approximately 62,200 lbs, which represents 8.0 percent of the estimated total mass of DNAPL of 780,000 lbs presented in Appendix C). The vertical extent of the target zone is shown on Figure 4.20. Descriptions of ERH and SVE technologies are provided in Subsection 4.4.6 above.

The mass of TCVOC within the volume of shallow groundwater defined by the parameters above is approximately 19,400 lbs, which represents 12.4 percent of the estimated total mass of TCVOC in groundwater of 156,960 lbs.

The total mass of TCVOC within the volume of soil and groundwater defined above represents 10.5 percent of the estimated total DNAPL mass of 780,000 lbs presented in Appendix C.

ISCO by injection would be used to introduce chemical oxidant into groundwater to react with and destroy organic contaminants. Multiple injections of the oxidant are usually required and for this site would be completed using installed wells because of the depth of the target zone. Alkaline persulfate would be used as the oxidant because it would take advantage of the synergistic effects of the elevated pH in groundwater between 10 s.u. and 12.5 s.u. to activate the alkaline persulfate. This technology is non-selective meaning that other organic material present in the target zone would be oxidized along with the targeted organic material. Therefore, overdosing would be required to effectively treat the groundwater. ISCO was successfully demonstrated to reduce contaminants to carbon dioxide (CO_2) and water at small sites in permeable material (McGuire et al., 2013, 2014).

ISB by injection in wells would be used to establish vertical "curtains" of biological activity where impacted groundwater would flow through treating (degrading) VOC. Multiple injections of the substrate (emulsified vegetable oil), *Dehalococoides* spp. (DHC) and enhancements are usually required to maintain suitable conditions for biological activity. Additionally, an electron donor would be released into groundwater and would be transported downgradient of each "curtain." The electron donor would promote further contaminant biodegradation in the aquifer. The target zone for this technology would be within areas of pH that are less than 10 s.u., since it is not effective in higher pH.

4.4.10 VOC Mass Removal/Reduction Alternative M9

Mass Reduction Alternative M9 was designed to further reduce TCVOC concentrations in shallow and deep groundwater and in shallow and deep soil potentially containing DNAPL (PTW) that could be a future source of contamination in soil and groundwater. The M9 alternative includes elements from the M8 alternative plus elements for in situ treatment of deep groundwater and soil as follows:

- Treatment using ISCO of deep soil below -60 ft NGVD containing TCVOC concentrations greater than 500 mg/kg within the zone where pH is between 10 s.u. and 12.5 s.u.
- Treatment using ISB of deep soil below -60 ft NGVD containing TCVOC concentrations greater than 500 mg/kg within the zone where pH is less than 10 s.u.
- Treatment using ISCO of deep groundwater below -60 ft NGVD containing TCVOC concentrations greater than 10 mg/L within the zone where pH is between 10 s.u. and 12.5 s.u.
- Treatment using ISB of deep groundwater below -60 ft NGVD containing TCVOC concentrations greater than 10 mg/L within the zone where pH is less than 10 s.u.

The M9 alternative layout is presented on Figure 4.21. Figure 4.21 shows the areas above 2.5 ft NGVD, between 2.5 ft NGVD and above -21 ft NGVD, and below -60 ft NGVD that have TCVOC concentrations greater than 500 mg/kg. It also shows areas that have TCVOC concentrations greater than 10 mg/L within the zones where pH is between 10 s.u. and 12.5 s.u. and less than 10 s.u through the full depth of the Site. Figure 4.22 presents north/south and east/west cross-sections showing the TCVOC plume developed from the MVS/EVS through some of these areas. The cross-section locations are shown on Figure 4.21.

The mass of TCVOC within the volume of soil defined by the parameters above is approximately 525,800 lbs, which represents 67.4 percent of the estimated total mass of DNAPL of 780,000 lbs presented in Appendix C. The vertical extent of the target zones are shown on Figure 4.22.

The mass of TCVOC within the volume of ~~shallow~~ groundwater defined by the parameters above is approximately 87,500 lbs, which represents 55.7 percent of the estimated total mass of TCVOC in groundwater of 156,960 lbs.

The total mass of TCVOC within the volume of soil and groundwater defined above represents 78.6 percent of the estimated total DNAPL mass of 780,000 lbs presented in Appendix C

Descriptions of the technologies are provided in Subsections 4.4.6 and 4.4.9.

4.5 pH Reduction/Enhanced Containment Alternatives

The pH Reduction/Enhanced Containment Alternatives were determined based on the 2015 Draft FS report and Agencies' review of and comments on that report. The alternatives are focused on evaluating selected potential technologies and process options for reducing or enhancing containment of pH in soil and groundwater. The seven reduction/enhanced containment alternatives include:

~~1. No Action~~

1. No Additional Action (i.e., only a containment alternative from Subsection 4.3 is implemented).
2. pH2: pH >12.5 s.u. reduction by shallow soil and groundwater in situ treatment.

3. pH3: pH >12.5 s.u. enhanced containment by shallow soil and groundwater in situ treatment.
4. pH4: pH >12.5 s.u. enhanced containment of shallow soil and groundwater by vertical barrier.
5. pH5: pH >12.5 s.u. reduction by shallow and deep soil and groundwater in situ treatment.
6. pH6: pH >12.5 s.u. enhanced containment by shallow and deep soil and groundwater in situ treatment.
7. pH7: pH >12.5 s.u. enhanced containment of shallow and deep soil and groundwater by vertical barrier.

The pH targeted by the above alternatives includes pH in shallow (ground surface to -60 ft NGVD) and/or deep (-60 ft NGVD to the bottom of the impacted aquifer) zones within portions of the upland areas. The estimated total soil volumes and quantity of pH >12.5 s.u. (quantified as acid-neutralizing capacity [ANC] as presented in Appendix F) in the shallow and deep target zones based on the estimated total ANC of 200 Megaequivalents (Meq) acid presented in Appendix F are shown on Figure 4.23 and summarized in the table below.

Table 4.3 Summary of Estimated Soil Volumes and Quantity of pH within Target Zones

Targeted Zone	Estimated Impacted Soil Volume (yd^3)	Estimated Quantity of pH (ANC) (Meq acid)
Shallow	78,068	91
Deep	85,690	97
Not Targeted	10,560	12

Table 4.3 and Figure 4.23 also include the small portion that is not targeted.

The following subsections describe the seven reduction/enhanced containment pH alternatives designated as No Additional Action and pH2 through pH7 selected for inclusion in this FS Report, which are listed in Table 4.1 along with other grouped alternatives.

4.5.1 No Additional Action pH Reduction/Enhanced Containment Alternative

Under the No Additional Action alternative, only a containment alternative (see Subsection 4.3) would be implemented with no additional remedial action performed. This pH reduction/enhanced containment alternative ~~is required by CERCLA and the NCP and~~ is the baseline alternative against which the effectiveness of the other pH reduction/enhanced containment alternatives is compared.

4.5.2 pH Reduction Alternative pH2

The pH Reduction Alternative pH2 was designed to reduce, by in situ treatment, pH >12.5 s.u. (i.e., PTW) in shallow soil and groundwater that could be a future source of contamination in soil and groundwater. The pH2 alternative includes the following elements:

- Treatment using in situ mixing of sodium persulfate with shallow soil and groundwater above -60 ft NGVD containing pH greater than 12.5 s.u.

The 12.5 s.u. target treatment level was selected because material with pH greater than 12.5 s.u. would be characteristically hazardous for corrosivity in accordance with the Code of Federal Regulations (40 CFR 261.22) and is considered PTW as presented in Appendix B.

The pH2 alternative layout is presented on Figure 4.24 and includes contours for pH of 10 s.u. and 12.5 s.u. As shown on Figure 4.24, pH greater than 12.5 s.u. is mostly within the east side of the 605 Alexander Avenue property. Figure 4.24 also shows the areas above -60 ft NGVD that have pH greater than 12.5 s.u. Figure 4.25 presents north/south and east/west cross-sections showing the pH developed from the MVS/EVS through some of these areas. The cross-section locations are shown on Figure 4.24. The volume of aquifer defined by the parameters above have an ANC that is approximately 11.2 percent of the estimated ANC in the aquifer with pH greater than 7 s.u. (pH neutral) as presented in Appendix F. The vertical extent of the target zone is shown on Figure 4.25.

In situ reagent mixing would involve mixing a chemical reagent vertically into the unsaturated and saturated subsurface using either a single auger or multiple augers equipped with mixing paddles. The augers would penetrate the ground and mix the soil and groundwater as they rotate. The reagent would be simultaneously injected through the hollow drill stem as the augers retreat back to the surface. Each treated soil column would be typically 3 to 5 ft in diameter after mixing. The treatment process would be repeated over the treatment area, overlapping each soil column to ensure complete mixing. Sodium persulfate would be used. The pH pilot studies (CRA, 2011) conducted for the Site, indicate that it would be expected that pH values would rebound after treatment and therefore would require over treatment to initially reduce the pH below the target treatment level of 12.5 s.u. (e.g., 10-11 s.u.).

4.5.3 pH Enhanced Containment Alternative pH3

The pH Enhanced Containment Alternative pH3 was designed to contain, by in situ treatment, pH >12.5 s.u. (i.e., PTW) in shallow soil and groundwater that could be a future source of contamination in soil and groundwater. The pH3 alternative includes the following elements:

- Treatment using in situ mixing of cement with shallow soil and groundwater above -60 ft NGVD containing pH greater than 12.5 s.u.

The pH3 alternative layout is the same as the pH2 alternative and is presented on Figure 4.24. Figure 4.24 shows the areas above -60 ft NGVD that have pH greater than 12.5 s.u. Figure 4.25 presents north/south and east/west cross-sections showing the pH developed from the MVS/EVS through some of these areas. The cross-section locations are shown on Figure 4.24. The ANC within the volume of aquifer defined by the parameters above is the same as the pH2 alternative, approximately 11.2 percent.

A description of the mixing technology is provided in Subsection 4.5.2. Cement would be used to contain the pH greater than 12.5 s.u by stabilization. The technology would involve the mixing of a binding agent (cement) into soil to greatly reduce the potential ability of contaminants to migrate with groundwater. It will also reduce the permeability of the soil, which reduces groundwater flow through the area.

4.5.4 pH Enhanced Containment Alternative pH4

The pH Enhanced Containment Alternative pH4 was designed to contain, by in situ vertical barrier, pH >12.5 s.u. (i.e., PTW) in shallow soil and groundwater that could be a future source of contamination in soil and groundwater. The pH3 alternative includes the following elements:

- Construction of a vertical slurry barrier wall around shallow soil and groundwater above -60 ft NGVD containing pH greater than 12.5 s.u.

The pH4 alternative layout is presented on Figure 4.26 that includes the conceptual potential location of a vertical slurry barrier wall around the areas above -60 ft NGVD that have pH greater than 12.5 s.u. Figure 4.25 presents north/south and east/west cross-sections showing the pH developed from the MVS/EVS through some of these areas. The cross-section locations are shown on Figure 4.24. The ANC within the volume of aquifer defined by the parameters above is the same as the pH2 and pH3 alternatives, approximately 11.2 percent.

A vertical slurry barrier wall would be used to enhance the containment of groundwater with high pH and prevent it from reaching environmental receptors and potential extraction wells related to the containment alternatives. (See Subsection 4.3). The vertical slurry barrier wall would also contain other contaminants preventing horizontal migration but also limiting contaminant extraction by pumping groundwater related to the containment alternatives and the Mass Reduction Alternatives, M100, M150, M200, and ~~M200~~MSP. (See Subsection 4.4.2). Extraction of contaminants would be limited to groundwater movement under the vertical slurry barrier wall due to pumping.

The alignment shown on Figure 4.26 would result in a vertical slurry barrier wall approximately 1,650 ft long and approximately 70 to 75 ft bgs. The vertical slurry barrier wall would be installed to ground surface, at a top elevation of approximately 12 ft NGVD and base elevation of approximately -60 ft NGVD. The spoils would be placed within the contained area and under the proposed PDCE barrier. (See Subsection 4.3).

4.5.5 pH Reduction Alternative pH5

The pH Reduction Alternative pH5 was designed to reduce, by in situ treatment, pH >12.5 s.u (i.e., PTW) in shallow and deep soil and groundwater that could be a future source of contamination in soil and groundwater. The pH5 alternative includes the following elements:

- Treatment using in situ mixing of sodium persulfate with shallow and deep soil and groundwater containing pH greater than 12.5 s.u.

The pH5 alternative layout is presented on Figure 4.27. Figure 4.27 shows the areas that have pH greater than 12.5 s.u. Figure 4.28 presents north/south and east/west cross-sections showing the pH developed from the MVS/EVS through some of these areas. The cross-section locations are shown on Figure 4.24. The volume of aquifer defined by the parameters above have an ANC that is approximately 23.3 percent of the estimated ANC in the aquifer with pH greater than 7 s.u. (pH neutral) as presented in Appendix F. The vertical extent of the target zones are shown on Figure 4.28.

A description of the technology is provided in Subsection 4.5.2.

4.5.6 pH Enhanced Containment Alternative pH6

The pH Enhanced Containment Alternative pH6 was designed to contain, by in situ treatment, pH >12.5 s.u (i.e., PTW) in shallow and deep soil and groundwater that could be a future source of contamination in soil and groundwater. The pH6 alternative includes the following elements:

- Treatment using in situ mixing of cement with shallow and deep soil and groundwater containing pH greater than 12.5 s.u.

The pH6 alternative layout is the same as the pH6 alternative and is presented on Figure 4.27. Figure 4.27 shows the areas that have pH greater than 12.5 s.u. Figure 4.28 presents north/south and east/west cross-sections showing the pH developed from the MVS/EVS through some of these areas. The cross-section locations are shown on Figure 4.24. The ANC within the volume of aquifer defined by the parameters above is the same as the pH5 alternative, approximately 23.3 percent.

A description of the technology is provided in Subsection 4.5.3.

4.5.7 pH Enhanced Containment Alternative pH7

The pH Enhanced Containment Alternative pH7 was designed to contain, by in situ vertical barrier, pH >12.5 s.u (i.e., PTW) in shallow and deep soil and groundwater that could be a future source of contamination in soil and groundwater. The pH7 alternative includes the following elements:

- Construction of a vertical slurry barrier wall around shallow and deep soil and groundwater containing pH greater than 12.5 s.u.

The pH7 alternative layout is presented on Figure 4.29 that includes the conceptual potential location of vertical slurry barrier walls around the areas that have pH greater than 12.5 s.u. Figure 4.28 presents north/south and east/west cross-sections showing the pH developed from the MVS/EVS through some of these areas. The cross-section locations are shown on Figure 4.24. The ANC within the volume of aquifer defined by the parameters above is the same as the pH5 and pH6 alternatives, approximately 23.3 percent.

A description of the technology is provided in Subsection 4.5.4. The alignment shown on Figure 4.29 would result in vertical slurry barrier walls including: approximately 970 ft long and approximately 70 to 75 ft bgs for shallow pH enhanced containment (see Subsection 4.5.4); approximately 2,235 ft long and approximately 110 to 115 ft bgs for deep pH enhanced containment within the 605 Alexander Avenue property; and approximately 625 ft long and approximately 150 to 155 ft bgs for deep pH enhanced containment outside of the 605 Alexander Avenue property. The vertical slurry barrier walls would be installed to ground surface, at a top elevation of approximately 12 ft NGVD and base elevations of approximately -60 ft NGVD, -100 ft NGVD, and -140 ft NGVD. The spoils would be placed within the contained area and under the proposed PDCE barrier. (See Subsection 4.3).

5. Containment Alternatives - Initial Screening and Detailed Evaluation

5.1 Initial Screening

The purpose of an initial screening of alternatives is to potentially reduce the number of alternatives for the detailed evaluation, if appropriate. Cleanup action alternatives or components may be eliminated from further consideration if:

(i) it is determined (by the Agencies) based on a preliminary analysis that an alternative or a component so clearly does not meet the minimum requirements specified in WAC 173-340-360. This includes an alternative or a component for which costs are clearly disproportionate under WAC 173-340-360(3)(e).

(ii) the alternative or component is not technically possible at the site.

The minimum requirements in WAC 173-340-360 include threshold requirements as follows:

- Protect human health and the environment
- Comply with cleanup standards
- Comply with applicable state and federal laws
- Provide for compliance monitoring

The threshold criteria in CERCLA and the NCP include overall protection of human health and the environment and compliance with Applicable or Relevant and Appropriate Requirements (ARARs). These are included in the WAC threshold requirements. Determining if an alternative is administratively and technically possible is analogous to the NCP criterion of implementability (administrative and technical).

The containment alternatives are described in Subsection 4.3. Except for the No Action alternative, it has been determined that the containment alternatives would meet the minimum requirements and are administratively and technically possible. The No Action alternative is retained for comparison with the other alternatives consistent with CERCLA and the NCP even though it does not meet the minimum/threshold requirements.

It is recognized for this Site that a reasonable restoration time frame, which is meaningful and a reliable estimate, cannot be reasonably established because of inherent uncertainties in existing conditions and in the future response of those conditions to site remediation activities. This is a fundamental reason for including containment in all the alternatives described in Section 4., except the No Action Alternative. It is further recognized that a restoration time frame for this Site will likely exceed 100 years for all feasible remediation alternatives. Therefore, for the purpose of evaluating and comparing alternatives, a 100-year period of time is used for comparing the potential effectiveness over the long term in the disproportionate cost analyses.

The following Subsections present the initial screening of the containment alternatives C100, C150, and C200 with respect to relative costs for alternatives that have similar technical implementability and potential effectiveness.

5.1.1 Containment Alternative C100

Alternative C100 is fully implementable and would be effective to protect human health and the environment by eliminating and managing potential exposure pathways. Proper maintenance and monitoring would ensure permanence and effectiveness of the containment alternative.

The relative cost of this alternative would be lowest of the containment alternatives based on a lower groundwater extraction rate that would require, for example, smaller equipment, less consumables (e.g., less power and chemicals for ex situ treatment), and less solids disposal. The contingency pH treatment (see Subsection 4.3.2) would increase cost for pH treatment equipment and the operation and maintenance (O&M) costs for power consumption, chemical usage, and solids disposal, but would not increase the size of the treatment plant and other equipment that would be sufficiently sized to accommodate up to 50 percent more flow from adding dilution water.

5.1.2 Containment Alternative C150

Alternative C150 is fully implementable and would be effective to protect human health and the environment by eliminating and managing potential exposure pathways. Proper maintenance and monitoring would ensure permanence and effectiveness of the containment alternative.

The relative cost of this alternative would be slightly higher than the containment alternative C100 based on a higher groundwater extraction rate that would require increased O&M, for example, more consumables (e.g., more power and chemicals for ex situ treatment) and more solids disposal. The treatment plant/equipment size would be relatively the same. However, when factoring in the contingency pH treatment (see Subsection 4.3.2), the treatment plant/equipment would need to be larger to accommodate up to 50 percent more flow from adding dilution water and therefore the capital costs would be slightly higher as well. Additionally, the O&M costs for consumables and solids disposal would further increase commensurate with the additional flow.

5.1.3 Containment Alternative C200

Alternative C200 is fully implementable and would be effective to protect human health and the environment by eliminating and managing potential exposure pathways. Proper maintenance and monitoring would ensure permanence and effectiveness of the containment alternative.

The relative cost of this alternative would be higher than the containment alternatives C100 and C150 based on a higher groundwater extraction rate that would require larger treatment plant equipment and more consumables (e.g., more power and chemicals for ex situ treatment) and more solids disposal. When factoring in the contingency pH treatment (see Subsection 4.3.2), the larger treatment plant equipment associated with the C150 alternative would be adequate to accommodate the up to 50 percent more flow from adding dilution water. The O&M costs for consumables and solids disposal would further increase commensurate with the additional flow. The relative O&M cost of the C200 alternative with the contingency pH treatment would be higher than the C150 alternative with the contingency pH treatment, but the treatment plant equipment would be the same as noted above. The higher O&M costs would be based on a higher groundwater extraction rate that would require, for example, more consumables (e.g., more power and chemicals for ex situ treatment) and more solids disposal. The relative cost of the C200 alternative with the contingency pH treatment would be greater than the C100 alternative with the contingency pH treatment since the treatment plant equipment would be larger and O&M costs would be greater.

5.1.4 Summary

All three containment alternatives (C100, C150, and C200) are fully implementable and similar in O&M required. The effectiveness of the drawdown (a measure of containment; see Subsection 5.2) increases with increases in pumping rate, which in turn increases the costs to construct, operate, and maintain to some degree. The potential benefits of increasing the pumping rate do not appear to clearly add disproportionate costs (i.e., no large increase in costs). Therefore, the initial screening did not eliminate any of the alternatives based on the requirements presented above.

5.2 Detailed Evaluation

Purpose and Evaluation Criteria

The detailed evaluation of the Containment Alternatives involved using the calibrated groundwater flow model developed for the Site, as presented in Appendix E, to determine if the alternatives meet the model-based objectives provided by the Agencies. In general, the purpose and objectives of the modeling evaluation include:

- Evaluate potential discharge of TCVOC mass to the surface water bodies that surround the Site peninsula.
- Evaluate the degree of hydraulic containment achieved by groundwater extraction.

The specific Model-Based Performance Objectives for the Containment Alternatives consist of:

1) Within the hydraulic control boundaries provided by the Agencies on March 30, 2016, there must be inward gradients and a target drawdown of at least 1 foot (See Appendix E).

~~1)~~2) The Site groundwater flow model must be used to estimate the future mass discharge to Commencement Bay and the Hylebos Waterway with the containment system in place. In addition to needing to meet RAGs presented in Subsection 3.1, as a minimum, the containment system must result in an estimated TCVOC mass discharge of less than 0.2 percent of the current estimated total TCVOC mass in the aquifer~~ (i.e., 0.2 percent of 780,000 lbs).~~.

~~2)~~3) ~~The Site groundwater~~Groundwater flow ~~model must be used to show that the simulated drawdown within the Site peninsula along the 1,000 μg/L TCVOC contour in groundwater is at least 1 foot and show that groundwater flow under~~beneath the Waterway ~~is~~must be directed to the plant~~-~~-west toward the containment system.

Per MTCA and CERCLA, other factors to consider include:

- Potential risks.
- Practicability.
- Current use of the site, surrounding areas, and associated resources that are, or might be, affected by releases from the site.
- Potential future use of the site, surrounding areas, and associated resources that are, or might be, affected by releases from the site.
- Availability of alternative water supplies.
- Likely effectiveness and reliability of institutional controls.
- Ability to control and monitor migration of hazardous substances from the site.
- Toxicity of the hazardous substances at the site.
- Natural processes that reduce concentrations of hazardous substances and have been documented to occur at the site or under similar site conditions.

5.2.1 Containment Alternative C100

Evaluation of Model-Based Performance Objectives

Containment Alternative C100 includes a physical hydraulic barrier wall along the Site peninsula adjacent to the Waterway and upland groundwater extraction wells on the Site peninsula. The location and number of upland extraction wells were optimized using the groundwater flow model. The objective of optimization was to maximize TCVOC groundwater plume containment while not placing extraction wells where the pH was greater than 10 s.u. (to minimize fouling of extraction wells). For Containment Alternative C100, the optimization resulted in eleven extraction wells (including existing inactive extraction well EXT-9) at a total groundwater pumping rate of 157.5 gpm. The detailed modeling evaluation of Containment Alternative C100 is presented in Appendix E, and the results of the modeling evaluation are summarized below relative to meeting Model-Based Performance Objectives~~ 1 and 2~~.

Containment Alternative C100 achieves inward gradients and simulated drawdown of at least 1 foot where TCVOC concentrations are above 1,000 µg/L in the 15-ft zone (see Figure 1 of Appendix E). Containment Alternative C100 achieves inward gradients and simulated drawdown of at least 1 foot within the majority of the hydraulic control boundaries for the 25-ft to 75-ft zones (see Figures 2 to 4 in Appendix E), which essentially meets Model-Based Performance Objective 1). However, the simulated drawdown is less than 1 foot within a significant portion of the hydraulic control boundaries for the 100-ft and 130-ft zones (see Figures 5 and 6 in Appendix E), and this does not meet Model-Based Performance Objective 1), although inward gradients are simulated for these zones.

Containment Alternative C100 results in an estimated TCVOC mass discharge of less than 0.2 percent of the total TCVOC mass in the aquifer, which meets Model-Based Performance Objective ~~1~~2) (see Table 2 of Appendix E). The TCVOC mass discharge to the surface water bodies surrounding the Site peninsula is approximately 0.02 percent of the total TCVOC mass in the aquifer (188 lbs) after the 1,000-year simulation duration.

~~Containment Alternative C100 essentially achieves simulated drawdown of 1 ft or greater where TCVOC concentrations are above 1,000 µg/L in the 15-ft to 50-ft zones on the Site peninsula (see Figures 1 to 3 of Appendix E). However, the simulated drawdown is less than 1 ft in significant areas where TCVOC concentrations are above 1,000 µg/L in the 75-ft to 130-ft zones (see Figures 4 to 6 of Appendix E), which does not meet the required drawdown component of Model-Based Performance Objective 2.~~

Figures 4, 5, and 6 of Appendix E show that simulated groundwater flow directions under the Waterway in the 75-ft, 100-ft, and 130-ft zones, respectively, are directed toward the Site peninsula and the groundwater extraction system, which meets ~~the groundwater flow direction component of~~ Model-Based Performance Objective ~~2.~~3).

Since Containment Alternative C100 does not meet the required drawdown component of Model-Based Performance Objective ~~2,~~1), it is not evaluated further in the FS.

5.2.2 Containment Alternative C150

Evaluation of Model-Based Performance Objectives

Containment Alternative C150 is based on Containment Alternative C100 but with increased extraction rates. Containment Alternative C150 applies the same extraction wells as Containment Alternative C100, but with pumping rates increased by up to 50 percent from that applied in Containment Alternative C100. The total groundwater pumping rate applied for Containment Alternative C150 corresponds to 226.25 gpm, which is approximately 44 percent higher than Alternative C100. The detailed modeling evaluation of Containment Alternative C150 is presented in Appendix E, and the results of the modeling evaluation are summarized below relative to meeting Model-Based Performance Objectives~~ 1 and 2~~.

Containment Alternative C150 achieves ~~Model-Based Performance Objective 1~~inward gradients and simulated drawdown of at least 1 foot where TCVOC concentrations are above 1,000 µg/L in the 15-ft zone (see ~~Table 2 of~~Figure 8 in Appendix E). ~~The TCVOC mass discharge to the surface water bodies surrounding the Site peninsula is approximately 0.004 percent of the total TCVOC mass in the aquifer (35 lbs) after the 1,000-year simulation duration, which is 0.016 percent less than Alternative C100.~~

Containment Alternative C150 achieves ~~simulated drawdown of 1 ft or greater~~inward gradients and simulated drawdown of at least 1 foot within the hydraulic control boundaries for the 25-ft and 50-ft zones (see Figures 9 and 10 in Appendix E), which meets Model-Based Performance Objective 1). Containment Alternative C150 achieves inward gradients and simulated drawdown of at least 1 foot within the vast majority of the hydraulic control boundaries for the 75-ft to 130-ft zones (see Figures 11 to 13 in Appendix E), The 1-foot simulated drawdown encompasses where TCVOC concentrations are above 1,000 µg/L in the ~~15~~75-ft to 130-ft zones on the Site peninsula~~ (see Figures 8 to 13 of Appendix E), which meets the required drawdown component~~. The above in combination with simulating inward gradients for the 75-ft to 130-ft zone hydraulic control boundaries, satisfies the intent of Model-Based Performance Objective ~~2.~~1). Simulating significant drawdown (i.e., 1 ft or more) in the 160-ft zone is not expected since much of this zone lies below the zone of apparent confining effect where lower permeability is represented in the groundwater flow model (see Figure 14 of Appendix E).

Containment Alternative C150 achieves Model-Based Performance Objective 2) (see Table 2 of Appendix E). The TCVOC mass discharge to the surface water bodies surrounding the Site peninsula is approximately 0.004 percent of the total TCVOC mass in the aquifer (35 lbs) after the 1,000-year simulation duration, which is 0.016 percent less than Alternative C100.

Containment Alternative C150 achieves simulated groundwater flow directions under the Waterway in the 75-ft, 100-ft, and 130-ft zones that are directed toward the Site peninsula and the groundwater extraction system, which meets ~~the groundwater flow direction component of~~ Model-Based Performance Objective ~~2~~3) (see Figures 11, 12, and 13 of Appendix E).

Other Factors to Consider

Containment Alternative C150 is designed to eliminate, reduce, or otherwise control risks posed through potentially complete exposure pathways and migration routes. Therefore, a properly operated, maintained, and monitored C150 containment alternative would protect human health and the environment, including potential ecological receptors, by containing and preventing exposure to media with concentrations of COC above SSLs and by meeting the Site RAGs (see Subsection 3.1).

The technologies proposed are common and practical for containing a large complex site such as this and could be effectively operated, maintained, and monitored. The C150 alternative components presented herein are administratively and technically possible at the Site. The applicable state and federal laws (see Subsection 3.3) would be complied with during the design and implementation phases by meeting the substantive requirements. Administratively, substantive requirements of permitting would be met in terms of the following:

1. Construction - storm water, potential air monitoring, and building.
2. Post Construction and Long-term operations - National Pollutant Discharge Elimination System (NPDES) (to include wastewater sampling, storm water sampling, air monitoring).

Pre-Construction and Construction (including demolition and construction) - might include Washington State Environmental Policy Act (SEPA), Ecology construction storm water permitting requirements, Port of Tacoma tenant improvement requirements for off-property work, City of Tacoma construction permitting requirements, and Joint Aquatic Resources Permit Application (JARPA) working in water ways (US Army Corps Of Engineers - requirements for general permit, nationwide permit, standard individual permits, and letter of permission - as authorized under Section 10 and/or Section 404). It is most likely that a sheet pile vertical barrier wall would require the most effort and would take the longest time to meet the substantive requirements. Port of Tacoma officials report that recently observed permitting time frames in the Tacoma Tideflats area has taken up to 1.5 years to complete. Air monitoring might be required during construction if emissions are expected during construction.

Post-construction, an impermeable barrier (PDCE barrier) over an area of approximately 34.5 acres would result in large quantities of runoff during storm events and would need to meet NPDES substantive requirements. Discharge from the GWETS would need to meet NPDES substantive requirements as well. Air discharge from the GWETS would need to meet the substantive requirements of applicable State and Federal air emissions regulations.

ICs and compliance monitoring along with O&M are very reliable and effective means to ensure control of potential future migration of hazardous substances. Compliance monitoring would include performance monitoring, confirmation monitoring, and protection monitoring. The C150 containment alternative would include compliance monitoring in the forms of the Common Elements of ICs and monitoring (see Subsection 4.2), substantive requirements of permitting, five-year reviews, and field-based performance objectives. The existing network of monitoring wells is likely more than adequate to monitor the effectiveness and field-based performance objectives. The compliance monitoring would ensure that potential exposure to residual threats are eliminated or managed.

The C150 alternative would be compatible with the current and anticipated future uses of the Site and surrounding areas, which are industrial with generally paved surfaces.

This alternative would prevent future potential discharges into surface water that could potentially adversely impact ecological populations. The area is serviced by a municipal water supply and the groundwater beneath the Site has been determined to be non-potable (see Appendix A).

Since the containment system would not significantly alter the geochemical conditions in the subsurface, natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

5.2.3 Containment Alternative C200

Evaluation of Model-Based Performance Objectives

Containment Alternative C200 is based on Containment Alternative C100 but with increased extraction rates, which are higher than the C150 alternative extraction rates as well. Containment Alternative C200 applies the same extraction wells as Containment Alternative C100, but with pumping rates increased by up to 100 percent from that applied in Containment Alternative C100. The total groundwater pumping rate applied for Containment Alternative C200 corresponds to 281.5 gpm, which is approximately 79 percent higher than Alternative C100 and 24 percent higher than Alternative C150. The detailed modeling evaluation of Containment Alternative C200 is presented in Appendix E, and the results of the modeling evaluation are summarized below relative to meeting Model-Based Performance Objectives~~ 1 and 2~~.

~~Containment Alternative C200 achieves Model-Based Performance Objective 1 (see Table 2 of Appendix E).~~Containment Alternative C200 achieves inward gradients and simulated drawdown of at least 1 foot where TCVOC concentrations are above 1,000 µg/L in the 15-ft zone (see Figure 15 in Appendix E). Containment Alternative C200 achieves inward gradients and simulated drawdown of at least 1 foot within the hydraulic control boundaries for the 25-ft and 50-ft zones (see Figures 16 and 17 in Appendix E), which meets Model-Based Performance Objective 1). Similar to Containment Alternative C150, Containment Alternative C200 achieves inward gradients and simulated drawdown of at least 1 foot within the vast majority of the hydraulic control boundaries for the 75-ft to 130-ft zones (see Figures 18 to 20 in Appendix E), The 1-foot simulated drawdown encompasses where TCVOC concentrations are above 1,000 µg/L in the 75-ft to 130-ft zones on the Site peninsula. The above in combination with simulating inward gradients for the 75-ft to 130-ft zone hydraulic control boundaries, satisfies the intent of Model-Based Performance Objective 1). Simulating significant drawdown (i.e., 1 ft or more) in the 160-ft zone is not expected since much of this zone lies below the zone of apparent confining effect where lower permeability is represented in the groundwater flow model (see Figure 21 of Appendix E).

Containment Alternative C200 achieves Model-Based Performance Objective 2) (see Table 2 of Appendix E). The TCVOC mass discharge to the surface water bodies surrounding the Site peninsula is approximately 0.004 percent of the total TCVOC mass in the aquifer (30 lbs) after the 1,000-year simulation duration, which is 0.016 percent less than Alternative C100 and essentially the same as Alternative C150.

~~Containment Alternative C200 achieves simulated drawdown of 1 ft or greater where TCVOC concentrations are above 1,000 µg/L in the 15-ft to 130-ft zones on the Site peninsula (see Figures 15 to 20 of Appendix E), which meets the required drawdown component of Model-Based Performance Objective 2. Simulating significant drawdown (i.e., 1 ft or more) in the 160-ft zone is not expected since much of this zone lies below the zone of apparent confining effect where lower permeability is represented in the groundwater flow model (see Figure 21 of Appendix E).~~

Containment Alternative C200 achieves simulated groundwater flow directions under the Waterway in the 75-ft, 100-ft, and 130-ft zones that are directed toward the Site peninsula and the groundwater extraction system, which meets ~~the groundwater flow direction component of~~ Model-Based Performance Objective ~~2~~3) (see Figures 18, 19, and 20 of Appendix E).

Other Factors to Consider

The consideration of other factors for Containment Alternative C200 is consistent with the evaluation for Containment Alternative C150. The Containment Alternative C200 meets the Model-Based Performance Objectives similar to Containment Alternative C150.

5.2.4 Disproportionate Cost Analysis

A disproportionate cost analysis (DCA) is designed to evaluate if the incremental costs of an alternative over that of a lower cost alternative exceed the incremental degree of benefits potentially achieved by the more costly alternative. As presented in WAC 173-340-360(3)(f), the evaluation criteria are as follows:

(i) Protectiveness

(ii) Permanence

(iii) Effectiveness over the long term

(iv) Management of short-term risks

(v) Technical and administrative implementability

(vi) Consideration of public concerns

(vii) Cost

These MTCA evaluation criteria are analogous to the NCP evaluation criteria under CERCLA.

In the DCA process, each alternative is assigned a rank (score) for each criterion using a scale of 1 to 10 (10 being the best) that represent a judgement of how well an alternative satisfies a criterion. Since each criterion is not considered equal by the Agencies, each rank is multiplied by a weighting factor or percentage representative of the criterion before the ranks are added up to produce a total that is referred to as an 'overall benefit score.' The overall benefit score is divided by the relative cost (normalized by dividing the actual costs by the order of magnitude of the lowest cost alternative [e.g., 10,000,000]) to come up with a relative benefit score to cost ratio. These ratios are compared and the higher the ratio the more beneficial the alternative is.

Table 5.1 presents the weighting percentages developed for this Site and the rationale for each, which are summarized below:

(i) Protectiveness - 30%

(ii) Permanence - 20%

(iii) Effectiveness over the long term - 20%

(iv) Management of short term risks - 10%

(v) Technical and administrative implementability - 10%

(vi) Consideration of public concerns - 10%

The following presents an evaluation of Containment Alternatives C150 and C200 with respect to the above DCA process.

Protectiveness

Both Containment Alternatives C150 and C200 would provide similar protectiveness.

The required protection for human health and the environment would be met through access restrictions, ICs, and engineered barriers (i.e., PDCE and sheet pile vertical barrier wall). The PDCE would protect against incidental ingestion, inhalation, and dermal contact with impacted soil and shallow DNAPL. It would prevent runoff of potentially impacted surface water. Additionally, the PDCE might reduce infiltration/percolation through impacted soil in the vadose zone, potentially reducing migration. The sheet pile vertical barrier wall along the Waterway would isolate the impacted embankment material preventing direct contact by human and ecological receptors. The sheet pile vertical barrier wall would also prevent flushing of shallow soil by tidal fluctuations and prevent shallow groundwater discharge to surface water and aquatic receptors. The treatment of impacted groundwater would prevent discharge of impacted water to surface water bodies.

Potential risks associated with the Site would be reduced within the construction time frame and would continue to be reduced over time as contaminated groundwater is extracted and treated. Overall environmental quality would improve by preventing direct contact with, incidental ingestion of and inhalation of hazardous substances, and potential discharge of groundwater with concentrations above SSLs to surface water.

Permanence

Both Containment Alternatives C150 and C200 would offer essentially the same practical solution and equal permanence.

Groundwater extraction under this alternative would contain the impacted groundwater plumes, thus reducing contaminant mobility. The treatment of the extracted groundwater would destroy contaminants, resulting in a reduction of their toxicity and volume. Migration and potential release of hazardous substances would be mitigated by maintaining inward hydraulic gradients and demonstrating containment using existing monitoring wells to achieve field-based performance objectives that would be determined during the design phase. The treatment process would result in the generation of solids that would require off-Site transportation and disposal.

Effectiveness Over the Long Term

Containment Alternatives C150 and C200 would be equally effective over the long term since they equally meet the ~~model-based performance objectives~~Model-Based Performance Objectives and are anticipated to equally meet the field-based performance objective. Containment Alternative C200 has an increased risk of drawing in groundwater with higher pH since the pumping rates are higher. As discussed in Subsection 4.3.2, pumping groundwater with high pH should be avoided in order to minimize/prevent: potential fouling of the treatment system; the need for treatment of high pH water; and disposal of additional solids associated with this high pH groundwater. Therefore, a lower groundwater pumping rate would be preferred to minimize this potential risk.

Both Containment Alternatives C150 and C200 would include technologies that are common and practical for containing a large complex site, could be effectively operated, maintained, and monitored, and are proven to be successful and reliable over time. Both alternatives reduce risk by eliminating or managing potential exposure pathways and containing hazardous substances remaining at the Site. Long-term effectiveness would require ongoing operation and/or maintenance of the components, monitoring, and maintenance of ICs.

The installation of the PDCE barrier would be an effective and reliable solution to eliminate exposure to the impacted soil, impacted embankment material, and shallow DNAPL. The asphalt cover would need to be maintained and periodically repaired or replaced. The long-term integrity and effectiveness of well-designed and constructed PDCE barriers is well documented. PDCE barrier technology must be used in combination with ICs to protect the integrity of the barrier material, and other technologies to address potential migration of subsurface impacts under the PDCE barrier.

The installation of the sheet pile vertical barrier wall is an effective and reliable solution to provide isolation of the impacted embankment material and to prevent discharge of impacted shallow groundwater to the Hylebos. The installation of sheet pile vertical barrier wall to the depths anticipated is commonly done in both upland and marine settings.

The GWETS would be effective in maintaining containment and would reduce mass over time through extraction and treatment of contaminated groundwater.

Management of Short-term Risks

The short-term risks during construction and implementation of both alternatives would be the same and would be managed through standard safety and health procedures that would be documented in a Site-specific health and safety plan (HASP). The types of procedures that would be required are those regularly practiced for the types of construction anticipated.

In addition to the HASP, other plans for activities such as soil management, traffic control, and air monitoring would be developed to protect human health and the environment during construction and implementation.

Technical and Administrative Implementability

As discussed in Subsection 5.1, both alternatives are equally implementable.

The technical implementability of a PDCE barrier is high as PDCE barrier is a proven technology that was used successfully at many sites and PDCE barrier materials (e.g., asphalt and granular bedding materials) are readily available. The technical implementability of sheet pile vertical barrier wall technology is high as well as this technology is widely used for containment in upland and marine applications, and materials and equipment to install sheet pile vertical barrier walls are widely available. A barrier wall could be easily installed to the depths anticipated. Groundwater extraction wells are commonly used, and are generally simple to maintain. Experience at the Site has shown that extraction wells could be operated for long periods of time outside of the zone where groundwater pH is greater than 10 s.u. Wells could be maintained and rehabilitated using standard techniques. Well construction contractors and materials are readily available.

Since the engineered barriers and groundwater extraction technology are proven technologies and typically applied at many sites; services, capabilities, equipment, specialists, and materials should be readily available for implementation of these remedial technologies. Permitting of these remedial technologies is also expected to be obtained without significant difficulties.

Consideration of Public Concerns

Ecology held a public comment period from October 23, 2015 through February 1, 2016 for the approved SCR (CRA, 2014c), during which, Ecology received a total of 14 letters and emails. The following four common significant themes were apparent in the public comments:

1) Several comments were largely unrelated to the Site, and focused more on the CB/NT site, sediment cleanup standards, and uses of the Hylebos.
2) Some comments believed that the Exposure Pathway Assessment (sediment and shallow groundwater discharge assessment) is incomplete.
3) A few comments believed that the full extent of the biological receptors has not been assessed.
4) A couple of comments believed that the northern boundary of the plume extent has not been fully defined.

As the comments in Item 1 above were largely unrelated to the Site, they are outside the scope of this FS. The comments in Items 2, 3, and 4 above were addressed through the 2016 Anchor QEA investigation sediment and porewater sampling in the Hylebos as discussed in Subsection 2.4.5 and 2.4.6. To the extent that the comments were related to Upland Areas of the Site, they would be addressed by a containment system.

Public notice and participation is an integral part of the remedy selection process. The public notice and participation requirements for cleanups conducted are set forth in MTCA (WAC 173-340-600), NCP 40 CFR 300.430(f)(3)(i), and CERCLA §117. The public will have an opportunity to voice any concerns regarding the FS during a public comment period.

It is expected that the public will be supportive of a reliable containment system that protects human health and the environment by eliminating all potential exposure pathways. Containment systems, which could be effectively operated, maintained, and monitored, are common and have proven to be reliable and effective solutions for large complex sites like this one. Mobility of mass within the containment system would be of minimal concern as long as there is hydraulic control of the target zones. A containment alternative is the foundation of any other measures that are deemed appropriate to address Site conditions.

Cost

The estimated costs for Containment Alternatives C150 and C200 are presented in Appendix G and were developed in accordance with guidance (USEPA, 2000) specified by the Agencies. The costs include a placeholder for potential mitigation for the loss of intertidal zone along the embankment to comply with the Clean Water Act. The cost estimates include periods of 30 years (yrs), in accordance with the guidance (USEPA, 2000), and 100 years, at the request of the Agencies. Discount factors for O&M and periodic costs include 7 percent, in accordance with the guidance (USEPA, 2000), and 1.5 percent (2016 Discount Rate for OMB Circular No. A-94 for the 30-Year Real Interest Rate on Treasury Notes and Bonds of Specific Maturities), at the request of the Agencies. A summary of the capital, O&M, and periodic costs is as follows:

Table 5.2 Summary of Containment Alternatives Estimated Costs

Cost Type	Alternative C150	Alternative C200
Capital	$38,700,240	$38,700,240
O&M/Periodic (30yrs;7%)	$15,656,240	$16,490,000
O&M/Periodic (30yrs;1.5%)	$30,652,600	$32,266,220
O&M/Periodic (100yrs;7%)	$18,469,760	$19,429,760
O&M/Periodic (100yrs;1.5%)	$70,539,760	$74,009,760

As shown in the above table, the estimated capital costs are the same since the same plant would be constructed for either extraction system. The O&M/Periodic costs for the C200 alternative are higher than the C150 alterative due to requirements for treating the additional flow such as increased power consumption, chemical usage for solids removal and pH adjustment, and production of solids requiring off-Site disposal.

Disproportionate Cost Analysis Summary

Table 5.3 presents a DCA summary table that provides relative benefit score to cost ratios for the Containment Alternatives C150 and C200 using weighting percentages from Table 5.1 and the scoring from Table 5.3. As shown in Table 5.3, the C150 alternative has a benefit score to cost ratio of 1.36 that is slightly greater than the benefit score to cost ratio for the C200 alternative of 1.34.

The following provides additional discussion regarding the common elements costs, cash flow projections, and alternative durations.

Figure 5.1 presents the common elements capital cost distribution for Containment Alternatives C150 and C200. As shown on this figure, the costs are the same. Figure 5.2 presents the alternatives anticipated 30-year cash flow projections. As shown on this figure, the costs are similar; however, they are higher for C200 alternative. Figure 5.3 shows the anticipated durations for the different components of the alternatives, which are the same.

Since Containment Alternatives C150 and C200 are essentially equivalent based on the evaluation criteria other than cost, there is no tangible degree of incremental benefit of the higher cost alternative. This is substantiated by C150 alternative having a higher benefit score to cost ratio than C200 alternative in Table 5.3.

5.2.5 Summary

Containment Alternatives C150 and C200 both meet the Model-Based Performance Objectives and Containment Alternative C100 does not. Containment Alternatives C150 and C200 would be equally implementable, effective, and permanent. Since Containment Alternatives C150 and C200 are essentially equivalent based on the evaluation criteria and the C150 alternative has a higher benefit score to cost ratio, there is no tangible degree of incremental benefit to justify selecting the higher cost alternative. Therefore, the identified preferred alternative is Containment Alternative C150.

6. VOC Mass Removal/Reduction Alternatives - Initial Screening and Detailed Evaluation

6.1 Initial Screening

The VOC mass removal/reduction alternatives are described in Subsection 4.4. The initial screening criteria are described in Subsection 5.1.

The VOC mass removal/reduction alternatives are designed to remove or reduce concentrations of contaminants, primarily TCVOC, in groundwater and soil. The VOC mass removal/reduction alternatives would not protect human health and the environment, including potential ecological receptors, at the Site by themselves. Therefore, they would not meet all the minimum/threshold requirements. However, in combination with containment technologies they would meet the minimum/threshold requirements (see Subsection 5.1). Accordingly, the VOC mass removal/reduction alternatives all assume that appropriate containment technologies are implemented at the Site. Therefore, none of the VOC mass removal/reduction alternatives were removed from further evaluation based on this initial screening.

The VOC mass removal alternatives M3 and M4 (see Subsection 4.4 for descriptions) would include excavation of the same quantity of shallow soil containing concentrations of TCVOC greater than 100 mg/kg. Therefore, these two alternatives would be equally effective in removing VOC mass from the Site. The difference between these alternatives would be the method of treatment/disposal after the soil is excavated. The M3 alternative includes on-Site treatment and backfilling whereas the M4 alternative includes off-Site transportation, treatment, and disposal. Based on discussions with vendors the cost would be approximately $720 per ton of soil for transportation, treatment, and disposal at an off-Site hazardous waste facility. On-Site treatment via ex situ SVE and backfilling is expected to be significantly less, on the order of $150 per ton, since there would not be any transportation or disposal costs. There would be some additional cost for backfilling under the M3 alternative but this would not be a significant cost and would be less than the cost to import clean backfill for excavated areas under the M4 alternative. Therefore, the costs for the M4 alternative would be clearly disproportionate compared to the M3 alternative, which would be equally as effective in removing concentrations of TCVOC greater than 100 mg/kg in shallow soil.

Similarly, the M6 and M7 alternatives (see Subsection 4.4 for descriptions) would be equally as effective because they would include the same technologies for treating and removing soils and the only difference would be the method of treatment/disposal for excavated soil, which is the same as the M3 and M4 alternatives. Therefore, the costs for the M7 alternative would be clearly disproportionate compared to the M6 alternative, which would be equally as effective.

The remaining VOC mass removal/reduction alternatives would be sufficiently different because of the technologies used and/or areas targeted that determining which alternatives' costs would be clearly disproportionate under WAC 173-340-360(3)(e) and/or have the ~~greatest~~lowest relative benefit score to cost ratio in the initial screening is not evident. Therefore, no additional VOC mass removal/reduction alternatives were removed from further evaluation based on this initial screening criterion.

The VOC mass removal/reduction alternatives and components presented herein are administratively and technically possible at the Site and therefore none of the VOC mass removal/reduction alternatives were removed from further evaluation based on this initial screening criterion. However, the M8 and M9 alternatives effective implementation might not be feasible because of the depth and size of the targeted zones and other activities on the peninsula. These alternatives include in situ treatment of VOC in deep soil and groundwater north of the 605 Alexander Avenue property. This is discussed further in the following detailed evaluation subsection.

Based on the above, the initial screening eliminated the M4 and M7 alternatives from further evaluation.

6.2 Detailed Evaluation

Purpose and Evaluation Criteria

The purpose of the detailed evaluation is to select an alternative, retained following the initial screening, which does not have an incremental cost that exceeds the incremental degree of benefits potentially achieved. The detailed evaluation of the VOC ~~Mass Removal/Reduction Alternatives~~mass removal/reduction alternatives involved assessing MTCA and CERCLA factors to be considered (see Subsection 5.2) and conducting a disproportionate cost analysis per WAC 173-340-360(3)(f). The detailed evaluation assumes that containment is part of the selected remedy for the Site, which is consistent with the initial screening of the VOC mass removal/reduction alternatives.

6.2.1 No Additional Action VOC Mass Removal/Reduction Alternative

The No Additional Action VOC Mass Removal/Reduction Alternative would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment. It would not alter or undermine the practicality and effectiveness of a containment alternative and therefore would be compatible with the use at the Site. This alternative would not reduce/remove or enhance containment of VOC mass in media at the Site and thus would not increase permanence or long-term effectiveness. However, VOC mass would be reliably contained by containment technologies. There are no short-term risks and it is fully implementable. Since this alternative would not alter the geochemical conditions in the subsurface, natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

6.2.2 VOC Mass Reduction Alternatives M100, M150, and M200

The detailed evaluation of the VOC Mass Reduction Alternatives M100, M150, and M200 involved using the calibrated groundwater flow model developed for the Site, as presented in Appendix E, to determine TCVOC mass reduction that might be achieved by groundwater extraction.

The simulated TCVOC mass removal by groundwater extraction is evaluated relative to the total TCVOC mass in the aquifer beneath the Site calculated from TCVOC concentrations in soil (above a threshold soil concentration of 100 mg/kg) equal to approximately 780,000 lbs presented in Appendix C. Soil concentrations represent mass in the dissolved, sorbed, and DNAPL phases.

6.2.2.1 VOC Mass Reduction Alternative M100

VOC Mass Reduction Alternative M100 includes a physical hydraulic barrier wall along the Site peninsula adjacent to the Waterway and two upland mass removal groundwater extraction wells on the Site peninsula. Groundwater extraction was represented in the model only from areas of elevated concentrations in the shallow and deep TCVOC groundwater plume to yield reduction in TCVOC mass. Two extraction wells were simulated to pump from shallow and deep groundwater with high dissolved concentrations of TCVOC outside the areas of elevated pH (i.e., ~~less~~greater than [>]10 s.u.). Figure 22 of Appendix E shows the locations and depths of two proposed mass reduction extraction wells, one shallow and one deep. A total groundwater pumping rate of 35 gpm was applied for VOC Mass Reduction Alternative M100. The rationale for this pumping rate is discussed in Appendix E. Simulated mass-weighted particle capture for VOC Mass Reduction Alternative M100 was completed for 30 years and 100 years, as requested by the Agencies.

VOC Mass Reduction Alternative M100 would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands VOC would already be reliably contained. However, it would increase the rate of VOC removal from the subsurface in the ~~near~~short term and the total quantity of VOC removed in the long term in combination with a containment alternative, and thus would significantly increase permanence and long-term effectiveness. The technology proposed is common and practical for extracting contaminated groundwater from a large complex site such as this and could be effectively operated, maintained, and monitored. There are some manageable short-term risks related to construction and it is implementable. The M100 alternative is not expected to alter or undermine the practicality of a containment alternative and could be easily incorporated into the design of the GWETS. It would enhance the drawdown and gradients within the containment system, which would require optimization if the M100 alternative was selected to be combined with a containment alternative. The alternative would be compatible with the current and anticipated future uses of the Site and surrounding areas, which are industrial with generally paved surfaces. Since the M100 alternative would not significantly alter the geochemical conditions in the subsurface, natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

6.2.2.2 VOC Mass Reduction Alternative M150

VOC Mass Reduction Alternative M150 is based on VOC Mass Reduction Alternative M100. VOC Mass Reduction Alternative M150 applies the same extraction wells as VOC Mass Reduction Alternative M100, but with pumping rates increased by 50 percent from that applied in VOC Mass Reduction Alternative M100. A total groundwater pumping rate of 52.5 gpm was applied for VOC Mass Reduction Alternative M150.

VOC Mass Reduction Alternative M150 would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands VOC would already be reliably contained. However, it would increase the rate of VOC removal from the subsurface in the ~~near~~short term and the total quantity of VOC removed in the long term in combination with a containment alternative, and thus would significantly increase permanence and long-term effectiveness. The rate of removal and quantity of VOC removed would be greater than the M100 alternative as shown on Figures 30 and 31 in Appendix E. The technology proposed is common and practical for extracting contaminated groundwater from a large complex site such as this and could be effectively operated, maintained, and monitored. There are some manageable short-term risks related to construction and it is implementable. The M150 alternative is not expected to alter or undermine the practicality of a containment alternative and could be easily incorporated into the design of the GWETS. It would enhance the drawdown and gradients within the containment system, which would require optimization if the M150 alternative was selected to be combined with a containment alternative. The alternative would be compatible with the current and anticipated future uses of the Site and surrounding areas, which are industrial with generally paved surfaces. Since the M150 alternative would not significantly alter the geochemical conditions in the subsurface, natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

6.2.2.3 VOC Mass Reduction Alternative M200

VOC Mass Reduction Alternative M200 is based on VOC Mass Reduction Alternative M100. VOC Mass Reduction Alternative M200 applies the same extraction wells as VOC Mass Reduction Alternative M100, but with pumping rates increased by 100 percent from that applied in VOC Mass Reduction Alternative M100. A total groundwater pumping rate of 70 gpm was applied for VOC Mass Reduction Alternative M200.

VOC Mass Reduction Alternative M200 would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands VOC would already be reliably contained. However, it would increase the rate of VOC removal from the subsurface in the ~~near~~short term and the total quantity of VOC removed in the long term in combination with a containment alternative, and thus would significantly increase permanence and long-term effectiveness. The rate of removal and quantity of VOC removed would be greater than the M100 and M150 alternatives as shown on Figures 30 and 31 in Appendix E. The technology proposed is common and practical for extracting contaminated groundwater from a large complex site such as this and could be effectively operated, maintained, and monitored. There are some manageable short-term risks related to construction and it is implementable. The M200 alternative is not expected to alter or undermine the practicality of a containment alternative and could be easily incorporated into the design of the GWETS. It would enhance the drawdown and gradients within the containment system, which would require optimization if the M200 alternative was selected to be combined with a containment alternative. The alternative would be compatible with the current and anticipated future uses of the Site and surrounding areas, which are industrial with generally paved surfaces. Since the M200 alternative would not significantly alter the geochemical conditions in the subsurface, natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

6.2.3 VOC Mass Reduction Alternative MSP

The detailed evaluation of the VOC Mass Reduction Alternatives MSP involved using the calibrated groundwater flow model developed for the Site, as presented in Appendix E, to determine TCVOC mass reduction that might be achieved by groundwater extraction in areas of higher mass in soil below the water table and outside areas of high pH (~~e.g., greater than~~ i.e., >10 s.u.).

The simulated TCVOC mass removal by groundwater extraction is evaluated relative to the total TCVOC mass in the aquifer beneath the Site calculated from TCVOC concentrations in soil (above a threshold soil concentration of 100 mg/kg) equal to approximately 780,000 lbs presented in Appendix C. The soil concentrations represent mass in the dissolved, sorbed, and DNAPL phases.

VOC Mass Reduction Alternative MSP includes a physical hydraulic barrier wall along the Site peninsula adjacent to the Waterway and eleven upland groundwater mass removal and containment extraction wells strategically positioned on the Site peninsula. Groundwater extraction was represented in the model from areas of elevated concentrations of TCVOC in the shallow and deep soil below the water table to reduce TCVOC mass (i.e., strategic pumping). Nine extraction wells were simulated to pump from shallow and deep groundwater with high concentrations of

TCVOC outside the areas of elevated pH (i.e., pump in areas where pH is less than [<]10 s.u.). Additionally, two extraction wells were simulated to pump from shallow groundwater to supplement the groundwater containment achieved by pumping in zones of high TCVOC concentrations. Figure 23 of Appendix E shows the strategic locations of the eleven proposed groundwater mass reduction and containment extraction wells, four shallow and seven deep. A total groundwater pumping rate of 210 gpm was applied for VOC Mass Reduction Alternative MSP. The rationale for this pumping rate is discussed in Appendix E. Simulated mass-weighted particle capture for VOC Mass Reduction Alternative MSP was completed for 30 years and 100 years, as requested by the Agencies.

VOC Mass Reduction Alternative MSP would replace the components related to groundwater pumping of a containment alternative because it satisfies the model-based containment objectives for the Site (see Appendix E). It would minimize potential risks to human health and the environment because the uplands VOC would be reliably contained. It would increase the rate of VOC removal from the subsurface in the ~~near~~short term and the total quantity of VOC removed in the long term by strategic pumping, and thus would significantly increase permanence and long-term effectiveness. The technology proposed is common and practical for extracting contaminated groundwater from a large complex site such as this and could be effectively operated, maintained, and monitored. There are some manageable short-term risks related to construction and it is implementable. The MSP alternative could be easily incorporated into the design of a treatment system presented for the containment alternatives. The parts other than the extraction wells of a containment alternative would need to be included with the MSP alternative to protect human health and environment as discussed above. The alternative would be compatible with the current and anticipated future uses of the Site and surrounding areas, which are industrial with generally paved surfaces. Since the MSP alternative would not significantly alter the geochemical conditions in the subsurface, natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

6.2.4 VOC Mass Removal Alternative M3

The VOC Mass Removal Alternative M3 includes removing elevated concentrations of TCVOC in shallow (-4 ft NGVD) soil by excavation, on-Site treatment of the soil, and on-Site backfilling of the treated soil. It would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands TCVOC mass would already be reliably contained. It would reduce very little potential for migration of TCVOC via leaching to groundwater and volatilization, adding ~~little~~a small degree of permanence and long-term effectiveness. Excavation of shallow soil would be practical and implementable with some short-term risks for construction and added effort to manage saturated soil and potential release of VOC to ambient air during material handling. The M3 alternative is not expected to alter or undermine the practicality of a containment alternative or its effectiveness. The alternative would be compatible with the current and anticipated future uses of the Site and surrounding areas, which are industrial with generally paved surfaces. Since the M3 alternative would not significantly alter the geochemical conditions in the subsurface, natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

6.2.5 VOC Mass Reduction Alternative M5

The VOC Mass Reduction Alternative M5 includes treating elevated concentrations of TCVOC in shallow (-21 ft NGVD) soil by in situ ERH and in situ SVE. It would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands TCVOC mass would already be reliably contained. It would reduce some potential for migration of TCVOC via leaching to groundwater and volatilization compared to the M3 alternative, but still adding a very ~~little~~small degree of permanence and long-term effectiveness. In situ treatment of shallow soils by ERH and SVE would be practical and implementable as these technologies have proven to be successful at reducing VOC concentrations in unsaturated (SVE) and saturated (ERH) soils at other sites. There would be some short-term risks for construction and operation of the technologies. The M5 alternative is not expected to alter or undermine the practicality of a containment alternative or its effectiveness. The alternative would be compatible with the current and anticipated future uses of the Site and surrounding areas, which are industrial with generally paved surfaces. Since the M5 alternative would not significantly alter the geochemical conditions in the subsurface outside the immediate target zone, natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

6.2.6 VOC Mass Removal/Reduction Alternative M6

The M6 alternative is a combination of the excavation and in situ ERH treatment elements from the M3 and M5 alternatives, respectively. It would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands TCVOC mass would already be reliably contained. It would further reduce some potential for migration of TCVOC via leaching to groundwater and volatilization compared to the M3 and M5 alternatives, but still adding a very ~~little~~small degree of permanence and long-term effectiveness. As noted previously the technologies would be practical and implementable at the Site. There would be some short-term risks for construction, operation of the technologies, and added effort to manage saturated soil and potential release of VOC to ambient air during material handling. The M6 alternative is not expected to alter or undermine the practicality of a containment alternative or its effectiveness. The alternative would be compatible with the current and anticipated future uses of the Site and surrounding areas, which are industrial with generally paved surfaces. Since the M6 alternative would not significantly alter the geochemical conditions in the subsurface outside the immediate target zone, natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

6.2.7 VOC Mass Removal/Reduction Alternative M8

The M8 alternative includes the shallow soil treatment from the M5 alternative (ERH and SVE) and treatment of elevated concentrations of TCVOC in shallow (-60 ft NGVD) groundwater (and soil) by ISCO and ISB. It would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands TCVOC mass would already be reliably contained. It would further reduce some potential for migration of TCVOC via leaching to groundwater, groundwater flow, and volatilization compared to the M3, M5, and M6 alternatives, but adding a very ~~little~~small degree of permanence and long-term effectiveness. As noted previously the technologies from the M5 alternative would be practical and implementable at the Site. The ISCO technology would be practical and implementable, as this technology has proven to be successful at reducing VOC concentrations in saturated soils at other sites. The ISB technology would also be practical and implementable for similar reasons; however, the treatment relies on maintaining optimal conditions for biological activity and contaminated groundwater passing through/near the treatment curtains. Therefore the effectiveness might be limited if the optimal conditions cannot be maintained because of Site-specific subsurface conditions (e.g., pH above

10 s.u., low dissolved oxygen content [DOC], high salt content) and/or if impacted groundwater does not pass through/near the treatment curtains under natural flow or groundwater pumping conditions. There would be some short-term risks for construction, operation of the technologies, and protection of the injection wells from traffic on the Port of Tacoma properties. The M8 alternative is not expected to alter or undermine the practicality of a containment alternative, but it might alter the effectiveness by altering the groundwater flow patterns in the target zone. For example, ISCO might alter the hydraulic conductivity if significant quantities of solids are precipitated out of solution. This could potentially impact drawdown and gradients within the containment system and might reduce the quantity of TCVOC mass that would be extracted from the subsurface over time. However, the M8 alternative would reduce concentrations of TCVOC in the target zones in ~~the short term~~a shorter time frame, which otherwise would be extracted by the containment system. Despite the concern of impacting the containment alternative, it would still be compatible with the use at the Site since the target zone would still be reliably contained. It would alter the geochemical conditions in the subsurface and therefore natural processes (e.g., biodegradation) documented to occur at the Site that reduce concentrations of hazardous substances might be affected.

6.2.8 VOC Mass Removal/Reduction Alternative M9

The M9 alternative includes the shallow soil and groundwater treatment from the M8 alternative and treatment of elevated concentrations of TCVOC in deep (below -60 ft NGVD) groundwater and soil by ISCO and ISB. It would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands TCVOC mass would already be reliably contained. It would significantly reduce the potential for migration of TCVOC via leaching to groundwater, groundwater flow, and volatilization compared to the M3, M5, M6, and M8 alternatives, adding significant additional permanence and long-term effectiveness. As noted previously the technologies from the M8 alternative would be practical and implementable at the Site. The ISCO technology would be practical and implementable in the deeper target zones, as this technology has proven to be successful at reducing VOC concentrations in deep saturated soils at other sites. The ISB technology would also be practical and implementable for similar reasons; however, the treatment relies on maintaining optimal conditions for biological activity and contaminated groundwater passing through/near the treatment curtains. Therefore, the effectiveness might be limited. Another potential difficulty is with potential overlapping of technologies that might impact the effectiveness. For example, applying ISCO near ISB might cause loss of optimal conditions for biological activity in the short-term and inhibit native microbial populations in the long-term. This might delay implementation of a technology that is not compatible with another. There would be some short-term risks for construction and operation of the technologies. There would be significant short-term risks for protection of the injection wells from traffic on the Port of Tacoma properties because of the large area required to implement the technologies. The M9 alternative is not expected to alter or undermine the practicality of a containment alternative, but it might alter the effectiveness by changing the groundwater flow (i.e., hydraulic conductivity) in the target zone. This could potentially impact drawdown and gradients within the containment system and might reduce the quantity of TCVOC mass that would be extracted from the subsurface over time. However, the M9 alternative would reduce concentrations of TCVOC in the target zones in ~~the short term~~a shorter time frame, which otherwise would be extracted by the containment system. Despite the concern of impacting the containment alternative, it would still be compatible with the use at the Site since the target zones would still be reliably contained. It would alter the geochemical conditions in the subsurface and therefore natural processes (e.g., biodegradation) documented to occur at the Site that reduce concentrations of hazardous substances might be affected.

6.2.9 Disproportionate Cost Analysis

A DCA of the VOC ~~Mass Removal/Reduction Alternatives~~mass removal/reduction alternatives was conducted using the same process described in Subsection 5.2.4. The following presents an evaluation of VOC Mass Removal/Reduction Alternatives M100, M150, M200, MSP, M3, M5, M6, M8, and M9, and the No Additional Action alternative with respect to the DCA process.

Protectiveness

The VOC ~~Mass Removal/Reduction Alternatives~~mass removal/reduction alternatives would not protect human health and the environment, including potential ecological receptors, at the Site by themselves. Therefore, they would not meet all the minimum/threshold requirements. However, they would in combination with a containment alternative, each of which meet the minimum/threshold requirements (see Subsection 5.1) or parts of a containment alternative in the case of the MSP alternative. Accordingly, the VOC mass removal/reduction alternatives assume that all or part of a containment alternative is implemented at the Site to meet the minimum/threshold requirements.

Permanence

The No Additional Action alternative would not add any permanence to a Site remedy.

Alternatives M100, M150, and M200 would each add a significant degree of permanence since concentrations of TCVOC in the subsurface would be reduced over time via extraction of impacted groundwater that would remove TCVOC mass. ~~In comparison to the potential removal of TCVOC mass for the C150 containment alternative presented in Section 5 (i.e., quantities of approximately 120~~The added degree of permanence would be significant because between approximately 305 and 326 thousand lbs of TCVOC ~~[dissolved phase] or 513 thousand pounds of TCVOC [~~(dissolved, sorbed, and DNAPL phases~~]~~) outside areas of pH >10 s.u. would be extracted over 100 years~~), the added degree of permanence would be significant (i.e., added quantities between approximately 99 and 128 thousand lbs of TCVOC [dissolved phase] or total quantities between 663 and 720 thousand pounds of TCVOC [dissolved, sorbed, and DNAPL phases] extracted over 100 years)~~ as shown in ~~Tables 2 and 3~~Table 4 in Appendix E. The M200 alternative would add the highest degree of permanence since it would remove a greater quantity of TCVOC mass over time compared to the M100 and M150 mass removal/reduction alternatives ~~and the C150 containment alternative~~ as shown in ~~Tables 2 and 3~~Table 4 in Appendix E.

Alternative MSP would add a significant degree of permanence since concentrations of TCVOC in the subsurface would be reduced over time via targeted extraction of impacted groundwater (i.e., strategic pumping) that would remove TCVOC mass. In comparison to the M100, M150, and M200 alternatives, the added degree of permanence would be significant in the short term (i.e., ~~84~~324 thousand~~ lbs [dissolved phase] or 656 thousand~~ lbs [dissolved, sorbed, and DNAPL phases] compared to less than ~~44~~292 thousand~~ lbs [dissolved phase] or less than 402 thousand~~ lbs [dissolved, sorbed, and DNAPL phases] ~~in~~ extracted outside areas of pH >10 s.u. in 20 years). The added degree of permanence would be greater in the long term (i.e., ~~147~~329 thousand~~ lbs [dissolved phase] or 766 thousand~~ lbs [dissolved, sorbed, and DNAPL phases]) as shown in ~~Tables 2 and 3~~Table 4 in Appendix E.

Alternative M3 would add a very ~~little~~small degree of permanence since up to 23 thousand lbs of TCVOC mass (dissolved, sorbed, and DNAPL phases) would be excavated, treated on Site, and backfilled on Site. The added degree of permanence would be very ~~little~~small in comparison to the M100, M150, M200, and MSP alternatives.

Alternative M5 would add a very ~~little~~small degree of permanence since up to 62 thousand lbs of TCVOC mass (dissolved, sorbed, and DNAPL phases) would be removed from the subsurface by in situ treatment. The added degree of permanence would be much less than the M100, M150, M200, and MSP alternatives, but more than the M3 alternative.

Alternative M6 would add a very ~~little~~small degree of permanence similar to the M5 alternative since up to 66 thousand lbs of TCVOC mass (dissolved, sorbed, and DNAPL phases) would be removed from the subsurface by a combination of excavation, treatment on Site and backfilling on Site, and in situ treatment. The added degree of permanence would be much less than the M100, M150, M200, and MSP alternatives, but more than the M3 alternative and slightly more than the M5 alternative.

Alternative M8 would add a very ~~little~~small degree of permanence since up to 82 thousand lbs of TCVOC mass (dissolved, sorbed, and DNAPL phases) would be removed from the subsurface by in situ treatment. The added degree of permanence would be less than the M100, M150, M200, and MSP alternatives, but more than the M3, M5, and M6 alternatives.

Alternative M9 would add a significant degree of permanence since up to 613 thousand lbs of TCVOC mass (dissolved, sorbed, and DNAPL phases) would be removed from the subsurface by in situ treatment. The added degree of permanence ~~in the short-term (i.e., 20 years to implement the M9 alternative)~~ would be ~~less than the MSP alternative (719 thousand lbs [dissolved, sorbed, and DNAPL phases]) and~~ greater than ~~all~~the other mass reduction/removal alternatives ~~(23 to 506 thousand lbs [dissolved, sorbed, and DNAPL phases]). In the long term (i.e., 100 years), the added degree of permanence would be less than the MSP, M100, M150, and M200 alternatives and much greater than the rest~~.

It is noted that for all mass removal/reduction alternatives, the ~~targeted zones and~~ areas outside the target zones would still contain elevated TCVOC concentrations that would require containment to maintain long-term permanence.

Effectiveness Over the Long Term

The No Additional Action alternative would not have any effectiveness over the long term.

Alternatives M100, M150, and M200 would have effectiveness over the long term since outside the areas of pH >10 s.u. they would remove approximately ~~85~~ 39.1 to ~~92~~41.7 percent of the total TCVOC mass (dissolved, sorbed, and DNAPL phases) and enhance a containment system. These alternatives might shorten the length of time of O&M for some parts of the Site since they remove a significant amount of mass. However, there may still be areas that would require long-term containment.

Alternative MSP would have the greatest effectiveness over the long term with the exception of Alternative M9 since outside the areas of pH >10 s.u. it would remove the most mass (approximately ~~84~~42.1 percent of dissolved, sorbed, and DNAPL phases) and meet the model-based containment objectives. It might shorten the length of time of O&M for some parts of the Site since it removes the second most mass of all the alternatives. However, there may still be areas that would require long-term containment.

Alternatives M3, M5, M6, and M8 would have less effectiveness over the long term compared to the M100, M150, M200, and MSP alternatives since they would remove much less mass. These alternatives would not affect the length of time for O&M of a containment alternative that was modeled for 100 years and would be required to contain the remaining mass outside the targeted areas. Additionally for the M8 alternative, the effectiveness of ISB might be limited as discussed in Subsection 6.2.~~6~~7.

Alternative M9 would have ~~less~~the most effectiveness over the long term compared to the ~~MSP alternative~~other alternatives since it would remove ~~less of~~ the most VOC mass. Similar to MSP alternative, it might affect the length of time for O&M of a containment alternative for some parts of the Site. However, there may still be areas that would require long-term containment. Additionally, the effectiveness of ISB might be limited as discussed in Subsection 6.2.~~7~~8.

Management of Short-Term Risks

The short-term risks during construction and implementation of the alternatives would be managed through standard safety and health procedures that would be documented in a Site-specific HASP. The types of procedures that would be required are those regularly practiced for the types of construction anticipated. The M9 alternative would present more short-term risks because the scope extends to greater depths, covers a greater area outside of the 605 Alexander Avenue property, and would require up to 20 years to maintain/protect injection points in areas of active business and traffic. The M100, M150, M200, and MSP alternatives would present the lowest short-term risks, excluding the No Additional Action alternative, because they could be implemented relatively quickly, would involve the least amount of equipment and smallest areal footprint (e.g., less noise impact, construction-related risks, and potential for fugitive emissions), the infrastructure would be underground, and would have the lowest potential for human/ecological exposure. Soil excavation with on-Site treatment would include additional short-term risks such as exposure to high concentration of VOC in soil, water, and air (from vitalization), managing access to large open holes, managing stockpiles hazardous materials including saturated soils, and managing potential water run-off from stockpiled materials. ERH and SVE would include additional short-term risks such as hazards related to high temperatures, high-voltage electricity, controlling and treating VOC, and vapor migration through existing utilities. ISCO and ISB would include additional short-term risks such as chemical transport, mixing, and handling, chemical daylighting (i.e., chemicals flowing to and over ground surface), and managing soils (drill cuttings) and equipment over a large footprint. Additionally, ERH, ISCO, and ISB might delay startup of parts of the containment system to permit implementation of these technologies.

In addition to the HASP, other plans for activities such as soil management, traffic control, and air monitoring would be developed to protect human health and the environment during construction and implementation.

Technical and Administrative Implementability

As discussed in Subsection 6.1, all of the VOC mass removal/reduction alternatives are implementable.

The technical implementability of the M100, M150, M200, MSP, M3, M5, and M6 alternatives are considered good since these technologies have been successful at similar depths at other sites. Additionally, the target zones are within the 605 Alexander Avenue property or in areas outside building envelopes and therefore access to the target zones would be relatively easy since the area would be either void of any operations or in manageable areas.

The technical implementability of the M8 alternative is considered fair to good since these technologies have been successful at similar depths at other sites; however, some of the target zones would be below building envelopes and in roadways. This would make access to these target zones more difficult. The remainder of the target zones would be within the 605 Alexander Avenue property or in areas outside building envelopes and roadways where access would be relatively easy.

The technical implementability of the M9 alternative is considered fair since the additional depth of target zones in some areas might present difficulties, some of the target zones would be below building envelopes and roadways making access more difficult, and overlapping target zones require different technologies that might affect each other or delay implementation.

Since the technologies selected are proven and typically applied at many sites; services, capabilities, equipment, specialists, and materials should be available for implementation of these remedial alternatives. Permitting of these remedial alternatives is also expected to be obtained without significant difficulties.

Consideration of Public Concerns

As noted in Subsection 5.2.4, under *Consideration of Public Concerns*, a containment system alone would be protective of human health and the environment by eliminating all potential exposure pathways and is a common, reliable, and effective solution for large complex sites like this one, which could be effectively operated, maintained, and monitored. Additionally, public concerns regarding the Hylebos documented during a public comment period from October 23, 2015 through February 1, 2016 for the approved SCR (CRA, 2014c) are addressed through the 2016 Anchor QEA investigation sediment and porewater sampling in the Hylebos. (See Subsection 2.4.5 and 2.4.6). ~~The public made no comments related to VOC mass removal/reduction in these correspondences.~~

Mobility of mass within the containment system would be of minimal concern as long as there is hydraulic control of the target zones. Therefore, the mass removal/reduction alternatives do not materially enhance protectiveness, would add minimal long-term effectiveness and permanence in terms of containment, and none would provide any incremental benefit to mitigating potential impacts from the Site and overall potential impacts from other sites adjacent to the Waterways and Commencement Bay. Short-term risks for some of the alternatives might be of concern, but could be managed. Any other potential measures in addition to a containment alternative to address Site conditions are not necessary but rather augmentations to a system that reliably contains contaminants at the Site. For these reasons, it is expected that the public would be supportive of any overall remedy for the Site that includes containment.

Public notice and participation is an integral part of the remedy selection process. The public notice and participation requirements for cleanups conducted are set forth in MTCA (WAC 173-340-600), NCP 40 CFR 300.430(f)(3)(i), and CERCLA §117. The public will have an opportunity to voice any concerns regarding the FS during a public comment period.

Cost

The estimated costs for VOC Mass Removal/Reduction Alternatives M100, M150, M200, MSP, M3, M5, M6, M8, and M9, and the No Additional Action alternative are presented in Appendix G and were developed in accordance with guidance (USEPA, 2000) specified by the Agencies. The cost estimates include periods of 30 years, in accordance with the guidance (USEPA, 2000), and 100 years, at the request of the Agencies. Discount factors for O&M and periodic costs include 7 percent, in accordance with the guidance (USEPA, 2000), and 1.5 percent (2016 Discount Rate for OMB Circular No. A-94 for the 30-Year Real Interest Rate on Treasury Notes and Bonds of Specific Maturities), at the request of the Agencies. A summary of the capital, O&M, and periodic costs, which include costs for containment required to meet the threshold criteria discussed previously, is provided in Table 6.1 below. The alternatives are listed/ranked from most to least added degree of permanence (i.e., most to least lbs of TCVOC mass removed/reduced [see Table 6.3]) in accordance with WAC 173-340-360(3)(e)(ii)(A).

Table 6.1 Summary of VOC Mass Removal/Reduction Alternatives Estimated Costs

Alternative	Capital	Capital plus O&M/Periodic (30yrs;7%)	Capital plus O&M/Periodic (30yrs;1.5%)	Capital plus O&M/Periodic (100yrs;7%)	Capital plus O&M/Periodic (100yrs;1.5%)
M9	$35,480,940	$401,254,360	$442,991,030	$405,747,880	$488,428,190
MSP	$38,854,780	$54,877,530	$70,216,710	$57,750,000	$110,920,000
M200	$38,903,190	$56,232,640	$72,794,730	$59,300,000	$116,430,000
M150	$38,903,190	$55,838,770	$72,032,470	$58,850,000	$114,790,000
M100	$38,903,190	$55,442,430	$71,265,400	$58,390,000	$113,140,000
~~M9~~	~~$35,4880,940~~	~~$401,254,360~~	~~$442,991,030~~	~~$405,747,880~~	~~$488,428,190~~
M8	$114,264,240	$142,006,010	$167,471,640	$146,499,530	$212,908,800
M6	$52,488,140	$68,144,380	$83,140,740	$72,637,900	$128,577,900
M5	$50,712,040	$66,368,280	$81,364,640	$70,861,800	$126,801,800
M3	$41,366,240	$57,022,480	$72,018,840	$61,516,000	$117,456,000
No Additional Action*	$38,700,240	$54,356,480	$69,352,840	$57,170,000	$109,240,000

~~Note~~Notes:
Costs for compliance monitoring are assumed to be included in a selected containment alternative.
* meaning no additional action will be conducted beyond implementing a containment alternative.

As shown in Table 6.1 the MSP alternative ranked the second highest for added degree of permanence would have a cost that is similar to or less than alternatives with lesser degrees of permanence. The M9 alternative ranked ~~second~~ highest for added degree of permanence would have the highest cost, which is much higher than the other VOC mass removal/reduction alternatives. The M200 alternative ranked third for added degree of permanence has a cost that is slightly higher compared to the MSP, M150 and M100 alternatives over 30 years using a discount rate of 7 percent and lower in costs compared to the M8, M6, M5, and M3 alternatives that are ranked lower for added degree of permanence.

Disproportionate Cost Analysis Summary

Table 6.2 presents a DCA summary table that provides relative benefit score to cost ratios for the VOC ~~Mass Reduction/Removal Alternatives~~mass reduction/removal alternatives using weighting percentages from Table 5.1. As shown in Table 6.2, the MSP alternative has a benefit score to cost ratio of 1.~~51~~37 that is greater than the benefit score to cost ratios for the other alternatives. The next highest ratios are 1.~~42~~32, 1.~~41~~31, and 1.~~40~~30 for the M100, M150, and M200 alternatives, respectively. The M3 alternative had the next highest ratio of 1.17 followed by 1.03 for the No Additional Action alternative. The benefit score to cost ratios for the remaining alternatives are less than No Additional Action alternative, which indicate that the costs exceed the benefits of these alternatives. The benefit score to cost ratios for M9 of 0.18 and M8 of 0.46 are the lowest and are clearly disproportionate in cost compared to the other alternative ratios.

The following provides additional discussion regarding the relationship between costs and TCVOC mass potentially addressed, cash flow projections, and alternative durations.

The table below summarizes the quantity of TCVOC mass (dissolved, sorbed, and DNAPL phases) potentially addressed by each alternative in ~~100~~ 20 years as presented in Subsection 4.4 and Appendix E. Figure 6.1 presents the information graphically. A 20-year time frame was selected because all the non-pumping mass removal alternatives (M3, M5, M6, M8, and M9) are estimated to be completed after 20 years. An estimated quantity of TCVOC mass potentially addressed by Containment Alternative C150 to represent the No Additional Action VOC Mass Removal/Reduction Alternative is included in the table for comparison purposes.

Table 6.3 Summary of Estimated Quantity of VOC Mass Potentially Addressed by each VOC Mass Removal/Reduction Alternative

Alternative	Estimated Quantity of TCVOC Mass Potentially Addressed (lbs)	Estimated Percent of Total Estimated TCVOC Mass (%)	Estimated Cost (~~100yrs~~30yrs;7%) per Pound of TCVOC Potentially Addressed ($/lb)
M9	613,300	78.6	654
MSP	~~766,835~~323,883*	~~98.3~~41.5	~~75~~169
M200	291,648*	37.4	193
M150	285,394*	36.6	196
M100	275,132*	35.3	202
~~M9~~	~~613,300~~	~~78.6~~	~~662~~
M8	81,600	10.5	1,740
M6	66,200	8.5	1,029
M5	62,200	8.0	1,067
M3	23,200	3.0	2,458
No Additional Action	151,735*	19.5	358

Note: *Represents mass outside areas of pH >10 s.u. only.

Note that estimated quantity of TCVOC mass potentially addressed for the alternatives that incorporate groundwater extraction (i.e., MSP, M200, M150, M100, and No Additional Action [equivalent to C150]) were determined using the three-dimensional (3D) groundwater flow model that was specifically constructed and calibrated for the Site. The Site groundwater flow model provides a useful tool to evaluate the potential effectiveness of the groundwater mass reduction remedial alternatives that incorporate groundwater extraction. It is noted that the model assumes idealized mass transport controlled by advection and equilibrium sorption and all mass is assumed to be either dissolved in the groundwater or sorbed onto the aquifer matrix. Potential effects of non-aqueous phase liquids are not included. The potential effects of diffusion into low-permeability units or areas are not included. Additionally, the estimates do not include potential effects of high pH potentially reaching extraction wells, all contributing to the uncertainty of the mass estimates. However, the evaluation approach was applied consistently for all alternatives.

The MSP alternative adds the second greatest degree of permanence over the other alternatives and has the highest benefit score to cost ratio, addresses up to ~~98.3~~41.5 percent of the estimated total TCVOC mass for a cost of approximately $~~57.8M.~~54.9M (capital plus 30 years O&M at a discount rate of 7 percent). This is equivalent to approximately $~~75~~169/lb. Additionally, the MSP alternative is predicted to remove a significant quantity of TCVOC mass (dissolved, sorbed, and DNAPL phases) in the short term (i.e., ~~656~~324 thousand lbs in ~~ten~~ 20 years)

The M200 alternative, which is ranked ~~second~~third in adding degree of permanence and has the fourth highest benefit score to cost ratio, addresses less than the MSP alternative achieves (~~92.3~~37.4 percent) for a similar cost of approximately $~~59.3M (capital plus 100 years O&M at a discount rate of 7 percent),~~56.2M, which is equivalent to approximately $~~82~~193/lb.

The M150 and M100 alternatives are ranked lower in adding degree of permanence since they remove less mass and cost more per pound of TCVOC mass addressed. However, their benefit score to cost ratios are slightly greater than the M200 alternative.

The M9 alternative adds the ~~fifth~~ greatest degree of permanence, but has a very low benefit score to cost ratio (i.e., disproportionate cost) that is less than the ratio for the No Additional Action alternative. It addresses up to 78.6 percent of the estimated total TCVOC mass for a cost of approximately $~~406M~~401M. This is equivalent to approximately $~~662~~654/lb. assuming all the targeted mass is removed. As noted above, the effectiveness of the M9 alternative is less certain than the other alternatives and is expected to be more difficult to implement. It would also present more short-term risks than any other alternative.

The remaining alternatives ~~(excluding~~including No Additional Action~~)~~ remove less mass for significantly greater cost per pound. The benefit score to cost ratios for the M3 alternative is above the ratio for the No Additional Action alternative and the remaining ratios are below.

Figure 6.2 presents the relationship between estimated cost and estimated quantity of TCVOC mass potentially addressed by the alternatives. As shown on the figure the MSP, M100, M150, and M200 alternatives remove the largest quantity of TCVOC mass for the lowest costs. The figure also shows that the M9 alternative, which ~~also~~ addresses ~~a significant amount of~~the most mass, is disproportionate in cost since it is approximately ~~8~~seven times greater in cost than the above noted alternatives. Figure 6.3 presents the alternatives anticipated 30-year cash flow projections. As shown on this figure, the costs are lowest for the MSP alternative~~, except for the No Action alternative.~~. The M8 and M9 alternatives costs are much greater in comparison to the other alternatives. Figure 6.4 shows the anticipated durations for the different components of the alternatives. The MSP, M100, M150, and M200 alternatives require a short time (~~less than~~ 6 months to 1 year) to construct and include operation and maintenance over the entire time frame of 100 years. The duration for ISB for Alternatives M8 and M9 including construction is approximately ~~17~~19 years. The remaining alternatives are shown to be completed within 2 years. Figure 6.5 presents the relationship between estimated time and estimated quantity of TCVOC mass potentially addressed by the alternatives. As shown on the figure, after approximately ~~20~~2 years of operation the quantity of TCVOC mass removed for the MSP alternative is the greatest. After approximately 20 years, only the M9 alternative potentially addresses more mass than the MSP alternative. After 100 years, the MSP alternative still removes the most mass of all the alternatives that include groundwater extraction (i.e., MSP, M100, M150, and M200).

6.2.10 Summary

Each of the alternatives, except the No Additional Action alternative, would simply augment a containment system that is reliably operated and maintained. The Mass Reduction/Removal Alternatives in addition to a containment alternative to address Site conditions are not necessary to protect human health and the environment and would provide minimal additional protectiveness. However, it is recognized that there might be a desire to achieve some additional mass removal to augment the mass reduction expected from a containment system. The disproportionate cost analysis indicates that a point of diminishing returns is quickly reached after the mass reduction alternatives that include groundwater extraction (i.e., less or similar benefit for more cost).

The MSP alternative has the lowest cost, the highest benefit score to cost ratio, and includes the hydraulic component of a containment alternative since it meets the model-based containment objectives. The MSP alternative potentially addresses the most mass in the short term and the second most mass in the long term. The M9 alternative potentially addresses the most mass in the long term, but was shown to be disproportionate in cost. The M100, M150, and M200 alternatives have the next highest benefit score to cost ratios, but remove less mass than the MSP ~~and M9 alternatives.~~alternative. The M100, M150, and M200 alternatives would require higher sustainable individual and collective groundwater pumping rates when combined with a containment alternative as would be required to meet all the minimum/threshold requirements. The ~~M9~~M8 alternative was shown to be disproportionate in cost ~~along with the M8 alternative~~. The remaining VOC Mass Reduction/Removal Alternatives (M3, M5, and M6) remove less mass and have lower benefit score to cost ratios. The No Additional Action alternative does not remove any additional mass.

Based on the above evaluation, the identified preferred alternative is VOC Mass Reduction Alternative MSP since it has the highest benefit score to cost ratio, removes the highest quantity of mass in the short term ~~and long term~~, and has the lowest per pound cost. The MSP alternative is a cost-effective means to remove additional mass from the subsurface and meet the model-based containment objectives and can be reliably operated and maintained.

7. pH Reduction/Enhanced Containment Alternatives - Initial Screening and Detailed Evaluation

7.1 Initial Screening

The pH reduction/enhanced containment alternatives are described in Subsection 4.5. The initial screening criteria are described in Subsection 5.1.

The pH reduction/enhanced containment alternatives are designed to reduce or otherwise enhance containment of high pH in groundwater and soil. The pH reduction/enhanced containment alternatives would not protect human health and the environment, including potential ecological receptors, at the Site by themselves. Therefore, they would not meet all the minimum/threshold requirements. However, in combination with containment technologies they would meet the minimum/threshold requirements (see Subsection 5.1). Accordingly, the pH alternatives all assume that appropriate containment technologies are implemented at the Site. Therefore, none of the pH alternatives were removed from further evaluation based on this initial screening.

The pH alternatives are sufficiently different because of the technologies used and/or areas targeted that determining which alternatives' costs would be clearly disproportionate under WAC 173-340-360(3)(e) in the initial screening is not evident. Therefore, none of the pH alternatives were removed from further evaluation based on this initial screening criterion.

The pH alternatives and components presented herein are administratively and technically possible at the Site and therefore none of the pH alternatives were removed from further evaluation based on this initial screening criterion.

Based on the above, the initial screening did not eliminate any of the pH alternatives.

7.2 Detailed Evaluation

Purpose and Evaluation Criteria

The purpose of the detailed evaluation is to select an alternative, retained following the initial screening, which does not have an incremental cost that exceeds the incremental degree of benefits potentially achieved. The detailed evaluation of the pH Reduction/Enhanced Containment Alternatives involved assessing MTCA and CERCLA factors to be considered (see Subsection 5.2) and conducting a disproportionate cost analysis per WAC 173-340-360(3)(f). The detailed evaluation assumes that containment is part of the selected remedy for the Site, which is consistent with the initial screening of the pH alternatives.

7.2.1 No Additional Action pH Reduction/Enhanced Containment Alternative

The No Additional Action pH Reduction/Enhanced Containment Alternative would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment. It would not alter or undermine the practicality and effectiveness of a containment alternative and therefore would be compatible with the use at the Site. This alternative would not reduce or enhance containment of high pH in media at the Site and thus would not increase permanence or long-term effectiveness. However, the high pH would be reliably contained by containment technologies. There are no short-term risks and it is fully implementable. Since this alternative would not alter the geochemical conditions in the subsurface, natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

7.2.2 pH Reduction Alternative pH2

The pH Reduction Alternative pH2 includes reducing high pH in shallow groundwater and soil by in situ mixing of sodium persulfate. It would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands high pH would already be reliably contained. It would reduce a little pH. Therefore, the pH2 alternative would add a very ~~little~~small degree of permanence and limited long-term effectiveness. It would prevent the potential for migration of a little high pH water to extraction wells; however, the extraction wells would be positioned to minimize this potential already. Additionally, the containment alternatives include a contingency for pH treatment. The pH2 alternative would not reduce the time for O&M of a containment alternative.

Based on discussions with an experienced contractor, in situ mixing to a depth of -60 ft NGVD (approximately 75 ft below grade) would be practical and implementable with some difficulty if the subsurface contains deleterious material and/or non-cohesive soil that could bind the mixing equipment. There would be short-term risks for construction and managing the sodium persulfate. The pH2 alternative is not expected to alter or undermine the practicality of a containment alternative, but it might alter the effectiveness by changing the groundwater flow (i.e., hydraulic conductivity) in the target zone. This could potentially impact drawdown and gradients within the containment system and might reduce the quantity of TCVOC mass that would be extracted from the subsurface over time. Despite this concern, it would still be compatible with the use at the Site since the target zone would still be reliably contained. It would alter the geochemical conditions in the subsurface and therefore natural processes (e.g., biodegradation) documented to occur at the Site that reduce concentrations of hazardous substances might be affected. However, since sodium persulfate is an oxidant and would be introduced into zones of TCVOC mass and high pH, it would be expected that concentrations of TCVOC within the target zone would decrease since the high pH is likely to activate the sodium persulfate, which in theory will oxidize ~~TCVOC~~CVOC. It should be noted that only a small percentage (i.e., less than one percent) of the TCVOC mass is present within the zones of pH greater than or equal to 12.5 s.u. Therefore, this added benefit is not expected to be significant with respect to reducing the quantity of TCVOC mass. There are safety concerns while handling sodium persulfate since the dust can be hazardous primarily if inhaled; however, these concerns would be minimized with handling and storage in accordance with the manufacturer's guidelines and a health and safety program.

7.2.3 pH Enhanced Containment Alternative pH3

The pH Enhanced Containment Alternative pH3 includes containment of high pH in shallow groundwater and soil by in situ mixing of cement. It would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands high pH would already be reliably contained. It would not reduce pH. Therefore, the pH3 alternative would not add any permanence and long-term effectiveness. It would prevent the potential for migration of a little high pH water to extraction wells; however, the extraction wells would be positioned to minimize this potential already. Additionally, the containment alternatives include a contingency for pH treatment. The pH3 alternative would not reduce the time for O&M of a containment alternative.

Based on discussions with an experienced contractor, in situ mixing to a depth of -60 ft NGVD (approximately 75 ft below grade) would be practical and implementable with some difficulty if the subsurface contains deleterious material and/or low permeability soil that could bind the mixing equipment. There would be short-term risks for construction and managing the cement. The pH3 alternative is not expected to alter or undermine the practicality of a containment alternative, but it might alter the effectiveness by changing the groundwater flow (i.e., hydraulic conductivity) in the target zone. This could potentially impact drawdown and gradients within the containment system and might reduce the quantity of TCVOC mass that would be extracted from the subsurface over time. Despite this concern, it would still be compatible with the use at the Site since the target zone would still be reliably contained. It would alter the geochemical conditions in the subsurface and therefore natural processes (e.g., biodegradation) documented to occur at the Site that reduce concentrations of hazardous substances might be affected. The introduction of cement would not decrease concentrations of TCVOC within the target zone. It should be noted that only a small percentage (i.e., less than one percent) of the TCVOC mass is present within the zones of pH greater than or equal to 12.5 s.u. There are safety concerns while handling cement since it is caustic (high pH); however, these concerns would be minimized with handling and storage in accordance with the manufacturer's guidelines and a health and safety program. Another concern would be due to the exothermic cementitious reactions that produce heat that could increase vitalization of VOC near the ground surface. Air collection and treatment devices might be needed to capture VOC that volatilize during the mixing process. This might also slow the mixing process in order to control the reaction.

7.2.4 pH Enhanced Containment Alternative pH4

The pH Enhanced Containment Alternative pH4 includes containment of high pH in shallow groundwater and soil by construction of a vertical slurry wall north, south, and west of the high pH. The eastern extent of the high pH would be contained by a sheet pile vertical barrier wall that is part of the containment alternatives. It would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands high pH would already be reliably contained. It would not reduce pH. Therefore, the pH4 alternative would not add any permanence and long-term effectiveness. It would prevent the potential for migration of a little high pH water to shallow extraction wells; however, the extraction wells would be positioned to minimize this potential already. Additionally, the containment alternatives include a contingency for pH treatment. The pH4 alternative would not reduce the time for O&M of a containment alternative.

Based on discussions with an experienced contractor, construction of the slurry wall to a depth of -60 ft NGVD (approximately 75 ft below grade) would be practical and implementable with some difficulty if the subsurface contains deleterious material. There would be short-term risks for construction and managing the slurry. The pH4 alternative is not expected to alter or undermine the practicality of a containment alternative, but it might alter the effectiveness by changing the groundwater flow (i.e., hydraulic conductivity) in the target zone. This could potentially impact drawdown and gradients within the containment system and might reduce the quantity of TCVOC mass that would be extracted from the subsurface over time. Despite this concern, it would still be compatible with the use at the Site since the target zone would still be reliably contained. Additionally, it should be noted that only a small percentage (i.e., less than one percent) of the TCVOC mass is present within the zones of pH greater than or equal to 12.5 s.u. It would not alter the geochemical conditions in the subsurface except in the immediate vicinity of the wall and therefore natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

7.2.5 pH Reduction Alternative pH5

The pH Reduction Alternative pH5 includes reducing high pH in shallow and deep groundwater and soil by in situ mixing of sodium persulfate. This alternative would involve the same processes as the pH2 alternative, but the mixing would extend to greater depths. It would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands high pH would already be reliably contained. It would further reduce pH compared to the pH2 alternative. Therefore, the pH5 alternative would add a ~~little more~~small degree of permanence and long-term effectiveness compared to the pH2 alternative. It would prevent the potential for migration of some high pH water to extraction wells; however, the extraction wells would be positioned to minimize this potential already. Additionally, the containment alternatives include a contingency for pH treatment. The pH5 alternative would not reduce the time for O&M of a containment alternative.

Based on discussions with an experienced contractor, in situ mixing to depths below -60 ft NGVD (approximately 75 ft below grade) would be implementable but not with conventional equipment resulting in increased costs. There would be additional difficulties if the subsurface contains deleterious material and/or non-cohesive soil that could bind the mixing equipment, which would increase with depth. There would be short-term risks for construction and managing the sodium persulfate. The pH5 alternative is not expected to alter or undermine the practicality of a containment alternative, but it might further alter the effectiveness by changing the groundwater flow (i.e., hydraulic conductivity) in the target zone. This could potentially impact drawdown and gradients within the containment system and might further reduce the quantity of TCVOC mass that would be extracted from the subsurface over time. Despite this concern, it would still be compatible with the use at the Site since the target zone would still be reliably contained. It would further alter the geochemical conditions in the subsurface and therefore natural processes (e.g., biodegradation) documented to occur at the Site that reduce concentrations of hazardous substances might be further affected. However, since sodium persulfate is an oxidant and would be introduced into zones of TCVOC mass and high pH, it is expected that concentrations of TCVOC within the target zone would decrease since the high pH is likely to activate the sodium persulfate, which in theory will oxidize ~~TCVOC~~CVOC. It should be noted that only a small percentage (i.e., less than one percent) of the TCVOC mass is present within the zones of pH greater than or equal to 12.5 s.u. Therefore, this added benefit is not expected to be significant with respect to reducing the quantity of TCVOC mass. There are safety concerns while handling sodium persulfate since the dust can be hazardous primarily if inhaled; however, these concerns would be minimized with handling and storage in accordance with the manufacturer's guidelines and a health and safety program.

7.2.6 pH Enhanced Containment Alternative pH6

The pH Enhanced Containment Alternative pH6 includes containment of high pH in shallow and deep groundwater and soil by in situ mixing of cement. This alternative would involve the same processes as the pH3 alternative, but the mixing would extend to greater depths. It would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands high pH would already be reliably contained. It would not reduce pH. Therefore, the pH6 alternative would not add any permanence and long-term effectiveness. It would prevent the potential for migration of some high pH water to extraction wells; however, the extraction wells would be positioned to minimize this potential already. Additionally, the containment alternatives include a contingency for pH treatment. The pH6 alternative would not reduce the time for O&M of a containment alternative.

The pH6 alternative would have the same difficulties with mixing at depth as the pH5 alternative. There would be short-term risks for construction and managing the cement. The pH6 alternative is not expected to alter or undermine the practicality of a containment alternative, but it might further alter the effectiveness by changing the groundwater flow (i.e., hydraulic conductivity) in the target zone. This could potentially impact drawdown and gradients within the containment system and might reduce the quantity of TCVOC mass that would be extracted from the subsurface over time. Despite this concern, it would still be compatible with the use at the Site since the target zone would still be reliably contained. It would further alter the geochemical conditions in the subsurface and therefore natural processes (e.g., biodegradation) documented to occur at the Site that reduce concentrations of hazardous substances might be further affected. The introduction of cement would not decrease concentrations of TCVOC within the target zone. It should be noted that only a small percentage (i.e., less than one percent) of the TCVOC mass is present within the zones of pH greater than or equal to 12.5 s.u. There are safety concerns while handling cement since it is caustic (high pH); however, these concerns would be minimized with handling and storage in accordance with the manufacturer's guidelines and a health and safety program. Another concern would be due to the exothermic cementitious reactions that produce heat and would vaporize the VOC in the subsurface. Air collection and treatment devices might be needed to capture VOC that volatilize during the mixing process. This might also slow the mixing process in order to control the reaction.

7.2.7 pH Enhanced Containment Alternative pH7

The pH Enhanced Containment Alternative pH7 includes containment of high pH in shallow and deep groundwater and soil by construction of vertical slurry walls north, south, and west of the shallow high pH and in all directions around the deep high pH. The eastern extent of the shallow high pH would be contained by a sheet pile vertical barrier wall that is part of the containment alternatives. It would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands high pH would already be reliably contained. It would not reduce pH. Therefore, the pH7 alternative would not add any permanence and long-term effectiveness. It would prevent the potential for migration of some high pH water to extraction wells; however, the extraction wells would be positioned to minimize this potential already. Additionally, the containment alternatives include a contingency for pH treatment. The pH7 alternative would not reduce the time for O&M of a containment alternative.

Based on discussions with an experienced contractor, construction of slurry walls to depths greater than -60 ft NGVD (approximately 75 ft below grade) would be practical and implementable with some difficulty if the subsurface contains deleterious material and depending on the subsurface soil types at depth. The contractor indicated that the slurry walls would be constructed to ground surface because the construction technique relies on an established slope to prevent segregation and permit the backfill material to slide down through the slurry. There would be short-term risks for construction and managing the slurry. The pH7 alternative is not expected to alter or undermine the practicality of a containment alternative, but it might further alter the effectiveness by changing the groundwater flow (i.e., hydraulic conductivity) in the target zone. This could potentially impact drawdown and gradients within the containment system and might reduce the quantity of TCVOC mass that would be extracted from the subsurface over time. This would be most significant in the shallow zone above the deeper high pH target zone, where high concentrations of TCVOC exist. The deeper slurry wall would effectively prevent groundwater flow in this area and therefore prevent extraction of higher concentrations of TCVOC within parts of the shallow zone. Despite this concern, it would still be compatible with the use at the Site since the target zone would still be reliably contained. It would not alter the geochemical conditions in the subsurface except in the immediate vicinity of the wall and therefore natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

7.2.8 Disproportionate Cost Analysis

A DCA of the pH Reduction/Enhanced Containment Alternatives was conducted using the same process described in Subsection 5.2.4. The following presents an evaluation of pH Reduction/Enhanced Containment Alternatives pH2 through pH7 and the No Additional Action alternative with respect to the DCA process.

Protectiveness

The pH Reduction/Enhanced Containment Alternatives would not protect human health and the environment, including potential ecological receptors, at the Site by themselves. Therefore, they would not meet all the minimum/threshold requirements. However, they would in combination with a containment alternative, each of which meet the minimum/threshold requirements (see Subsection 5.1). Accordingly, the pH alternatives all assume that one of the containment alternatives is implemented at the Site to meet the minimum/threshold requirements.

Permanence

The No Additional Action alternative would not add any permanence to a Site remedy.

Alternative pH2 would add a very ~~little~~small degree of permanence since the high pH in the shallow zone would be reduced to less than 12.5 s.u. However, the targeted zone and areas outside the target zone would still contain elevated pH, including pH greater than 12.5 s.u. in the deep zone. This residual high pH would require O&M of a containment alternative for long-term permanence.

Alternatives pH3 and pH4 would not add any degree of permanence since enhanced containment of the high pH within the cemented aquifer or within slurry walls in the shallow zone would not affect the length of time for O&M of a containment alternative.

Alternative pH5 would add a ~~little~~small degree of permanence greater than the pH2 alternative since the high pH in the shallow and deep zones would be reduced to less than 12.5 s.u. However, the targeted zones and areas outside the target zones would still contain elevated pH that would require O&M of a containment alternative for long-term permanence.

Alternatives pH6 and pH7 would not add any degree of permanence since enhanced containment of the high pH within the cemented aquifer or within slurry walls in the shallow zone would not affect the length of time for O&M of a containment alternative. Alternative pH7 might decrease the degree of permanence of a containment alternative since the deeper slurry wall would effectively prevent groundwater flow in the parts of the shallow zone where higher concentrations of TCVOC are and therefore prevent extraction of groundwater with these higher concentrations of TCVOC.

Effectiveness Over the Long Term

The No Additional Action alternative would not have any effectiveness over the long term.

Alternative pH2 would have very little effectiveness over the long term since it does not treat all groundwater and soil with elevated pH, including groundwater and soil at depth with pH greater than 12.5 s.u. Additionally, there is a possibility that pH values could rebound in the targeted zone based on the results of the extensive pH studies conducted for the Site. This alternative would not affect the length of time for O&M of a containment alternative.

Alternatives pH3 and pH4 would have limited overall effectiveness over the long term since they do not enhance containment of all groundwater and soil with elevated pH, including groundwater and soil at depth with pH greater than 12.5 s.u. The limited effectiveness in the target zone would be in terms of preventing migration of high pH to a containment alternative extraction wells. However, this is considered a low risk since the extraction wells would be located away from the high pH. Additionally, the containment alternatives include a contingency for pH treatment. These two alternatives would not affect the length of time for O&M of a containment alternative. Additionally for the pH4 alternative, groundwater with elevated pH might migrate below the vertical slurry wall and/or the sheet pile vertical barrier wall since hydraulic containment within the target zone is not expected because none of the wells from a containment alternative would be within the area surrounded by the walls.

Alternative pH5 would have a little effectiveness over the long term since it treats all of the groundwater and soil with pH greater than 12.5 s.u. However, it does not treat all groundwater and soil with elevated pH and there is a possibility that pH values could rebound in the targeted zone based on the results of the extensive pH studies conducted for the Site. This alternative would not affect the length of time for O&M of a containment alternative.

Alternatives pH6 and pH7 would have limited overall effectiveness over the long term since they do not enhance containment of all groundwater and soil with elevated pH. The limited effectiveness in the target zone would be in terms of preventing migration of high pH to a containment alternative extraction wells. However, this is considered a low risk since the extraction wells would be located away from the high pH. Additionally, the containment alternatives include a contingency for pH treatment. These two alternatives would not affect the length of time for O&M of a containment alternative. Additionally for the pH7 alternative, groundwater with elevated pH might migrate below the shallower vertical slurry wall and/or the sheet pile vertical barrier wall since hydraulic containment within the target zone is not expected because none of the wells from a containment alternative would be within the area surrounded by the walls. For the pH in the deeper zone, the deeper vertical slurry walls surround the pH greater than 12.5 s.u.

Management of Short-term Risks

The short-term risks during construction and implementation of the alternatives would be managed through standard safety and health procedures that would be documented in a Site-specific HASP. The types of procedures that would be required are those regularly practiced for the types of construction anticipated. The pH6 and pH7 alternatives might present more short-term risks because their scopes extend to greater depths compared to the pH3 and pH4 alternatives. The pH4 and pH7 alternatives that include a slurry wall would present the lowest short-term risks, excluding the No Additional Action alternative, because they involve the smallest areal footprint (e.g., less noise impact, construction-related risks, and potential for fugitive emissions), and less sub-surface disturbance for potential exposure to hazardous materials. The pH2, pH3, pH5, and pH6 alternatives that involve mixing of subsurface soils would include additional short-term risks such as chemical transport, mixing, and handling, managing soil stability and chemical daylighting (i.e., chemicals flowing to and over ground surface), and managing equipment over a large footprint.

In addition to the HASP, other plans for activities such as soil management, traffic control, and air monitoring would be developed to protect human health and the environment during construction and implementation.

Technical and Administrative Implementability

As discussed in Subsection 7.1, all of the pH alternatives are implementable.

The technical implementability of the pH2 and pH3 alternatives involving in situ mixing and pH4 alternative involving construction of vertical slurry walls is considered good since these technologies have been successful at similar depths at other sites. Additionally, the target zone is within the 605 Alexander Avenue property and therefore access to the target zone would be relatively easy since the area would be void of any operations. The pH2 and pH3 alternatives would be less implementable because they involve disturbance of large areas and depths of soil, which might affect surface stability.

The technical implementability of the pH5 and pH6 alternatives involving in situ mixing and pH7 alternative involving construction of vertical slurry walls is considered fair to good since the additional depth of target zones in some areas might present difficulties and require more specialized equipment as discussed previously in Subsection 7.2.5. Additionally, the targeted area on the Port of Tacoma property is under an existing building that further complicates implementation. The pH5 and pH6 alternatives would be the least implementable because they involve disturbance of even large areas and greater depths of soil, which might affect surface stability.

Since the in situ mixing and vertical slurry walls are proven technologies and typically applied at many sites; services, capabilities, equipment, specialists, and materials should be available for implementation of these remedial alternatives. Permitting of these remedial alternatives is also expected to be obtained without significant difficulties.

Consideration of Public Concerns

As noted in Subsection 5.2.4, under *Consideration of Public Concerns*, a containment system alone would be protective of human health and the environment by eliminating all potential exposure pathways and is a common, reliable, and effective solution for large complex sites like this one, which could be effectively operated, maintained, and monitored. Additionally, public concerns regarding the Hylebos documented during a public comment period from October 23, 2015 through February 1, 2016 for the approved SCR (CRA, 2014c) are addressed through the 2016 Anchor QEA investigation sediment and porewater sampling in the Hylebos. (See Subsection 2.4.5 and 2.4.6). ~~The public made no comments related to pH reduction/enhanced containment in these correspondences.~~

Mobility of pH within the containment system would be of minimal concern as long as there is hydraulic control of the target zones. Therefore, the pH reduction/enhanced containment alternatives do not materially enhance protectiveness, would add minimal or no long-term effectiveness and permanence in terms of containment, might negatively impact a containment system that would reliably contain all high pH, and none would provide any incremental benefit to mitigating potential impacts from the Site and overall potential impacts from other sites adjacent to the Waterways and Commencement Bay. Short-term risks for some of the alternatives might be of concern, but could be managed. Any other potential measures in addition to a containment alternative to address Site conditions are not necessary but rather augmentations to a system that reliably contains contaminants at the Site. For these reasons, it is expected that the public will be supportive of any overall remedy for the Site that includes containment.

Public notice and participation is an integral part of the remedy selection process. The public notice and participation requirements for cleanups conducted are set forth in MTCA (WAC 173-340-600), NCP 40 CFR 300.430(f)(3)(i), and CERCLA §117. The public will have an opportunity to voice any concerns regarding the FS during a public comment period.

Cost

The estimated costs for pH Reduction/Enhanced Containment Alternatives pH2 through pH7 and the No Additional Action alternative are presented in Appendix G and were developed in accordance with guidance (USEPA, 2000) specified by the Agencies. The cost estimates include periods of 30 years, in accordance with the guidance (USEPA, 2000), and 100 years, at the request of the Agencies. Discount factors for O&M and periodic costs include 7 percent, in accordance with the guidance (USEPA, 2000), and 1.5 percent (2016 Discount Rate for OMB Circular No. A-94 for the 30-Year Real Interest Rate on Treasury Notes and Bonds of Specific Maturities), at the request of the Agencies. There are no O&M costs associated with the pH alternatives. A summary of the capital costs for the pH alternatives and capital, O&M, and periodic costs for containment required to meet the minimum/threshold requirements discussed previously, is provided in Table 7.1 below. The alternatives are listed/ranked from most to least for added degree of permanence (i.e., most to least pH reduced [see Table 7.3]) in accordance with WAC 173-340-360(3)(e)(ii)(A), and thereafter from highest to lowest cost for alternatives that would not add any degree of permanence to a containment alternative (i.e., no pH reduction).

Table 7.1 Summary of pH Reduction/Enhanced Containment Alternatives Estimated Costs

Alternative	Capital	O&M/Periodic (30yrs;7%)	O&M/Periodic (30yrs;1.5%)	O&M/Periodic (100yrs;7%)	O&M/Periodic (100yrs;1.5%)
pH5	$174,488,040	$15,656,240	$30,652,600	$18,469,760	$70,539,760
pH2	$91,895,240	$15,656,240	$30,652,600	$18,469,760	$70,539,760
pH6	$101,386,040	$15,656,240	$30,652,600	$18,469,760	$70,539,760
pH3	$55,682,540	$15,656,240	$30,652,600	$18,469,760	$70,539,760
pH7	$50,548,440	$15,656,240	$30,652,600	$18,469,760	$70,539,760
pH4	$41,086,040	$15,656,240	$30,652,600	$18,469,760	$70,539,760
No Additional Action*	$38,700,240	$15,656,240	$30,652,600	$18,469,760	$70,539,760

~~Note~~Notes:
Costs for compliance monitoring are assumed to be included in a selected containment alternative.
* meaning no additional action will be conducted beyond implementing a containment alternative.

As shown in Table 7.1, the pH5 alternative ranked highest for adding a ~~little~~small degree of permanence would have the highest cost. The pH2 alternative ranked second for adding degree of permanence has a relatively high cost for the very ~~little~~small added degree of permanence. The lowest cost alternatives, pH4 and pH7, do not add any degree of permanence and might negatively impact a containment system that is the foundation of a successful remedy for the Site in terms of effectiveness and degree of permanence with respect to mitigating VOC.

Disproportionate Cost Analysis Summary

Table 7.2 presents a DCA summary table that provides relative benefit score to cost ratios for the pH Reduction/Enhanced Containment Alternatives using weighting percentages from Table 5.1. As shown in Table 7.2, the No Additional Action alternative has a benefit score to cost ratio of 1.03 that is greater than the benefit score to cost ratios for the other alternatives. The next highest ratio is 0.88 for the pH4 alternative, which is considerably lower than the ratio for the No Additional Action alternative. The benefit score to cost ratios for the remaining alternatives are less than No Additional Action alternative as well, which indicate that the costs exceed the benefits of these alternatives. The benefit score to cost ratios for pH2 of 0.47, pH5 of 0.28, and pH6 of 0.38 are the lowest and are disproportionate in cost compared to the other alternatives.

The following provides additional discussion regarding the relationship between costs and quantity of pH (ANC) potentially addressed, cash flow projections, and alternative durations.

The following table summarizes the quantity of pH (ANC) potentially addressed by each alternative as presented in Subsection 4.5 and based on the analysis in Appendix F. Figure 7.1 presents the information graphically.

Table 7.3 Summary of Estimated Quantity of pH (ANC) Potentially Addressed by each pH Alternative

Alternative	Estimated Quantity of pH (ANC) Potentially Addressed (Meq acid)	Estimated Percent of Total pH (ANC) (%)
pH5	188	23.3
pH2	91	11.2
pH6	188	23.3
pH3	91	11.2
pH7	188	23.3
pH4	91	11.2
No Additional Action	0	0

Note:
Estimated quantity of pH (ANC) in units of Megaequivalents acid. (See Appendix F)

The pH5 alternative adds a ~~little~~small degree of permanence greater than the other alternatives, would address up to 23.3 percent of the estimated total pH (ANC) for a cost of approximately $~~245M.~~190M (capital plus 30 years O&M at a discount rate of 7 percent). The pH2 alternative that is ranked second for adding degree of permanence would address about half of the ANC (11.2 percent) that the pH5 alternative would achieve, but for about ~~66~~57 percent of the cost of approximately $~~162M~~108M. As noted above, the remaining alternatives would not add any degree of permanence and would not address any additional pH compared to the pH2 and pH5 alternatives at costs ranging from $~~112~~54M to $~~172M~~117M. The two lowest cost enhanced containment alternatives, pH4 (approximately $~~112M~~54M) and pH7 (approximately $~~121M~~66M), might negatively impact a containment system that is the foundation of a successful remedy for the Site in terms of effectiveness and degree of permanence with respect to mitigating VOC. Additionally, the containment alternatives include a contingency for pH treatment that would cost approximately $27,000 (plus additional O&M) and might not be needed at all.

Figure 7.2 presents the relationship between estimated cost and estimated quantity of pH (ANC) potentially addressed by the alternatives. As shown on the figure the pH2 and pH5 alternatives would reduce relatively small quantities of pH for high costs. In terms of the other alternatives that would enhance containment, but not reduce pH, the slurry walls are more cost effective; however, they might affect the containment system negatively, as noted previously. Figure 7.3 presents the alternatives anticipated 30-year cash flow projections. As shown on this figure, there are no operation and maintenance costs anticipated (excluding O&M for containment) and therefore only capital costs are graphed. The conclusions that may be determined from this graph are the same as stated above for Figure 7.2. Figure 7.4 shows the anticipated durations for the different components of the alternatives. It is anticipated that all the pH alternatives could be completed within 4 years.

7.2.9 Summary

Each of the alternatives, except the No Additional Action alternative, would augment a reliable containment system. ~~However, none of the alternatives address all of the elevated pH at the Site.~~ The most aggressive pH alternative would potentially address 23.3 percent of the pH (ANC), leaving a minimum of 76.7 percent to be contained at the Site. Therefore, any potential concerns regarding migration of groundwater with elevated pH and/or extraction of groundwater with elevated pH would still exist. The potential benefits of some alternatives are minor and come at relatively high costs as indicated by their benefit score to cost ratios, which are all less than the No Additional Action alternative. In some cases (e.g., slurry walls), there might be negative effects to a containment system that is the foundation of a successful remedy for the Site in terms of effectiveness and degree of permanence with respect to mitigating VOC. The pH5 alternative that would potentially add a ~~little~~small degree of permanence to a containment alternative, greater than the other pH alternatives, is estimated to cost $136M ~~without considering~~in additional to the cost of containment. The pH Reduction/Enhanced Containment Alternatives in addition to a containment alternative to address Site conditions are not necessary to protect human health and the environment and would provide minimal additional protectiveness.

Based on the above evaluation, the identified preferred alternative is the No Additional Action pH Reduction/Enhanced Containment Alternative since the benefit score to cost ratios for the pH2 through pH7 pH alternatives are less than the No Additional Action alternative. Meaning, there would be no tangible degree of incremental benefit to justify selecting one of the pH2 through pH7 pH alternatives. Additionally, none of the pH alternatives would address more than 23.3 percent of the pH (ANC) and therefore elevated pH would still need to be reliably contained.

8. Select Preferred Remedy

Based on the evaluation presented in this FS, the preferred remedy consists of VOC Mass Reduction Alternative MSP combined with appropriate containment technologies from Containment Alternative C150. This alternative includes Common Elements (Subsection 4.2), containment, and VOC mass reduction as follows:

- Institutional Controls (ICs) - fence, use restrictions, soil management and Site-specific health and safety plans
- Groundwater Quality Monitoring
- Soil Vapor Monitoring
- PDCE Barrier for 605 & 709 Alexander Avenue Properties, Navy Todd Dump, N Landfill, and 709 Embankment Fill Area
- Sheet pile vertical barrier wall ~~adjacent to~~between the Site and the Hylebos

- VOC source area mass reduction by strategic groundwater pumping from nine extraction wells
- Hydraulic containment by groundwater pumping from eleven extraction wells (the nine ~~above~~ for VOC source area mass reduction by strategic groundwater pumping plus two additional wells)
- Ex situ treatment of extracted groundwater through a newly constructed conveyance and treatment system

The MSP alternative would reliably contain Site impacts ~~and would~~while significantly ~~reduce~~reducing mass ~~at a relatively quick rate and~~in the shortest time of all the alternatives for a reasonable cost, making it the most cost effective combination of containment and mass reduction/removal alternatives. This combination alternative is estimated to reduce the TCVOC mass outside areas of pH >10 s.u. by approximately ~~84~~98 percent over ~~10~~20 years while reliably achieving containment of Site impacts. If the above is selected as the preferred remedy for the Site, then it is recommended that the well locations and groundwater pumping rates be further optimized with the model developed for the Site during the design phase of the preferred remedy.

The recommended performance ~~standard~~objective for ~~CVOC~~TCVOC mass removal would be based on achieving 90 percent removal of the estimated mass of ~~CVOC~~TCVOC outside of the pH >10 s.u. at the site within 15 years ~~as outlined below:~~

~~25 percent of~~ . Based on current estimates derived using the ~~estimated CVOC~~site groundwater flow model, the TCVOC mass outside the high pH ~~(>~~(pH >10 s.u.) is approximately 331 thousand lbs. The expected rates of mass removal are as follows:

- 25 percent of the estimated TCVOC mass outside the high pH (pH >10 s.u.) will be removed by 2 years (approximately 12.5 percent per year for 2 years~~)~~). This is equivalent to approximately 82,750 lbs
- An additional 20 percent of the estimated ~~CVOC~~TCVOC mass outside high pH will be removed by 5 years ~~-~~(approximately 6.66 percent per year for 3 years~~)~~). This is equivalent to approximately 66,200 lbs
- An additional 25 percent of the estimated ~~CVOC~~TCVOC mass outside of the high pH will be removed by 10 years (approximately 5 percent per year for 5 years~~)~~). This is equivalent to approximately 82,750 lbs
- An additional 20 percent of the estimated ~~CVOC~~TCVOC mass outside of the high pH will be removed by 15 years (approximately 4 percent per year for 5 years~~)~~). This is equivalent to approximately 66,200 lbs

~~Once the CVOC mass removal performance objective of removing at least 90 percent of the estimated CVOC mass outside of the pH > 10 s.u. has been achieved or at such time that it is no longer feasible to pump groundwater with high concentrations of CVOC (i.e., CVOC within high pH) whichever occurs earlier, the remedy will be reassessed to focus on the objective of containment of remaining source zones and the groundwater plume to prevent expansion of the plume and to prevent discharges to the Hylebos above levels which could affect human health and the environment.~~

Note that estimated rates of mass removal were determined using the three-dimensional (3D) groundwater flow model that was specifically constructed and calibrated for the Site. The Site groundwater flow model provides a useful tool to evaluate the potential effectiveness of the groundwater mass reduction remedial alternatives that incorporate groundwater extraction. It is noted that the model assumes idealized mass transport controlled by advection and equilibrium sorption and all mass is assumed to be either dissolved in the groundwater or sorbed onto the aquifer matrix. Potential effects of non-aqueous phase liquids are not included. The potential effects of diffusion into low-permeability units or areas are not included. Additionally, the estimates do not include potential effects of high pH potentially reaching extraction wells, all contributing to the uncertainty of the mass estimates. However, the evaluation approach was applied consistently for all alternatives.

The recommended preferred remedy ~~provides~~ would protect human health and the environment in the short term and long term. It would provide both VOC mass reduction/removal at a relatively quick rate by strategic groundwater pumping and ~~pumps~~hydraulic containment reliably and effectively by pumping sufficient groundwater to achieve the Site model-based containment objectives.

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